STUK

GUIDE **YVL C.1** / 15 NOVEMBER 2013

STRUCTURAL RADIATION SAFETY AT A NUCLEAR FACILITY

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 7.18.

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Authorisation

According to Section 7 r of the Nuclear Energy Act (990/1987), the Radiation and Nuclear Safety Authority 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. The Nuclear Energy Act (990/1987) prescribes that *the use of nuclear energy must be safe; it shall not cause injury to people, or damage to the environment or property.* In designing a nuclear facility, the radiation safety of workers and the environment shall be ensured. The objective is to keep occupational doses as low as reasonably achievable and that authorised dose limits are not exceeded. The maximum values for individual radiation exposure are given in the Radiation Decree (1512/1991) issued by virtue of the Radiation Act (592/1991).

102. The Government Decree (717/2013) presents the general safety regulations for nuclear power plants. Chapter 3 of the Decree gives the regulations for radiation exposure and radioactive releases and Chapter 4 the design requirements for nuclear safety.

103. Government Decree (736/2008) presents the general regulations for the safety of disposal of nuclear waste. Chapter 2 of the Decree presents the regulations for radiation safety and Chapter 3 the design requirements for a nuclear waste facility.

104. Occupational doses at a nuclear facility can be affected by i.a. room layout and systems design as well as planning of the methods of work employed during operation.

2 Scope of application

201. This Guide applies to the design of a nuclear facility's structural radiation safety. It presents the radiation-safety related, detailed structural principles to be taken into account in the design of the nuclear facility. The design principles given in this Guide shall also be used in planning modifications to the nuclear facility.

202. Guide YVL A.1 "Regulatory oversight of safety in the use of nuclear energy" describes in detail a nuclear power plant's construction and operating licence procedure and STUK's control. The general safety principles for the design of the nuclear facility and its systems as well as requirements for the design process and organisation are given in Guide YVL B.1 "Safety design of a nuclear power plant". A nuclear facility's commissioning and the associated procedures are addressed in Guide YVL A.5 "Construction and commissioning of a nuclear facility".

203. The requirements for the treatment and storage of a nuclear facility's low and intermediate level waste as well as its decommissioning are presented in Guide YVL D.4 "Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility". The requirements for the final disposal facility of nuclear waste are given in Guide YVL D.5 "Disposal of nuclear waste". Radioactive releases from a nuclear facility are addressed in Guide YVL C.3 "Limitation and monitoring of radioactive releases from a nuclear facility", radiation measurements in Guide YVL C.6 "Radiation monitoring at a nuclear facility", environmental radiation monitoring in Guide YVL C.4 "Radiological monitoring of the environment of a nuclear facility", and occupational radiation protection at a nuclear facility during plant operation in Guide YVL C.2 "Radiation protection and exposure monitoring of nuclear facility workers". Water chemistry, purification systems design and the requirements set for the monitoring of radioactivity in primary coolant are addressed in Guide YVL B.5 "Reactor coolant circuit of a nuclear power plant".

3 General design requirements

301. Under Section 2 of the Radiation Act (592/1991), radiation exposure arising from a nuclear facility's operation shall be kept as low as reasonably achievable (optimisation principle, ALARA) and occupational exposure shall not exceed the maximum values confirmed by the Radiation Decree (principle of limitation). In addition, the maximum values of radiation exposure to an individual of the population from the operation of a nuclear facility are laid down by the Government Decrees (717/2013) and (736/2008). Even if the set limits were not exceeded it is not justifiable to not implement a

design option that would essentially reduce occupational or public dose.

302. A nuclear facility's Preliminary and Final Safety Analysis Report or the associated topical report shall give a summary of the most important radiation protection-related design features by which the optimisation principle in radiation protection is implemented at a nuclear facility. The summary shall also state how requirements that are presented in chapters 4 and 5 of this Guide will or have been implemented in designing and constructing the nuclear facility.

303. Sufficient expertise in radiation protection, radiation measuring and radiation physics shall be available in all phases of nuclear facility design. In the Preliminary Safety Analysis Report or in a separate topical report submitted with it, a procedure shall be described that takes into account structural radiation safety requirements during the various phases of the nuclear facility's design process. In addition, the description shall include a plan of the involvement of radiation safety experts in reviews made during the various phases of design and in decision-making affecting the implementation of radiation protection. Also the radiation safety experts and their qualification as well as the tools and calculation methods used shall be stated. The general requirements for the design process and organisation are given in Guide YVL B.1.

304. Operating experience feedback from similar types of nuclear facilities shall be utilised when considering radiation safety aspects in the design of a nuclear facility.

305. Design shall take into account the operation of a nuclear facility including commissioning, normal operation, anticipated operational occurrences, potential accidents and plant decommissioning. Decommissioning-related requirements to be taken into account during the design of a nuclear facility are given in Guide YVL D.4. Many of the design solutions considered useful for decommissioning are important also from the viewpoint of radiation protection and waste management during operation.

306. In designing and constructing a nuclear power plant, calculations must be performed to ensure that the collective annual dose during planned and anticipated regular work tasks does not exceed the value of 0.5 manSv per net electric power of 1 GW during normal operation averaged over the plant's design service life. Collective dose calculation shall be justified with operating experiences from similar types of operating nuclear power plant units.

307. During the various design phases, collective doses shall be looked at and optimised by working tasks and worker groups. In addition to collective doses, a design objective for individual occupational maximum doses shall be established.

308. With both the Preliminary and Final Safety Analysis Report, a topical report containing an assessment of the doses received by workers from plant operation shall be submitted for approval to the Radiation and Nuclear Safety Authority. The assessment shall take account of individual tasks causing doses of which a collective dose of more than 0.01 manSv is anticipated to accumulate annually. The dose assessments shall also be classified by action (radiation protection, operation, maintenance, repair, periodic inspection, fuel handling and waste treatment) or worker group. The report shall show dose rates in the working area, working time, number of workers and frequency of action. The safety analysis report shall include a summary of dose assessments and factors likely to affect doses.

4 Radiation safety aspects in the layout design of a nuclear facility

4.1 Radiation sources and shielding

401. At the design phase, the location of the nuclear facility's radiation sources and the amount of radioactive substances during normal operation shall be assessed. Radiation sources include e.g. the reactor and several systems connecting to it, spent fuel and radioactive waste.

402. Radiation shields shall be designed with adequate safety margins. Special attention shall be paid to the transfer and storage of spent fuel and components removed from the reactor as well as to rooms where work is done continuously. Assessments and analyses relating to the designing of radiation shields shall take into account scattering of radiation (incl. skyshine radiation), migration of radioactive substances as well as shield penetrations and openings. Labyrinth structures shall be used to prevent direct radiation penetrating e.g. doors.

403. A topical report of radiation shielding calculations and the calculation methods shall be submitted to the Radiation and Nuclear Safety Authority for approval with both the Preliminary and Final Safety Analysis Report. The report shall also present the modelling of the reactor, its structures and the radiation shield around it in radiation shielding calculations and calculated dose rates during power operation.

404. In a room where work is done, components containing significant amounts of radioactive substances shall be permanently shielded. If it is not possible to use fixed shields, provision shall be made in the dimensioning and structures of the rooms for the use of mobile shielding. These shall be quick to assemble and disassemble. Any components that may hinder the assembly of the shields shall be easy to remove and reassemble. Piping containing radioactive substances shall be shielded where necessary with e.g. concrete shields. Structures in rooms where the installation of radiation shields may be necessary shall be designed to withstand loads arising from the shields.

405. A nuclear facility's radiation shields shall be so designed that the annual dose to an individual of the population caused by direct radiation coming from the nuclear facility clearly remains below the limits given in Guides YVL C.3, YVL D.4 and YVL D.5.

4.2 Rooms and access routes

406. Those nuclear facility's rooms where regular working is necessary shall be designed such that the external dose rate and the probability of the intake of radioactive substances are low.

407. In the design phase, rooms shall be classified on the basis of the probable dose rate, surface contamination (surface activity) and airborne radionuclide concentration into at least three zones, which together form the controlled area. The principles of zone classification are given in Guide YVL C.2.

408. When a new controlled area is commissioned or an existing one modified, the licensee shall conduct their own commissioning inspection and ensure that the requirements of this Guide and those of Guide YVL C.2 are implemented.

409. Ventilation systems shall be so designed that the air is mainly clean enough during normal operation of the plant to make the wearing of respirators unnecessary. The origin of any airborne radioactive substances shall be possible to establish (i.a. by fitting the ventilation exhaust ducts with appropriate sampling points). The general requirements for the nuclear facility's ventilation systems are given in Guide YVL B.1.

410. Rooms with systems containing radioactive liquid shall be fitted with a drainage system for leak monitoring and collection. The rooms shall be designed such that door sills, floor chutes and the inclination of floors make possible the controlled conduction of leaks to systems for radioactive liquids. The floor drainage system shall be designed to prevent flooding of the rooms. In designing the drainage system, variations in room temperature and pressure shall be taken into account. At least one floor trap per room shall be fitted with a level alarm sensor.

411. The floors and walls of rooms into which radioactive liquids may leak shall be watertight to a level higher than where the rise in liquid level that is the basis of dimensioning may reach. Floor and wall surfaces shall be easy to decontaminate. Surface materials shall be chosen to enable and withstand planned decontamination. Surface materials are addressed in more detail in Guide YVL E.6.

412. Arrangements facilitating and speeding up work and thus reducing doses must be taken into account in the design of rooms, e.g. the proxim-

ity and availability of compressed air, water and electricity supply and lighting of working areas. Working areas and access routes shall be fitted with emergency lighting to provide against power failures.

413. Announcements and alarm signals shall reach workers. In addition, back-up methods (e.g. visible alarms) shall be used at the facility if room-specific noise levels and protective equipment possibly worn in working areas prevent alarm signals from being heard.

414. Access routes for personnel and the transportation of goods in the controlled area shall be designed to keep occupational radiation exposure low while using the routes. Radiation protection aspects shall be taken into account also in designing emergency exit routes for use during accidents. Access routes shall be dimensioned such that a person wearing protective equipment against radiation can easily move at the plant. Provision shall be made for the mechanical transportation of activated or contaminated objects by dimensioning the transport routes sufficiently spacious, structurally strong and unobstructed.

4.3 Boundary of controlled area

415. At the boundary of the controlled area, monitoring of the radioactive contamination of workers and tools shall be arranged. Personnel monitors as well as tool monitors shall be located in rooms where the background radiation remains low under all operational states and accidents. Dosimeters used for individual radiation exposure monitoring shall be kept in rooms where the background radiation remains low.

416. A room for the decontamination of personnel shall be located before the personnel monitors in the controlled area or supervised area. Rooms and equipment shall be reserved for first-aid treatment and decontamination of the injured.

417. The dimensioning of staff rooms, as well as rooms for the storage, maintenance and distribution of protective equipment and also access arrangements to the controlled area shall take into account the large number of workers present during outages. Male and female staff shall have their own changing rooms.

4.4 Component decontamination

418. A nuclear facility shall have rooms for the decontamination, repair and maintenance of activated or contaminated components and their parts. It shall be possible to place all systems and equipment that are of essential importance for decontamination in the decontamination rooms. In addition, separate rooms with radiation shielding shall be provided for the decontamination of highly activated and contaminated components.

419. If necessary, it shall be possible to handle the components and objects to be decontaminated remotely and in a protected manner.

420. Components requiring decontamination shall be identified during plant design. Their transport shall be planned such that their disassembling and transfer for decontamination does not result in significant occupational doses.

4.5 Accidents

421. Layout design shall be implemented in a way to facilitate the operational actions, maintenance and repairs necessary at the nuclear facility during and after postulated and severe accidents. Functions required during emergency preparedness arrangements are to be taken into account as well.

422. During a nuclear facility's design phase, the activity concentration, location and migration paths of radioactive substances released during an accident as well as dose rates onsite shall be assessed. Design shall assume the occurrence of an accident simultaneously at several nuclear facilities on the site. In designing radiation shields, the scattering of radiation as well as shield penetrations and openings shall be taken into account. Particular attention shall be paid to rooms where permanent stay is necessary or which may have to be visited during an accident or afterwards. These include, for instance, the main control room, emergency control room, local control centres, sampling rooms, laboratory facilities, the emergency preparedness centre and the

related access routes. Accessibility shall be taken into account when preparing the facility's procedures and guidelines for accident management (including severe accidents) as well as emergency response procedures.

423. The spreading of airborne radioactive substances to areas that are to be accessible during accidents shall be restricted. Procedures used during accidents shall describe the risk of the spreading of radioactive substances and its potential impact on the accessibility of rooms.

424. Doses received during accident management and emergency response shall be assessed in the plant design phase and shall not exceed the normal dose limits for radiation workers. In an actual accident, the dose limits may be exceeded in accordance with Section 8 of the Radiation Decree (1512/1991) (immediate measures to limit a radiation hazard and to bring a radiation source under control as well as the saving of human lives).

425. Furthermore, design shall indicate those places at the site area where the dose rate remains low during an accident. These may be used for the assembly of workers and measuring their contamination.

426. A topical report describing radiation safety during accidents shall contain a description of the calculation methods and results and shall be submitted to STUK for approval with both the Preliminary and Final Safety Analysis Report.

5 Radiation safety aspects in the systems design of a nuclear facility

5.1 Material choices

501. The generation and spreading of radioactive substances at a nuclear facility shall be restricted in accordance with the radiation protection optimisation principle. The corrosion, activation and migration of substances significantly affecting occupational dose shall be kept low by the choice of materials and structural designs, surface treatment as well as water chemistry and purification systems design.

502. Attention shall be paid to the components, systems, welded seam materials, and sealings of the primary circuit of a nuclear power plant that come into contact with the coolant. Special attention shall be paid to the reactor core structures. The use of materials having a low nickel, cobalt, silver and antimony content helps prevent the formation of the activation products ^{58}Co, ^{60}Co, ^{110m}Ag and ^{124}Sb in particular. Criteria and justification for the choice of materials and their effect on the facility radiation levels shall be given in both the Preliminary and Final Safety Analysis Report. Detailed information about the material choices shall be given in the construction plans for the components and structures.

5.2 Layout of systems

503. Parts and components of systems containing radioactive substances shall be located, as far as possible, in rooms such that workers are not unnecessarily exposed to radiation when operating, inspecting, maintaining and repairing them. Parts of systems containing considerable amounts of radioactive substances shall, as a general rule, be located in rooms of their own. Pipelines containing radioactive liquids shall be located away from clean piping and at a sufficient distance from components requiring maintenance.

504. Systems and components shall be designed and located such that the number of work phases performed while exposed to a high dose rate is small and of short duration. Control, measuring, monitoring and auxiliary equipment shall be located away from components containing radioactive substances and in a separate room or a shielded area. In designing and dimensioning rooms for components and systems, the necessary testing, maintenance, measurements, inspections and repairs shall be taken into account.

505. The sampling points of radioactive sampling lines shall be bundled up in vented cubicles with drainage.

5.3 Accumulation of radioactive substances and systems decontamination

506. Components and their parts shall be designed to prevent unintentional accumulation of radioactive substances. The materials and treatment of the surfaces of systems and components shall reduce contamination. The uncontrolled accumulation of particles containing radioactive substances in pipelines shall be prevented by fluid flow and chemistry design. The accumulation of radioactive substances in individual components and systems shall be anticipated by making the accumulation points shieldable and, if necessary, flushable.

507. A nuclear power plant's reactor circuit as well as primary circuit components containing significant amounts of radioactive substances shall be decontaminable.

508. It shall be possible to connect the necessary flushing and decontamination equipment to systems and piping that may contain radioactive liquids.

509. Pipelines shall be designed with few vent and drain lines. Drainage shall be led to a floor trap or a closed system. Venting shall be led to a radioactive gas treatment system.

510. Steam drying in a boiling water reactor shall be designed to keep low the dose rates and surface contamination of the turbine plant systems.

5.4 Treatment of waste waters, resins and concentrates

511. It shall be possible to sort wastewaters containing radioactive substances by their origin and composition. Treatment of radioactive liquids is also addressed in Guide YVL C.3.

512. The accumulation of resins and evaporator concentrates in the piping and components of the waste treatment system shall be reduced by structural design. The crystallisation and deposition of concentrates in the systems and tanks in question shall be minimised.

513. The design of radioactive liquid treatment systems shall make provision against leaks, and it shall be possible to promptly detect any leaks. The system's tanks shall have level alarm sensors and automation to prevent overfill. The probability of an uncontrolled release of resins and concentrates from the tanks shall be low.

514. Tanks containing radioactive substances shall be ventilated through the radioactive gas treatment system.

515. Washing, regeneration of filters and emptying of filter media shall be possible in compliance with radiation safety principles (e.g. remotely).

5.5 Maintenance and inspections

516. Pipelines shall be designed so that the number of welded joints subject to inspection is as small as possible and the welded joints are in locations easy to inspect.

517. Components and their parts (e.g. pumps, valves, electrical and I&C equipment) that are exposed to activation or contamination shall require as little maintenance as possible.

518. The manholes of tanks, pools and heat exchangers shall be adequately large for a worker wearing protective equipment to easily access an item for maintenance.

519. Components and their locations in closed rooms shall be recorded visually so that no time needs to be spent in search of them during maintenance work done later. It is advisable to video or photograph the installation, assembly and disassembly of components involving significant radiation exposure. This makes it easier to plan and implement corresponding work to be done later.

520. It shall be easy to remove and reinstall heat insulation of piping and components subject to maintenance and in-service inspection in systems containing radioactive substances. The heat insulation shall be made of materials and structures not easily contaminated via penetration or adherence.

6 Regulatory oversight by the Radiation and Nuclear Safety Authority

601. During a nuclear facility's construction and operating licence phases, STUK reviews from the Preliminary and Final Safety Analysis Reports as well as the separate topical reports submitted with them the fulfilment of requirements presented in chapters 3 to 5 of this Guide. During nuclear facility operation, STUK reviews the fulfilment of requirements in chapters 3 to 5 from plans for principles for plant or system modifications, pre-inspection documentation and updates to the Final Safety Analysis Report.

602. STUK conducts a commissioning inspection of radiation protection during the commissioning of a new nuclear facility's controlled area. STUK also conducts at its discretion a commissioning inspection of radiation protection when an operating facility's controlled area is modified. In the commissioning inspection, the implementation of the requirements given in this Guide and in Guide YVL C.2 is reviewed for applicable parts as well as the results of a commissioning inspection by the licensee.

603. During a nuclear power plant's commissioning, STUK at its discretion oversees neutron and gamma radiation measurements related to radiation protection made during low power and power tests near the reactor, primary circuit and other primary radiation sources as well as measurements to verify room classifications in the controlled area.

Definitions

Decontamination

Decontamination shall refer to cleaning radioactive substances from components, structures or rooms.

Contamination

Contamination refers to undesirable radioactive substances on surfaces (surface activity), or within solids, liquids or gases (also in the human body).

Decommissioning

Decommissioning shall refer to the dismantling of a permanently closed nuclear facility so that no special measures are required at the facility site due to radioactive materials originating from the dismantled facility.

Normal operation (DBC 1)

Normal operation (DBC 1) shall refer to the planned operation of a nuclear power plant according to the Operational Limits and Conditions and operational procedures in place. These also include testing, plant start-up and shutdown, maintenance and refuelling. As far as other nuclear facilities are concerned, normal operation shall refer to similar plant operation.

Anticipated operational occurrence

Anticipated operational occurrence (DBC 2) shall refer to such a deviation from normal operation that can be expected to occur once or several times during any period of a hundred operating years. (Government Decree 717/2013)

Accident

Accident shall refer to postulated accidents, design extension conditions and severe accidents. (Government decree 717/2013)

Optimisation principle

Optimisation principle means that operation is organised such that radiation exposure harmful for health is kept as low as is reasonably achievable.

Controlled area

Controlled area shall refer to a working area in which specific radiation protection procedures shall be followed and to where access is controlled.

Site area

Site area shall refer to an area in use by nuclear power plant units and other nuclear facilities in the same area, and to the surrounding area, where movement and stay are restricted by the Decree of the Ministry of the Interior issued under Section 52 of the Police Act (493/1995). (Government Decree 716/2013)

Annual dose

Annual dose shall refer to committed effective dose arising from external radiation within the period of one year and from intake of radioactive substances within the same period of time. (Government Decree 717/2013)

Nuclear waste

Nuclear waste shall refer to radioactive waste in the form of spent nuclear fuel or in some other form generated during or as a result of the use of nuclear energy. Nuclear waste also refers to materials, objects and structures which, having become radioactive during or as a result of the use of nuclear energy and having been removed from use, require special measures owing to the danger posed by their radioactivity. (Nuclear Energy Act 990/1987)

Nuclear facility

Nuclear facility shall refer to facilities used for the generation of nuclear energy, including research reactors, facilities implementing the large-scale final disposal of nuclear waste, and facilities used for the large-scale production, generation, use, processing or storage of nuclear material or nuclear waste. However, nuclear facility shall not refer to:

a. mines or milling facilities intended for the production of uranium or thorium, or premises and locations with their areas where nuclear waste from such facilities is stored or located for final disposal; or
b. premises finally closed and where nuclear waste has been placed in a manner approved as permanent by the Radiation and Nuclear Safety Authority. (Nuclear Energy Act 990/1987)

Nuclear power plant

Nuclear power plant shall refer to a nuclear facility for the purpose of electricity or heat production, equipped with a nuclear reactor, or a complex consisting of nuclear power plant units and other related nuclear facilities located at the same plant site.

Principle of limitation

Principle of limitation means that the radiation exposure of an individual shall not exceed the maximum values confirmed by the Radiation Decree.

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 Safety of Disposal of Nuclear Waste (736/2008).
5. Radiation Act (592/1991).
6. Radiation Decree (1512/1991).
7. Radiation Protection Aspects of Design for Nuclear Power Plants, Safety Guide, Safety Standards Series No. NS-G-1.13, IAEA, 2005.