REACTOR COOLANT CIRCUIT OF A NUCLEAR POWER PLANT

continues

With regard to new nuclear facilities, this Guide shall apply as of 1 December 2013 until further notice. With regard to operating nuclear facilities and those under construction, this Guide shall be enforced through a separate decision to be taken by STUK. This Guide replaces Guide YVL 2.4.

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Authorisation

According to Section 7 r of the Nuclear Energy Act (990/1987), the Radiation and Nuclear Safety Authority (STUK) shall specify detailed safety requirements for the implementation of the safety level in accordance with the Nuclear Energy Act.

Rules for application

The publication of a YVL Guide shall not, as such, alter any previous decisions made by STUK. After having heard the parties concerned STUK will issue a separate decision as to how a new or revised YVL Guide is to be applied to operating nuclear facilities or those under construction, and to licensees' operational activities. The Guide shall apply as it stands to new nuclear facilities.

When considering how the new safety requirements presented in the YVL Guides shall be applied to the operating nuclear facilities, or to those under construction, STUK will take due account of the principles laid down in Section 7 a of the Nuclear Energy Act (990/1987): *The safety of nuclear energy use shall be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience, safety research and advances in science and technology.*

According to Section 7 r(3) of the Nuclear Energy Act, *the safety requirements of the Radiation and Nuclear Safety Authority (STUK) are binding on the licensee, while preserving the licensee's right to propose an alternative procedure or solution to that provided for in the regulations. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety standards in accordance with this Act, the Radiation and Nuclear Safety Authority (STUK) may approve a procedure or solution by which the safety level set forth is achieved.*

Translation. Original text in Finnish.

1 Introduction

101. This Guide sets out the requirements for the design and pressure control of the primary circuit of a nuclear power plant and for the water chemistry of the primary circuit and the secondary circuit of a pressurised water reactor plant, and specifies in more detail the requirements pertaining to the design of the primary circuit set forth in Government Decree 717/2013.

102. Requirements related to the design of a nuclear power plant have also been set out in the following Guides:
- YVL A.1 Regulatory oversight of safety in the use of nuclear energy
- YVL A.3 Management system for a nuclear facility
- YVL A.7 Probabilistic risk assessment and risk management of a nuclear power plant
- YVL A.8 Ageing management of a nuclear facility
- YVL B.1 Safety design of a nuclear power plant
- YVL B.3 Deterministic safety analyses for a nuclear power plant
- YVL E.3 Pressure vessels and piping of a nuclear facility
- YVL E.4 Strength analyses of nuclear power plant pressure equipment
- YVL E.8 Valves of a nuclear facility
- YVL C.1 Structural radiation safety at a nuclear facility.

2 Scope of application

201. This Guide applies to the design of the primary and secondary circuit of nuclear power plants, to the design of pressure control and water chemistry conditions, and to the monitoring of water and radiochemistry conditions during operation. For the purposes of this Guide, pressure control refers to pressure regulation, the containment of pressure increase (overpressure protection), and pressure relief.

3 Integrity of the primary circuit

301. The primary circuit of a nuclear power plant shall be designed to meet the principles of defence-in-depth pertaining to the prevention of the dispersion of radioactive substances and related to the assurance of integrity as provided in Section 13 of Government Decree 717/2013. The primary components of the reactor cooling circuit, in particular the reactor pressure vessel, shall maintain their integrity in all design basis conditions and events. The risk of fast fracture shall be prevented through design solutions. Even in a case of a severe accident the possibility of the failure of the reactor pressure vessel so that the leak-tightness of the containment would be endangered shall be extremely low.

302. The integrity of primary and secondary circuit piping shall be ensured such that their design, fabrication, installations, operation and the related inspections satisfy stringent quality requirements.

303. The break preclusion and the LBB principle may be applied to the primary circuit, main steam piping and feedwater pipes of pressurised water and boiling water reactors if the requirements associated with the concept can be satisfied. If the principle is not applied or the requirements based on the principle are not fulfilled, piping shall be equipped with whip restraints.

304. For reactor internals and for the structures, components and associated systems of the primary circuit shall be used as the design bases:

a. If the LBB principle is met the effects of the pressure transient arising from the complete, instantaneous double-ended break of a pipe connected to the primary circuit which gives rise to the greatest pressure impact or is limiting with regard to the component/system
b. If the LBB principle is not met or it is not used for some other reason as a starting point of the primary system design those effects, which arise from the complete, instantaneous break of the primary circuit pipe limited with whip restraints.

305. The complete and instantaneous break of the primary circuit pipe with the largest diameter or main steam and feedwater pipes in pressurised and boiling water reactors shall be used as the design bases:
- for the dimensioning of the emergency cooling system, the emergency boration system and the containment
- for the qualification of components necessary for performing safety functionsto withstand the environmental effects arising in that condition;
- for the operability and integrity of the containment penetration and isolation valves
- when the stability of large primary circuit components is assessed

306. The strength design implications of the complete, instantaneous break of the primary circuit pipe with the largest diameter shall be analysed as design extension conditions (DEC B). These pressure transient and strength analyses shall be performed for the following items:
a. reactor internals and support structures
b. fuel
c. steam generator heat transfer tubes
d. flywheel mass of the pressurised water reactor coolant pump

307. In the analyses performed for design extension conditions, the initial assumptions can be realistically chosen. Based on the analysis, it shall be demonstrated that following an accident
a. the reactor can be maintained subcritical by means of reactivity control systems
b. the deformations in reactor internals do not endanger the coolability of the reactor
c. the steam generator heat transfer tubes are not damaged to an extent resulting in a loss of control over the accident

308. The permitted loads on the main components of a nuclear power plant at low operating temperatures shall be determined and used as a basis for specifying the pressure and temperature ranges for the safe operation of the components during normal operation.

309. Reliable protection shall be provided to prevent the permitted pressure and temperature ranges from being exceeded during normal operation.

310. Guide YVL E.4 covers break preclusion and leak before break (LBB) principles which, when duly satisfied, make it possible to construct the primary circuit piping without using pipe whip restraints to protect them against the dynamic effects of postulated pipe breaks.

4 Pressure control of the primary and secondary circuit

4.1 General requirements

401. The concept of defence-in-depth shall be applied in the design of the pressure control of a nuclear power plant. According to this concept, systems and components with different capacities shall be used for pressure control to ensure that counter measures are proportional to the severity of an anticipated operational occurrence or accident.

402. 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.

403. More detailed instructions for the design of valves of nuclear facilities are given in Guide YVL E.8.

4.2 Pressure control during normal operation and anticipated operational occurrences

404. Reactor pressure control shall be so designed as to ensure that pressure can be maintained within the limits required for the normal cooling of the reactor during normal operation and anticipated operational occurrences.

405. 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 safety valves to restrict pressure increase in the primary circuit.

406. Systems related to pressure control shall be so designed as to ensure that it will not be necessary – during normal operation and anticipated operational occurrences – to remove primary coolant outside closed systems, with the exception of a potential brief discharge to manage an operational occurrence.

407. When a relief valve is used for pressure control, its reliable closing shall be secured by means of a relief line shut-off valve.

408. Pressure control in the primary and secondary circuit shall be ensured even in the event of a loss of off-site power.

4.3 Overpressure protection

409. The primary circuit of a pressurised and boiling water reactor and the secondary circuit of a pressurised water reactor plant shall be provided with safety valves intended for overpressure protection, designed to open at the design pressure of the protected item when required.

410. The primary circuit of a pressurised and boiling water reactor and the secondary circuit of a pressurised water reactor plant shall be provided with several redundant safety valves. Redundant safety valves protecting the same item shall be set to open in succession to ensure that no more valves than required are opened to relieve overpressure.

411. No shut-off valves may be placed in the discharge line of a safety valve, nor between the item being protected and a safety valve. Where possible, no shut-off valve should be installed in the control line required for opening a safety valve. If an exception is made to this rule to facilitate testing or maintenance or to prevent a safety valve from being stuck open, the inadvertent closing of the shut-off valve shall be reliably prevented.

412. The safety valve shall be provided with a position indicator that is independent of the control equipment.

413. Due consideration in the design of the safety valves, their pilot valves and connecting piping shall be given for the potential accumulation of non-condensable gases and condensate as well as the adverse effects they may have.

414. When necessary, the set of safety valve used for overpressure protection and the associated piping shall be designed to discharge steam as well as a steam-water mixture and water.

415. The boiling water reactor overpressure protection and reactor scram systems shall be designed to operate independently of each other in such a way that a scram can be successfully accomplished during the type of accident described in Guide YVL B.3 that proves to be limiting in terms of overpressure protection even in the event that all of the safety valves designed for overpressure protection fail to open. Respectively, overpressure protection shall perform as provided in Guide YVL B.3 even if the scram function fails.

416. Components that can increase pressure in the primary circuit (e.g. pressuriser heaters or pumps) shall be equipped with a system that stops the operation of the component to prevent inadvertent pressure increase and is capable of performing the protection function also in the event of a single failure.

4.4 Pressure reduction

417. The primary circuit of a pressurised and boiling water reactor and the secondary circuit of a pressurised water reactor shall be provided with devices that can be used for controlled pressure reduction in postulated accidents.

418. The primary circuit shall be provided with a pressure reduction system to prevent the break of the reactor pressure vessel during a severe accident to the extent that it could endanger containment integrity.

419. The severe accident pressure reduction system shall be independent of any systems designed for managing the plant's anticipated operational occurrences and postulated accidents.

420. The severe accident pressure reduction system shall be capable of performing its safety function even in the event of a single failure.

421. Valves intended for pressure reduction shall be so designed that once required to open, they stay open reliably.

5 Water chemistry of the primary and secondary circuit

5.1 Chemistry conditions of the primary circuit

501. According to Section 13 the Government Decree on the Safety of Nuclear Power Plants (717/2013), *the fuel and reactor, the primary circuit of a nuclear power plant and the secondary circuit of a pressurised water reactor, applied water chemistry, the containment and safety functions shall be designed to meet the safety requirements set for ensuring the integrity of the fuel, the primary and secondary circuit, and the containment.*

502. The water chemistry of the primary coolant in pressurised and boiling water reactors shall minimise:

- the general corrosion of construction materials and material deterioration due to water chemistry conditions
- fuel cladding corrosion
- the release, transport and redeposition of activated corrosion products on the primary circuit pipe surfaces
- the formation of a boron-containing crud deposits on fuel surfaces
- local corrosion due to sludge formation

503. The water chemistry conditions of the primary circuit shall be designed to be compatible with the fuel cladding and the primary circuit materials in all operational states.

504. During the commissioning of the plant, the inner surfaces of the primary circuit shall be pre-passivated before the reactor is made critical. Successful completion of the pre-passivation process shall be followed by using material samples.

505. Optimised chemistry conditions in the primary circuit and in other systems important to safety shall be sustained to mitigate significant corrosion of construction materials.

506. The ingress of impurities into the primary circuit shall be prevented by having proper technical and administrative procedures. The quality and purity of the water and chemicals fed into the primary circuit shall be controlled. Raw and demineralised water treatment methods shall be able to produce make-up water fulfilling the quality requirements specified for power plant primary circuit and other systems. A boiling water reactor plant shall have a condensate purification system, and its efficiency shall be controlled.

507. The plant shall have a coolant purification system to sustain the water chemistry conditions of the primary coolant during normal operation and to limit the spreading of radioactive substances due to a possible fuel leakage. Capacity of the purification system shall be based on the amount of fission products released into the primary coolant as a result of the maximum allowable fuel leakage during power operation, the amount of the corrosion products dissolved from primacy circuit surfaces and on the amount of possible impurities introduced to the coolant. The purification system shall operate in all operational states, and the performance of the system shall be controlled at least while removing radioactive substances from the primary circuit.

508. A pressurised water reactor shall be provided with a degasification system. The capacity of the system shall be based on the amount of gaseous fission products released during the maximum allowed fuel leakage during operation, the amount of gases released in pressure reduction situations, and the amount of gases removed after an outage. Chemicals may also be used for degasification purposes when necessary.

5.2 Chemistry conditions of the secondary circuit

509. The water chemistry conditions of the secondary circuit of a pressurised water reactor plant shall be designed to minimise the probability of pipe breaks detrimental to nuclear or radiation safety. The secondary circuit and its water chemistry shall be designed to minimise:
- the ingress of gaseous and liquid corrosive substances into the secondary circuit
- corrosion due to coolant flow conditions
- the deposition of corrosion products in steam generators
- the accumulation of deleterious impurities in deposits

510. The secondary circuit construction materials inside the containment shall be compatible with the water chemistry conditions.

511. The concentrations of impurities detrimental to the integrity of steam generator heat transfer tubes shall be kept as low as possible, and the levels shall be monitored.

512. In order to maintain the specified water chemistry conditions in the secondary circuit, systems shall be in place for the purification, chemical injection and evacuation of non-condensable gases.

513. Pre-passivation of the secondary circuit water-steam cycle surfaces shall be carried out during the commissioning tests of the plant.

5.3 Monitoring of chemistry and radiochemistry conditions

514. The primary and secondary coolant's chemistry parameters shall be defined for each operational state to ensure the integrity of the fuel cladding and the primary circuit; to minimise the release, transport and redeposition of activated corrosion products on primary circuit surfaces; and to enable the estimation of corrosion rate in different systems. The parameters shall be classified according to their safety significance, and guideline or action level values shall be defined for them.

515. Operational action level values shall be defined for the activity concentrations of the most important radioactive substances present in the primary coolant. The most important radioactive substances refer to radionuclides that can be used for detecting fuel leakages and for estimating their size. The action level values shall be based on the maximum allowed fuel leakage during operation.

516. The uncertainties associated with the analysis or measurement methods shall be taken into account in the guideline and action level values.

517. The guideline and action level values shall be specified in such a manner that when the plant is operated according to them, chemistry conditions remain within the design bases defined in the final safety analysis report. Monitoring based on the guideline and action level values shall permit early detection of any deviations before they have significant safety consequences.

518. A sampling programme shall be in place for monitoring the chemistry parameters and activity concentrations in the primary and secondary circuit.

519. Records shall be kept to confirm that the parameters have remained within the guideline and action level values. Any individual deviation and diverging trends shall be analysed. An information system shall be in place for storing the measurement and analysis results.

520. Indicators representing the integrity of the primary circuit and fuel cladding shall be used in evaluating chemistry and radiochemistry conditions.

521. The plant shall have a sampling system to deliver representative samples for on-line analysers and measurements as well as for grab sampling during different operational states and their changes. A system shall be in place allowing primary coolant sampling during accident conditions.

522. Whenever technically feasible, on-line analysers or measuring instruments shall primarily be used for monitoring the parameters most important to safety. The responsibilities for operating and maintaining these analysers and instruments shall be clearly allocated, along with the responsibilities for keeping track of the analysis and measurement results.

523. Activity concentrations in the primary circuit shall be monitored by analysing each individual nuclide by means of laboratory specifications. To be able to detect potential fuel leaks, the radioactivity of the primary circuit of a pressurised water reactor shall be monitored using fixed on-line analysers. The detection limits and threshold values indicating a fuel leakage and suspected fuel leakage shall be specified.

524. A procedure based on the activity concentrations of fission products shall be in place for assessing the size and burnup and, when possible, the type of the fuel leakage.

525. The radioactivity of the secondary circuit shall be monitored using fixed on-line measurements to detect pipe breaks in the steam generators.

526. The amount of surface activity on primary circuit surfaces shall be monitored on a nuclide-specific basis.

527. The laboratory shall have advanced and adequate analysis and measuring equipment. In addition, the laboratory shall have standby equipment or alternative validated analysis methods for the chemistry parameters mentioned in Technical Specifications.

528. Alternative analysis or measurement procedures shall be specified for on-line analysers or measuring instruments in case of equipment failure.

5.4 Laboratory

529. A nuclear power plant shall have laboratory facilities suitable for handling the samples taken in normal operational conditions as well as during accidents. The analysis and measuring instruments used in the laboratory shall be technologically advanced.

530. The radiation safety requirements specified in Guide YVL C.1 and Guide YVL C.6 shall be taken into account in the design of the laboratory facilities. Additionally, the design of the laboratory facilities, storage of radioactive substances in the laboratory, laboratory work, and tracer tests outside the laboratory shall be carried out in compliance with Guide ST 6.1.

5.5 Decontamination

531. The facility shall have procedures in place for routine decontamination of individual components and component parts. The effectiveness of the decontamination process shall be monitored, and records shall be kept of the decontamination results. If a large-scale decontamination of the primary circuit surfaces is necessary, the surfaces shall be pre-passivated afterwards. The effectiveness of the decontamination process shall be monitored.

5.7 Chemicals and supplies

532. The licensee shall have a procedure in place for managing the chemicals and other supplies used at the plant, which shall ensure that no supplies will come into contact with the process that may:

- be detrimental to structures or components upon contact
- be activated into radioactive nuclides in the neutron flux of the reactor core when entering the primary circuit
- be harmful to the operation of systems important to safety
- significantly increase radiation doses when activated

533. All chemicals and supplies shall be suitable for their intended use.

5.8 Chemistry programme and quality management of chemistry operations

534. A nuclear power plant shall have a chemistry management programme in place for ensuring the safe operation of the plant and the long-term integrity of structures, systems and components, as well as for minimising the build-up of radio-

active substances and limiting radioactive and chemical discharges to the environment. Due consideration in the chemistry programme shall be given to IAEA Guide SSG-13 [7]. A description of the chemistry programme shall be provided in the plant management system documentation.

535. Guide YVL A.3 specifies the general requirements for safety and quality management that also impact the management system. The quality management of the chemistry laboratory shall also include the validation of analysis and measuring methods, the verification of calculations and data transfers, the traceability of measurements, and the quality assurance of the analysis and measurement results.

536. The analysis methods used in the laboratory to determine the concentrations of substances important to nuclear and radiation safety shall agree with the applicable industry standards.

537. Chemical and radiochemical analysis activities shall take into account the safety significance of the analysis-based monitoring in terms of reactor criticality, fuel integrity, the integrity of the primary circuit, and the transport and release of radioactive substances. Safety significance shall be defined in the chemistry and radiochemistry instructions.

6 Documentation to be submitted to STUK

6.1 Documents to be submitted in the decision-in-principle stage

601. The reports submitted directly to STUK when the application for a decision-in-principle is filed shall provide a description of the factors affecting primary circuit integrity and pressure control to the extent specified in section 6.1.1 of Guide YVL B.1, Safety design of a nuclear power plant.

6.2 Documents to be submitted in the construction license stage

602. The design bases related to primary circuit integrity shall be described in the preliminary and final safety analysis report.

603. Pressure control design bases and the description of systems related to pressure control shall take account of the provisions of section 6.1.2 of Guide YVL B.1, Safety design of a nuclear power plant.

604. The chemistry of the primary and secondary circuits, chemical and radiochemical laboratories and decontamination activities shall be described in the preliminary safety analysis report. The description shall include the information specified in requirement 609 of Guide YVL B.1 when applicable.

6.3 Documents to be submitted in the operating license stage

605. Pressure control as provided in section 6.1.3 of Guide YVL B.1, Safety design of a nuclear power plant.

606. The chemistry of the primary and secondary coolant, chemical and radiochemical laboratories and decontamination activities as well as an outline of the procedure used for managing chemical and other supplies shall be described in the preliminary safety analysis report. The description shall include the information specified in requirement 619 of Guide YVL B.1 when applicable.

6.4 System modifications in an operating nuclear power plant

607. A description of any modifications to in accordance with section 6.2 of Guide YVL B.1, Safety design of a nuclear power plant.

608. Pre-inspection documentation shall be drawn up for any major modifications to the chemistry during operation and submitted to STUK for approval. The pre-inspection documentation shall include the same information and clarifications as the final safety analysis report.

609. A decontamination plan for systems included in or associated with the primary circuit shall be submitted to STUK for approval.

7 Regulatory oversight by the Radiation and Nuclear Safety Authority

701. STUK verifies that the requirements for the integrity of the primary circuit, pressure control and the water chemistry of the primary and secondary circuit are met in connection with the processing of the preliminary and final safety analysis report for the new plant unit.

702. STUK will review any modifications concerning the pressure control of operating plant units in connection with the review of the relevant conceptual design plans of systems and components, system pre-inspection documents and construction plans for components. Modifications to the chemistry of the primary and secondary circuits will be reviewed by STUK based on the respective pre-inspection documents.

703. STUK will assess the systems and components used for pressure control and for controlling water chemistry conditions as part of the inspections specified in the in-service inspection programme. In particular, STUK will ensure that these systems and components are properly maintained, and that the results of their in-service testing and the experience gained from operating activities are taken into consideration.

704. STUK will oversee the maintenance and development of the water chemistry conditions of the primary and secondary circuit, as well as the radiochemistry conditions, laboratory operations and decontamination by means of inspections specified in the in-service inspection programme and separate inspections. The indicators for fuel integrity and structural integrity included in STUK's indicator system are also used for the purpose of monitoring water and radiochemistry conditions.

Definitions

Initiating event

Initiating event shall refer to an identified event that leads to anticipated operational occurrences or accidents.

The diversity principle

Diversity principle shall refer to the backing up of functions through systems or components having different operating principles or differing from each other in some other manner, with all systems or components able to implement a function separately. (Government Decree 717/2013)

Pre-passivation

Pre-passivation shall refer to a procedure whereby a thin, protective oxide layer is formed on the surface of a material when metal reacts with its environment. The formation of an oxide layer reduces the rate of corrosion.

Qualification

Qualification shall refer to a process to demonstrate the ability to fulfil specified requirements (corresponds to the qualification process of the ISO 9000 standard).

Corrosion

Corrosion shall refer to a physical and chemical reaction between metal and its environment that introduces changes to the metal's properties and may lead to a significant reduction in the functionality of the metal, its environment, or the technical system of which they are part.

Leak before break (LBB)

The leak before break (LBB) shall refer to a principle where piping does not have identified failure mechanisms creating the possibility of complete break, and faults that are not detected during inspections may at most create a small, local leak the detection of which allows the plant to be brought into a state where there is no risk of complete break.

Break preclusion

Break preclusion (BP) shall refer to the principle of using advanced technical and organisational procedures in piping construction, operations and maintenance in such a way that the LBB principle will be implemented and this may be credited for the nuclear power plant design and its provision against the consequences of a complete, instantaneous pipe break.

Postulated accident

Postulated accident shall refer to a deviation from normal operation which is assumed to occur less frequently than once over a span of one hundred operating years, excluding design extension conditions; and which the nuclear power plant is required to withstand without sustaining severe fuel failure, even if individual components of systems important to safety are rendered out of operation due to servicing or faults. Postulated accidents are grouped into two classes on the basis of the frequency of their initiating events: a) Class 1 postulated accidents (DBC 3), which can be assumed to occur less frequently than once over a span of one hundred operating years, but at least once over a span of one thousand operating years; b) Class 2 postulated accidents (DBC 4), which can be assumed to occur less frequently than once during any one thousand operating years.

Design extension condition (DEC)

Design extension condition (DEC) shall refer to:

a. an accident where an anticipated operational occurrence or class 1 postulated accident involves a common cause failure in a system required to execute a safety function (DEC A);
b. an accident caused by a combination of failures identified as significant on the basis of a probabilistic risk assessment (DEC B); or
c. an accident caused by a rare external event and which the facility is required to withstand without severe fuel failure (DEC C).

Pressure control

Pressure control shall refer to pressure regulation, overpressure protection and pressure reduction.

Blow-off valve

Blow-off valve shall refer to a valve type used to adjust or limit the pressure of a system or pressure vessel during disturbances.

Supplies

Supplies shall refer to the chemicals, sealing materials, insulation, plastics, grinding discs and other similar materials and items that the various power plant organisations use in their activities. Not all of the above products are among safety-classified supplies at a power plant, if they can be categorised as component-specific spare parts with system- and component level requirements.

Severe reactor accident

Severe reactor accident shall refer to an accident in which a considerable part of the fuel in a reactor loses its original structure. (Government Decree 717/2013)

Safety valve

Safety valve shall refer to a valve type that automatically limits the pressure in a pressure vessel or system once the pressure or temperature exceeds the pre-set limits.

Common cause failure

Common cause failure shall refer to a failure of two or more structures, systems and components due to the same single event or cause.

Single failure

Single failure shall refer to a failure due to which a system, component or structure fails to deliver the required performance.

References

1. Nuclear Energy Act (990/1987).
2. Nuclear Energy Decree (161/1988).
3. Government Decree on the Safety of Nuclear Power Plants (717/2013).
4. Government Decree on the Security in the Use of Nuclear Energy (734/2008).
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8. Radiation safety when using unsealed sources. Guide ST 6.1, Radiation and Nuclear Safety Authority, Helsinki 2008.