Radiation and Nuclear Safety Authority 106/0002/2016
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Guide YVL B.5, Primary circuit of a nuclear power plant

1 Introduction

In order to ensure primary and secondary circuit integrity, the following requirements have been set in subsection b) of the third paragraph of Section 10 of the Radiation and Nuclear Safety Authority Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018), “Engineered barriers for preventing the dispersion of radioactive materials”:

> *i. the primary circuit shall be designed and manufactured in compliance with high quality standards so that the likelihood of detrimental structural defects and mechanisms threatening the integrity of structures remains extremely low and any faults which occur during the life cycle of the primary circuit can be detected reliably through inspections;*
>
> *ia. the stresses imposed upon the primary circuit shall remain below the values defined for structural materials for preventing a fast growing crack during normal operational conditions, anticipated operational occurrences and accidents;*
>
> *ii. the primary circuit shall, with sufficient margins, withstand the stresses arising in normal operational conditions, anticipated operational occurrences, postulated accidents and design extension conditions;*
>
> *iii. the primary circuit and systems immediately connected to it, and components important to the safety of the secondary circuit of a pressurised water reactor, shall be reliably protected during anticipated operational occurrences and all accident scenarios, in order to prevent damage caused by over-pressurisation;*
>
> *iv. the water chemical conditions in the primary circuit and the secondary circuit of a pressurised water reactor shall not result in mechanisms that threaten their integrity; and*
>
> *v. leaks in the primary and secondary circuit of the nuclear power plant that affect safety shall be reliably detectable.*

The primary circuit is one of the engineered barriers for preventing the dispersion of radioactive materials, i.e. part of the structural defence-in-depth principle. The defence-in-depth principle refers to ensuring the safety of nuclear power plants by using consecutive, redundant functional and structural levels to prevent the harmful effects of failure and radiation.

With structural levels, the aim is to prevent the dispersion of radioactive materials. Structural levels, or levels based on release barriers for radioactive material, are related to the reliability and leak-tightness of mechanical structures and equipment. In a nuclear power plant, these barriers include the fuel cladding, the primary circuit and the containment. Radioactive material can only be released into the environment if all of these consecutive release barriers fail.

Guide YVL B.5 “Primary circuit of a nuclear power plant” specifies the requirements set for primary circuit integrity in STUK regulation Y/1/2018.

2 Scope of application

Guide YVL B.5 shall be applied to the design of primary and secondary circuits of nuclear power plants, the design of pressure control and water chemistry conditions as well as the in-service monitoring of water chemistry and radiochemical conditions. For the purposes of this Guide, pressure control means pressure regulation, overpressure protection and pressure reduction.

3 Justifications of the requirements

3.1 Chapter 3 Integrity of the primary circuit

The primary circuit of a nuclear power plant shall be designed to meet the defence-in-depth principles of Section 10 of STUK regulation Y/1/2018, set to prevent the release of radioactive material and related to ensuring integrity. The main components of the reactor coolant circuit, particularly the reactor pressure vessel, shall retain their integrity in all situations and events selected as the design basis. The risk of fast fracture shall be prevented with design solutions. Even in a severe reactor accident, the possibility of the reactor pressure vessel becoming fractured to the extent that the leak-tightness of the containment would be endangered shall be extremely small.

The integrity of the primary circuit shall be primarily ensured by means of high-quality design and manufacturing that minimises the likelihood of detrimental structural defects and mechanisms threatening the integrity of structures during plant operation. In order to prevent damage to the primary circuit, the loads that the primary circuit is subjected to during operational occurrences and accidents shall be taken into account with high safety margins during the design.

The primary circuit is one of the structures that have not been designed to be replaced during the service life of the plant. The primary circuit is subjected to particularly strict condition monitoring that aims to anticipate any created problems well in advance before they jeopardise the safety of the plant. As regards equipment that will be replaced during operation, condition monitoring is focused on ensuring their operability by means of inspections and tests. Condition monitoring also includes the utilisation of operating experience received from similar equipment at other nuclear power plants.

In order to ensure the timely detection of any possible primary circuit leaks, the nuclear power plant shall be equipped with leak monitoring systems that issue timely warnings allowing the plant to be shut down in a controlled manner without jeopardising safety.

The integrity of the primary circuit pipelines shall be ensured by meeting the high quality requirements in their design, operation and inspection as well as with an appropriate leakage monitoring system. These requirements are associated with the Break Preclusion (BP) and Leak Before Break (LBB) principles, the fulfilment of which enables the construction of certain primary and secondary circuit pipelines without whip restraints protecting from the dynamic impacts of postulated pipe breaks. Guide YVL E.4 “Strength analyses of nuclear power plant pressure equipment” describes in more detail the application of these principles to the design of primary and secondary circuits.

The Break Preclusion (BP) and Leak Before Break (LBB) principles ensuring the integrity of pipelines can be applied to the main coolant lines of the primary circuit and the pressuriser connecting line as well as the main steam and feed water pipelines, if the requirements associated with the principle are met. If the principle is not applied or the requirements associated with the principle are not met, the pipes shall be equipped with whip restraints. The second paragraph of Section 10 of STUK regulation Y/1/2018 defines that the primary circuit refers to the nuclear reactor cooling circuit. The main coolant lines of the primary circuit refer to pipes that form the cooling circuit starting from the reactor pressure vessel. The pressuriser connecting line refers to the pipe between the main coolant line and the pressuriser.

Therefore, there are two options for the design basis of reactor internals, primary circuit structures and components as well as systems connected to the primary circuit:

1. When the BP and LBB principles are met, the design basis shall be those pressure transient loads that derive from the complete and sudden break of a pipe connected to the main coolant line of the primary circuit, main steam and feedwater pipeline or the reactor pressure vessel with the greatest pressure impact or dimensioning the equipment/system. Therefore, if the primary circuit main coolant lines meet the BP and LBB principles, the design basis for the aforementioned structures and components shall be loads caused by the break of a pipe connected to the primary circuit main coolant line even if the BP and LBB principles were applied to this pipe (e.g. pressuriser connecting line).
2. If the BP or LBB principles are not met or are not used as the basis for pipeline design for some other reason, the design basis shall be any loads caused by the complete and sudden break of the primary circuit main coolant line, main steam and feed water pipelines or a pipe connected to the reactor pressure vessel. However, in this case, whip restraints are taken into account; they shall be installed around these pipelines according to requirement 303. Therefore, if there is no wish to apply the BP and LBB principles or their requirements are not met by the aforementioned pipes, the design basis for the aforementioned structures and components shall be the break of the pipe causing the biggest load impact.

Provision for breaks in the main steam line and the main feedwater pipe outside the containment shall be made to ensure that dynamic loads caused by the break do not compromise the functionality and integrity of the containment penetration and isolation valves (YVL B.6 “Containment of a nuclear power plant”).

A complete and sudden break of the primary circuit main coolant line with the highest diameter as well as the main steam and feedwater pipe shall constitute the design basis for

- the dimensioning of emergency cooling and/or boration systems as well as the containment;
- the qualification of equipment required for safety functions to withstand any environmental impacts arising in the situation in question;
- containment penetrations and the functionality and integrity of isolation valves
- while reviewing the stability of the main components of the primary circuit.

If the BP and LBB principles are applied to the primary circuit main coolant lines and main steam and feedwater pipelines (i.e. these pipes have not been equipped with whip restraints), the defence-in-depth related to plant design shall include analysis of the structural consequences of the complete and sudden break of these pipes as design extension condition (DEC B). Pressure transient and strength analyses shall be conducted for the following items:

a) reactor internals and its support structures
b) fuel
c) steam generator’s heat transfer tubes
d) flywheel of the reactor coolant pump of the pressurized water reactor.

If the BP and LBB principles are applied to the pressuriser connecting line, the consequences of the complete and sudden break of this pipe shall – as above – be analysed as a design extension condition. The analysis shall clarify the consequences of the break as regards the main coolant lines and containment structures.

Initial assumptions can be selected realistically in these analyses carried out as a design extension condition. Based on the analysis, it shall be demonstrated that, as a result of the break,

a) the reactor can be maintained sub-critical with reactivity control systems;
b) deformations of reactor internals shall not compromise the coolability of the reactor;
c) the steam generator’s heat transfer tubes are not damaged to the extent that control of the accident is lost;
d) any damage caused to the containment structures does not compromise the leak-tightness of the containment.

All operating temperatures shall be taken into consideration in the design of the main components of the nuclear power plant. The permitted loadings of the nuclear power plant’s main components at operating temperatures lower or higher than normal shall be analysed, and on this basis the pressure and temperature ranges for the safe operation of the components during normal operation shall be defined.

Operation outside the permitted pressure and temperature ranges during normal operation shall be prevented with reliable protections.

3.2 Chapter 4 Pressure control of the primary and secondary circuit

3.2.1 Chapter 4.1 General requirements

The defence-in-depth approach to safety shall be followed in the design of pressure control at the nuclear power plant. According to the principle, systems and equipment with different capabilities shall be employed for pressure control in such a way that preventive actions to mitigate the consequences of a transient or accident are proportional to the severity of the event.

The diversity principle shall be applied in the design of the pressure control systems of the reactor cooling system to reduce the likelihood of common cause failures.

To ensure the safety of the nuclear power plant it is essential that there are no interruptions in heat transfer from the reactor to the ultimate heat sink. An uninterrupted heat transfer is ensured when the coolant volume and the pressure and temperature conditions in the circuits are appropriate. Pressure regulation shall be reliable during reactor normal operational conditions as well as anticipated operational occurrences.

Overpressure protection of the primary and secondary circuit is essential for maintaining the integrity of the heat transfer chain. The pressure and temperature limits during normal operation of the primary circuit are determined on the basis of sufficient safety margins in order to prevent fast fracturing of pressure equipment. For a pressurised water reactor, on the other hand, these limits are determined on the basis of a sufficient margin with respect to boiling.

Pressure reduction may be required during an accident to interrupt a coolant leak, or to ensure reactor emergency cooling or residual heat removal. During a severe reactor accident, a rupture of the reactor pressure vessel at high pressure endangers containment integrity. Primary circuit pressure reduction is thus an integral part of a severe accident management strategy.

More detailed instructions on the design of safety valves and relief valves related to the pressure control of nuclear power plants are provided in Guide YVL E.8 “Valves of a nuclear facility”.

3.2.2 Chapter 4.2 Pressure control during normal operational conditions and anticipated operational occurrences

Reactor pressure control shall be designed so that the pressure can be maintained within the range of reactor normal cooling during normal operational conditions and anticipated operational occurrences.

Provisions shall be made for normal operational conditions and anticipated operational occurrences by means of systems intended for pressure control to ensure that it will not be necessary to use primary circuit safety valves to restrict pressure increase in the primary circuit. Systems intended for pressure control can be based on, e.g., relief valves, an isolation condenser or, in the pressurised water reactor, a pressuriser spray system.

Systems associated with pressure control shall be so designed as to ensure that it will not be necessary – during normal operation and anticipated operational occurrences – to remove coolant from the primary circuit with the exception of a possible brief discharge to manage a transient. This is to ensure that, during normal operation and anticipated operational occurrences, no significant amounts of primary coolant is lost outside the primary circuit and that the reliability of reactor core cooling is not unnecessarily compromised. Here, it is possible to utilise, for example, passive decay heat removal systems, such as isolation condensers.

The reliable closing of the relief valve shall be ensured with a shut-off valve of the discharge line. This is to prevent primary circuit leaks in an event where the relief valve fails and stays in the open position, and the aggravation of the operational occurrence into an accident.

The control of primary and secondary circuit pressure shall be ensured even in an event where the offsite power supply has been lost.

3.2.3 Chapter 4.3 Overpressure protection

One of the possible failure mechanisms of the primary circuit and the secondary circuit of a pressurised water reactor is the overpressure that these components are subjected to during different operational occurrences and accident situations. In order to prevent this failure mechanism, the primary circuit and the secondary circuit of a pressurised water reactor shall be protected by means of equipment that prevents the overpressure.

To prevent over-pressurisation, the primary circuit of the pressurised and boiling water reactors as well as the secondary circuit of the pressurised water reactor plant shall be equipped with safety valves intended for over-pressure protection.

The discharge capacity required for preventing overpressure shall be divided between several redundant safety valves. Redundant safety valves protecting the same item shall be set to open at several stages so that the number of opened valves corresponds to the required discharge capacity.

There shall be no shut-off valve in the discharge line of the safety valve and between the protected item and safety valve. This requirement shall ensure that, in the event of overpressure protection, there is no shut-off valve in the discharge line that could be closed by accident and prevent overpressure protection. A shut-off valve should also not be placed in the impulse line needed to open the safety valve. If exceptions to this rule are made to facilitate testing or maintenance or to provide against a stuck-open safety valve, the shut-off valve’s inadvertent closing shall be reliably prevented.

The safety valve shall be equipped with a position indicator which is independent of the control equipment and can be used by the plant’s operating personnel to ensure the position of, e.g., a stuck-open safety valve and take the necessary action in time to correct the situation.

In the design of the safety valves, their pilot valves and connecting pipelines, the possible accumulation of non-condensable gases and condensate plus their harmful effects shall be taken into account. In particular, hydrogen generated through radiolysis in the reactor can explode in the pilot valves or their connection piping and damage the valve. Condensate (water) can accumulate on the valve plate and prevent or delay its opening on demand.

The system of safety valves for overpressure protection and the connected pipelines shall be designed, where necessary, to discharge steam as well as steam-water mixture and water. In certain accidents, such as a “feed and bleed” situation in a primary or secondary circuit, it is necessary to discharge steam-water mixture and water in addition to steam through the safety valve.

The functions of the overpressure protection and scram system of a boiling water reactor shall be designed to operate independently from each other so that the scram is successful during an accident described in Guide YVL B.3 “Deterministic safety analyses for a nuclear power plant” that proves to be the most limiting for overpressure protection even if none of the safety valves designed for overpressure protection open. Correspondingly, even if the scram function fails, the overpressure protection function shall be accomplished as described in Guide YVL B.3. The hydraulic scram system of the boiling water reactor works according to the piston principle. The force that moves the control rods is the pressure difference between the reactor and the hydraulic system, that acts on the piston. If the reactor pressure increases excessively in relation to the pressure in the hydraulic system, the reactor scram may be partly prevented, jeopardising the reactor shut-down. To avoid this, the aforementioned phenomenon shall be taken into account in the design of the total capacity of the safety valves and when dimensioning the hydraulic system pressure.

Components that can increase pressure in the primary circuit (e.g. pressuriser heaters and pumps) shall be equipped with a system that will stop the operation of the component to prevent erroneous pressure increase. The system shall be capable of implementing the protection function also in case of a single failure.

3.2.4 Chapter 4.4 Pressure reduction

The primary circuit and the secondary circuit of the pressurised water reactor shall be provided with components that can be used to reduce pressure in a controlled manner in postulated accident situations. In certain accident situations, it is necessary to decrease reactor pressure to ensure that reactor cooling can be carried out with, e.g., low-pressure emergency core cooling pumps.

The primary circuit shall be provided with a pressure reduction system to prevent the break of the reactor pressure vessel during a severe reactor accident in a manner that could endanger the leak-tightness of the containment. In severe reactor accidents, the reactor pressure vessel may be fractured at full pressure and endanger the leak-tightness of the containment. To prevent this, the primary circuit shall have a pressure reduction function which must work reliably under the conditions of severe reactor accidents.

The pressure reduction system for severe reactor accidents shall be independent of systems designed for managing the plant’s anticipated operational occurrences and postulated accidents. A severe reactor accident can only occur if systems intended for mitigating the consequences of anticipated operational occurrences and postulated accidents are lost. To avoid, for the same reason, the loss of the system meant for severe reactor accidents in addition to the aforementioned systems, systems intended for mitigating the consequences of severe accidents shall be independent of the systems intended for mitigating the consequences of operational occurrences and postulated accidents.

The pressure reduction system for severe reactor accidents shall be able to fulfil the safety functions also in case of a single failure. Failure tolerance is required of the pressure reduction system for severe reactor accidents to ensure adequate functional reliability.

Valves intended for pressure reduction shall be designed so that, once they have opened, they stay open reliably. Their staying open is an absolute requirement for implementing the safety function.

3.3 Chapter 5 Water chemistry of the primary and secondary circuit

3.3.1 Chapter 5.1 Chemistry conditions of the primary circuit

Requirement 501 is an introduction to the requirements for primary and secondary circuit water chemistry, which are justified in Section 10 of STUK regulation Y/1/2018.

Requirement 502 contains a compilation of the purposes of the primary coolant water chemistry, which can be considered as generally known information. The purposes are also described in Section 3.4 of IAEA’s guide SSG-13, which defines the contents of the chemistry programme. Requirement 502 does not contain a specific reference to the reduction of dose rates, which is included as a purpose of water chemistry in the aforementioned Section 3.4 of IAEA’s guide SSG-13. The reason for this is that requirement 502 of Guide YVL B.5 lists the factors which contribute to keeping radiation dose rates as low as possible.

Requirement 503 is based on section 3.4 (a) of IAEA’s guide SSG-13, which requires that the chemistry programme ensures that water chemistry corresponds with, e.g., the materials of the primary circuit.

Requirement 504 is based on Section 5.19 of IAEA’s guide SSG-13, according to which the primary circuit surfaces shall be prepared before and during start-up to ensure that the surfaces attain a protective film. The protective film reduces corrosion and the release of corrosion products into the coolant. This way, the accumulation of radioactive substances on primary circuit surfaces is reduced as well. The scope of application of Guide YVL B.5 covers the water chemistry conditions of the primary circuit. Therefore, the Guide does not address the treatment applicable to primary circuit surfaces before commissioning. In Guide YVL B.5, the requirement for monitoring the success of pre-passivation through material samples is justified by information obtained from oxide film formation. A visual inspection and microscope study provide immediate information on the success of passivation. Later, more specific analyses and measurements can help clarify issues such as the composition and thickness of the oxide layer. The obtained information can be utilised, for example, in the occurrence of unexpected corrosion product concentrations in the primary circuit or exceptional radiation dose rates resulting from the primary circuit during plant operation.

Requirement 505 is based on Section 3.4 (d) of IAEA's guide SSG-13, which requires a chemistry programme to ensure that the integrity of auxiliary systems is retained and that the systems remain operable. In systems connected to the primary circuit, corrosion shall also be kept as low as possible to ensure that the systems do not release corrosion products into the primary coolant. Keeping corrosion rates as low as possible also ensures that the systems remain operable.

Requirement 506 is based on Section 5.5, concerning the use of high-quality water, of IAEA's guide SSG-13.

According to requirement 507, during normal operation, fission product amounts caused by the largest allowed fuel leak as well as the amounts of any impurities entering the coolant are used as dimensioning criteria of the purification system. The requirement for monitoring the efficiency of the purification system is based on Section 6.24 of IAEA's guide SSG-13, according to which radioactivity measurements are used to monitor the efficiency of the purification system particularly if the removal of radioactive substances is the primary purpose of the purification system.

Requirement 508 is based on the fact that a degasification system is used to remove gaseous fission products (xenon, cryptonite) from the primary coolant of the pressurised water reactor in a fuel leak situation. This ensures that no radioactive substances are released into the containment from the circuit when opening the reactor pressure vessel head. During pressure reduction, dissolved gases released from the coolant are removed with the degasification system. The particular purpose is to remove hydrogen from the coolant to ensure that no explosion hazard arises through the opening of the reactor pressure vessel head. In start-ups following outages, oxygen is removed from the primary coolant with the degasification system to achieve the reductive conditions in the coolant before proceeding to power operation. The operation of the degasification system is important with regard to minimising radiation doses and avoiding explosion hazards.

3.3.2 Chapter 5.2 Chemistry conditions of the secondary circuit

Requirement 509 includes general principles for the design of the water chemistry conditions of the secondary circuit. Similar topics have been discussed in Sections 3.4 (c), 4.43 and 4.44 of IAEA's guide SSG-13, which address the content of the chemistry programme and the secondary circuit.

Requirement 510 is based on Section 4.44 (c) of IAEA's guide SSG-13, according to which compatibility with the secondary circuit materials shall be taken into account in the selection of the secondary coolant pH and chemicals to be added to the coolant.

Requirement 511 is based on Section 4.46 of IAEA's guide SSG-13, according to which concentrations of harmful impurities in steam generators, such as sodium, chloride and sulphate as well as lead and copper, shall be kept as low as possible, and the concentrations shall be monitored.

Requirement 512 is based on the fact that purification of the steam generators' blow-off, input of chemicals required to adjust pH as well as the removal of non-condensable gases are required in order to maintain the secondary circuit water chemistry conditions. Systems shall be in place in the plant to accomplish these functions.

Requirement 513 is based on the fact that, through the film formed on secondary circuit surfaces, corrosion can be minimised. This helps reduce the formation of corrosion products, their release into the circuit and accumulation in the steam generators. Passivation does not normally require adding chemicals to the circuit; it occurs by maintaining pre-designed coolant conditions during the commissioning of the secondary circuit (e.g. temperature, its maintenance and restrictions concerning temperature changes).

3.3.3 Chapter 5.3 Monitoring of chemistry and radio chemistry conditions

Requirement 514 is based on Sections 3.4 (e), 4.4 and 4.5 of IAEA's guide SSG-13, which discusses the use of monitoring and supervision parameters as well as the definition of limit values and corrective measures. Requirement 514 is also based on WENRA's requirement E.07.3 for defining the criteria for protecting primary circuit pressure boundary. Limit values are defined for the parameters most important to safety, i.e. TechSpecs parameters, which include parameters affecting the maintenance of the chemical conditions of the primary circuit as well as corrosion of fuel cladding, structural materials of the primary circuit and steam generator tubes. The requirement for defining control and limit values for all operational states is based on WENRA's requirement H.04.1 concerning the coverage of all operational states in the Tech Specs. The requirement of Guide B.5 only applies to setting control and limit values; the general requirements for limit values included in the TechSpecs are provided in Guide YVL A.6 "Conduct of operations at a nuclear power plant".

Requirement 515 is based on Section 5.3 of IAEA's guide SSG-13 on setting strict limit values for all important radiochemistry parameters in different operational states. General requirements for the limit values included in the TechSpecs are provided in Guide YVL A.6.

Requirement 516 ensures that chemical and radiochemical conditions are monitored with sufficiently sensitive and accurate methods. Requirement 516 can be derived from WENRA requirement H.05.2, which requires setting conservative safety limits in order to take into account the uncertainty factors related to safety assessments.

The principle of requirement 517 is based on Section 4.3 of IAEA's guide SSG-13, according to which stricter limit values (control values) shall be in place for safety-relevant parameters in addition to set limit values in internal laboratory use. Deviations from limit values can be avoided by complying with these values.

According to requirement 518, the monitoring of primary circuit water chemistry conditions shall be planned by means of taking samples during normal operation and changes in operational conditions. The requirement can also be derived from Section 6.1 of IAEA's guide SSG-13, concerning the deployment of a chemistry monitoring programme.

Requirement 519 is based on Sections 7.1 and 7.6 of IAEA's guide SSG-13, which requires recording the analysis and quality control results in a manner deemed appropriate, comparing the results to the TechSpecs in particular, and analysing development trends. Guide YVL B.5 requires the use of a data system in accordance with the current practice. Quality control is not addressed at this point of Guide YVL B.5.

Requirement 520 is based on WENRA requirement B.02.4 concerning the constant monitoring of safety indicators. Furthermore, according to Section 6.6 of IAEA's guide SSG-13, the use of chemistry indicators for the most important chemistry parameters shall be considered. The use of chemistry indicators is a prevailing practice in Finland as well as internationally (e.g. WANO indicators).

According to requirement 521, it is important to obtain a sample of the primary coolant during an accident in order to assess the composition of possible releases based on its activity content.

Requirement 522 is based on Section 6.8 of IAEA's guide SSG-13, according to which continuously operating analysers or measuring instruments should primarily be used in monitoring parameters most relevant to safety. According to Section 6.11 of IAEA's guide SSG-13, responsibilities for calibrating and maintaining continuously operating analysers and measuring instruments shall be defined clearly. Because the devices are at the interface of two areas of technology, it is also important to determine who is responsible for monitoring the results (e.g. chemistry/operation).

Requirement 523 is based on Section 6.17 of IAEA's guide SSG-13, according to which monitoring carried out in a laboratory includes, e.g., radionuclide activity analyses. Section 6.22 of IAEA's guide SSG-13 also defines the analysed nuclides in more detail (fission products, corrosion products, other nuclides). In order to observe fuel leaks, it is essential to use continuously operating activity measurement for primary coolant activity. The requirement for observation limits of the measuring instrument and limitvalues related to fuel leaks or suspicion of fuel leaks is based on Section I.23 of IAEA's guide NS-G-2.2.

Requirement 524 does not include an assessment of the amount of fuel leaks because, based on the magnitude of the leaks, the amount of fission products released into the coolant from the fuel can be assessed. The requirement for assessing burn-up is based on Section 6.22 (a) of IAEA's guide SSG-13. Burn-up assessment can help locate leaking fuel assemblies. Exhaust gas activities as well as primary coolant activity concentrations can be used in fuel leakage assessment.

Requirement 525 is necessary in monitoring the integrity of the primary circuit. With continuously operating activity measurement, leaks from the primary to the secondary circuit can be observed quickly.

Requirement 526 is based on Section 6.29 of IAEA's guide SSG-13, which addresses the determination of the surface activity of primary circuit surfaces.

Requirement 527 is based on Sections 2.7 and 6.36 of IAEA's guide SSG-13, according to which a plant shall have adequate equipment and their redundant equipment. In Guide YVL B.5, the requirement for redundant devices has been specified to apply to equipment used for analysing TechSpecs parameters. Furthermore, WENRA requirement B.2.4 requires that staff have access to the necessary equipment and safe working conditions. Guide YVL B.5 does not address issues related to occupational safety.

Requirement 528 can be derived from WENRA requirement H.06.1, according to which actions performed by the operating personnel shall be defined for situations deviating from the Operational Limits and Conditions. In this case, laboratory analyses can be considered as such actions. Even though this would not involve measuring a TechSpecs parameter, compensating actions shall be defined to prepare for cases of measurement inoperability (a second measurement or laboratory analysis).

3.3.4 Chapter 5.4 Laboratory

The purpose of requirement 529 is to ensure that there is a laboratory in the nuclear power plant facility. The requirement completely excludes analyses and measurements performed outside the nuclear power plant. However, it is possible to commission an external laboratory to carry out individual analyses or activity measurements. The radioactivity of the samples may be a restricting factor when commissioning analyses from external actors. The advanced level of the laboratory's analysis and measuring instruments ensures the reliability of the analysis and measurement results and partly contributes to minimising the staff's radiation exposure through a reduction in the processing phases of samples.

Requirement 530 contains references to guide YVL C.1 “Structural radiation safety at a nuclear facility” as well as the Radiation Act and any decrees and regulations based on it.

3.3.5 Chapter 5.5 Decontamination

Requirements 531 and 531a are based on Sections 5.22 and 5.23 of IAEA's guide SSG-13, concerning the use of an efficient decontamination technique and passivation of the primary circuit after a possible decontamination. According to Section 5.22 of IAEA's guide SSG-13, decontamination procedures shall be validated. In Guide YVL B.5, the requirement has been replaced with a requirement for monitoring decontamination, because the decontamination methods are generally well known and there are prior user experiences.

3.3.6 Chapter 5.6 Chemicals and supplies

Requirement 532 is based on Section 9.1 of IAEA's guide SSG-13, according to which a plant shall have a system whose purpose is to prevent the use of chemicals and other substances containing harmful substances. Furthermore, Guide YVL B.5 describes the potential harmful effects of the substances.

Requirement 533 is based on the fact that approving chemicals and supplies is collaborative work between different organisations and that the suitability of the substances for their purpose shall be assessed in the user organisation (e.g. the technical suitability of seals or lubricants for the intended purpose).

3.3.7 Chapter 5.7 Chemistry programme and quality management of chemistry operations

Requirement 534 is based on chapter 3 “Chemistry Programme” of IAEA’s guide SSG-13.

Requirement 535 refers to Guide YVL A.3 “Leadership and management for safety”. For example, standard SFS-EN ISO/IEC 17025 sets laboratory-specific requirements that are not directly derivable from Guide YVL A.3. Such requirements concern, e.g., validating the analysis and measurement methods, reviewing data transfers of calculations, the traceability of measurements as well as assuring the quality of the analysis and measurement results.

Requirement 536 entails that concentrations of significant substances shall be defined according to standards applicable to the industry in terms of nuclear and radiation safety. In this context, parameters significant in terms of nuclear and radiation safety refer to parameters that are used to

- determine the most important radionuclides in terms of the radiation safety of the environment and employees, based on samples of various types;
- determine the most important radionuclides in disposed waste;
- monitor the criticality safety of the reactor and spent fuel;
- monitor parameters impacting the integrity of the fuel cladding and primary circuit;
- monitor parameters impacting the generation and release of corrosion products as well as their attachment to primary circuit surfaces;
- monitor chemicals in a storage container, intended for mitigating the consequences of an accident.

Requirement 537 is based on a requirement of Section 508 of Guide YVL A.3, concerning a management system procedure which ensures that the personnel understands the safety impacts of their work. The requirement is also included in Guide YVL B.5, because the aim is to highlight the importance of analysis activity in the reliable verification of fuel and primary circuit integrity and criticality safety.

3.4 Chapter 6 Documentation to be submitted to STUK

3.4.1 Chapter 6.2 Documents to be submitted in the construction licence stage

According to requirement 604, chemistry and radiochemistry laboratories and decontamination shall be described in the preliminary safety analysis report, and the contents of the description of the laboratories and decontamination activity shall, where applicable, be in accordance with requirement 609 of Guide YVL B.1 “Safety design of a nuclear facility”. The laboratories and decontamination facilities with their equipment shall be defined as plant systems. The description of primary and secondary circuit water chemistry shall include, at the least,

- the purpose of the maintenance of the water chemistry conditions
- design basis (general description)
- activity content of the primary coolant during operation
- basic principle of water chemistry conditions

- systems for maintaining water chemistry conditions in different operational conditions
- analyses and measurements used in monitoring (principles and systems)

3.4.2 Chapter 6.3 Documents to be submitted in the operating licence stage

According to requirement 606, chemistry and radiochemistry laboratories, decontamination and management of supplies shall be described in the final safety analysis report, and the contents of the description of the laboratories and decontamination activity shall, where applicable, be in accordance with requirement 620 of Guide YVL B.1. The laboratories and decontamination facilities with their equipment shall be defined as plant systems. The description of primary and secondary circuit water chemistry shall include, at the least,

- the purpose of the maintenance of the water chemistry conditions
- the principle of water chemistry conditions
- systems for maintaining water chemistry conditions in different operational conditions
- a detailed design basis for water chemistry conditions
- limit values of safety-relevant water chemistry parameters during normal operation in all operational conditions
- limit values of radionuclides during normal operation that help identify fuel leaks and assess their magnitude
- continuously operating measurements and laboratory analyses and measurements used in monitoring chemical and water chemistry conditions
- analysis and measurement methods covered by accreditation
- pre-passivation of primary circuit surfaces during hot tests
- passivation of secondary circuit surfaces during commissioning.

3.4.3 Chapter 6.4 System modifications in an operating nuclear power plant

According to requirement 608, pre-inspection documentation shall be drawn up for significant modifications made to primary and secondary circuit water chemistry, chemistry and radiochemistry laboratories, decontamination and management of supplies; it shall then be submitted to STUK for approval. Significant modifications include, e.g., changing to another type of water chemistry or deploying new admixture input. A TechSpecs change proposal with its justifications is sufficient in case of minor changes, such as those made to individual TechSpecs limit values.

Requirement 609 is based on the fact that the possible decontamination of the primary circuit and its connected systems, indicating exceptional conditions for the materials, is carried out systematically and the success of the action can thus be ensured. The plan concerning large-scale decontamination of the primary circuit shall include, at the least,

- a decontamination process which presents the scope of the decontamination; chemical procedures used in decontamination as well as passivation; the fixed and temporary systems used; monitoring the sample programme/continuously operating analysers of the monitored chemical and radiochemical parameters; and decontamination cycles: their length, temperature and pressure

- a suitability assessment of the purification method used for the decontaminated material, presenting material tests with the chemicals used, as well as the oxide layer measurements of samples taken from the primary circuit, the results of which indicate the characterisation of the oxide layer and the optimisation needs of the chosen chemical decontamination method
- the target level of purification, presenting the desired decontamination factor or dose rate level
- a radiation safety plan during decontamination, following the requirements of Guides YVL C.1 and YVL C.6 "Radiation monitoring at a nuclear facility"
- a processing plan for radioactive waste generated during decontamination, following Guide YVL D.4 "Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility", and
- a decontamination follow-up programme specifying the monitoring parameters for successful passivation, the chemical and radiochemical monitoring parameters and sampling programme for primary circuit purification after the passivation, as well as condition inspections of equipment, components and seals during the following outage.

3.5 Chapter 7 Regulatory oversight by the Radiation and Nuclear Safety Authority

STUK reviews compliance with the requirements that pertain to the integrity of the primary circuit, pressure control and primary and secondary circuit chemistry in connection with the processing of the preliminary and the final safety analysis report of a new plant unit.

STUK reviews any changes in pressure control at existing plant units in connection with the conceptual design phase of the systems and components associated with pressure control, the system pre-inspection documentation and the construction plans of the components. STUK reviews changes in primary and secondary circuit chemistry based on the pre-inspection documentation.

STUK assesses the systems and components utilised in pressure control and management of water chemistry conditions as part of the inspections included in the operational inspection programme. STUK controls in particular that these systems and components are maintained appropriately and that the results of their periodic tests as well as their operating experience are taken into consideration.

For the primary and secondary circuit, STUK monitors the maintenance and development of the water chemistry conditions, radiochemical conditions, laboratory activity and decontamination with inspections included in the operational inspection programme as well as with separate inspections. In STUK's indicator system, indicators for fuel integrity and leak-tightness are also used in monitoring water chemistry and radiochemical conditions.

4 International provisions concerning the scope of the Guide

IAEA's guide "Safety of Nuclear Power Plants: Design, Series No. SSR-2/1 (rev 1), February, 2016", "WENRA reference requirements" as well as the requirements for new nuclear power plants, drawn up by WENRA, have been taken into account in the requirements for the integrity, pressure control and overpressure protection of the primary circuit in this guide.

IAEA's guide SSG-13 "Chemistry Programme for Water Cooled Nuclear Power Plants" has been utilised in drawing up Guide YVL B.5. IAEA's guide is considerably more detailed than the YVL Guides; therefore, the requirements of IAEA's guide have been taken into account mainly on the level of principles. IAEA's guide is intended for licence holders as well as authorities.

In laboratory quality control, it is possible to comply with standards such as SFS-EN ISO/IEC 17025 "Competence of testing and calibration laboratories. General requirements."

The requirements of the guide also take into account requirements of some other guides (IAEA's guide NS-G-2.2 "Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants", Section I.23 as well as WENRA requirements B.02.2, E.07.3, H.04.1, H.05.2 and H.06.1).

5 Impacts of the Tepco Fukushima Dai-ichi accident

The Fukushima accident does not impact the scope of application of Guide YVL B.5.

6 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. In addition, the possibilities to reduce the so-called administrative burden have been considered.

With regard to the design of primary circuit, adjustments have been made as to which piping the BP and LBB principles can be applied to.

Requirement 303 has been adjusted so that the BP and LBB principles can be applied to the main coolant lines of the primary circuit and the pressuriser connecting line. Previously, the primary circuit had been defined as the scope of application. This adjustment results in equivalent changes to requirements 304, 305, 306 and 307 as well as the new requirement 306a.

Requirement 306a is a new requirement for analysing the break of the pressuriser connecting line as a DEC B incident, if the BP and LBB principles are applied to this pipe. The acceptance criterion for these analyses has been added to requirement 307 (subsection d).

The majority of the other changes are adjustments and corrections made to the requirements without changing the level of requirement. These changes have been found necessary after publishing the guide and during its deployment.

The requirements of the Guide do not contain any possibilities for reduction of administrative burden.