

## Guide YVL D.3, Handling and storage of nuclear fuel

### 1 Introduction

Spent nuclear fuel assemblies removed from a nuclear reactor are highly radioactive, generate heat and contain nuclear material and fission products. The safe handling and storage of nuclear fuel assemblies requires, in particular, that their integrity remains unaffected and the fuel rods are leak tight, any leaking fuel assemblies are isolated, effective radiation protection measures are employed, the nuclear fuel is cooled efficiently and the formation of critical fuel configurations is prevented. The last safety objective mentioned above also applies to the storage of fresh nuclear fuel.

Nuclear Energy Act (990/1987) Section 6 a stipulates that *nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland*. Based on Nuclear Energy Act Section 7 q the Radiation and Nuclear Safety Authority shall issue further regulations on technical details. According to STUK regulation STUK Y/4/2018 Section 16 nuclear waste shall be packed considering operational safety and long-term safety. STUK Regulations Y/1/2018 and Y/4/2018 set out requirements concerning handling, packing and storing of spent nuclear fuel and facilities performing these functions. Guide YVL D.3 presents requirements concerning encapsulation of spent nuclear fuel and the encapsulation facility. Requirements related to the manufacture of the canister are presented in Guide YVL D.7 "Release barriers of spent nuclear fuel disposal facility".

The Nuclear Energy Act lays down the basic requirements concerning the safe use of nuclear energy. The Radiation Act (859/2018) specifies the general principles of radiation safety and the provisions for radiation work.

According to Section 7h of the Nuclear Energy Act, a nuclear facility shall have premises, equipment and other arrangements to ensure the safe handling and storage of nuclear material required by the facility as well any nuclear waste generated during operation. According to Section 4 of the Nuclear Energy Decree (161/1988), the provisions given in the nuclear energy legislation on both nuclear material and nuclear waste are applied to spent nuclear fuel.

STUK Regulation (STUK Y/1/2018) applies to the handling and storage of nuclear fuel at nuclear power plants and storage facilities for fresh and spent nuclear fuel attached to a nuclear power plant. STUK Regulation (STUK Y/4/2018) applies to the encapsulation of spent nuclear fuel for disposal. STUK Regulation on the Security in the Use of Nuclear Energy (STUK Y/3/2016) applies to the handling, storage and encapsulation of nuclear fuel. STUK Regulation on the Emergency Arrangements of a Nuclear Power Plant (STUK Y/2/2018) applies, where applicable, to the handling, storage and encapsulation of nuclear fuel.

The update of Guide YVL D.3 considers the changes due to the replacement of the Government Decree on the Safety of Disposal of Nuclear Waste (736/2013) with

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STUK Regulation STUK Y/4/2016. Due to Regulation STUK Y/4/2016, several requirements in the 2013 Guide YVL D.3 were moved to the regulatory level. Such requirements have now been either removed from Guide YVL D.3 or changed to references to the updated version of STUK Regulation Y/4/2018. Due to the removal of the requirements, the sections and requirements of Guide YVL D.3 have been re-organised. With this change, several sections and subsections have been removed and some new ones have been added to replace them. The update of Guide YVL D.3 also considers the changes in the STUK Regulation (STUK Y/1/2018) concerning the storage of nuclear fuel.

Guide YVL D.3 includes many references to other YVL Guides because facilities within the scope of the Guide largely follow the same principles as those presented in YVL Guides prepared for nuclear power plants.

## 2 Scope of application

The scope of application is specified in requirement 201 of Guide YVL D.3.

*This Guide addresses*

- a. *the following operations taking place at nuclear power plants and other nuclear facilities: the dry storage of fresh nuclear fuel, the storage of fresh and spent nuclear fuel in storage pools adjacent to a reactor, and the storage of spent nuclear fuel in separate storage facilities;*
- b. *the transfers of nuclear fuel at the plant site and power plant area and in connection with storage and encapsulation, as well as the transfers of the transfer cask and the final disposal canister;*
- c. *the transfers of nuclear fuel between plant sites when transferring spent nuclear fuel from one licensee to another;*
- d. *the encapsulation of spent nuclear fuel for final disposal, excluding the closure of the canister (making a permanent joint);*
- e. *encapsulated nuclear fuel;*
- f. *the planning, design, construction, use and decommissioning of the aforementioned functions and the necessary facilities and systems.*

It has been specified in the scope of application that the Guide addresses, in accordance with item c, the transfers of nuclear fuel between plant sites when transferring spent nuclear fuel from one licensee to another. In addition, in accordance with item e, encapsulated nuclear fuel has been added to the scope of application of the Guide for clarity.

Requirement 202 states that the Guide addresses encapsulation solutions in which fuel is, as such, encapsulated into a disposal canister. The Guide does not address encapsulation solutions in which, for example, material found unsuitable for fuel in the reprocessing of nuclear fuel is placed in disposal.

Requirement 202 also specifies that the Guide shall not be applied to the transport of spent nuclear fuel via roads referred to in the Road Traffic Act (267/1981). This restriction is connected to nuclear fuel transfers taking place between plant sites, referred to in requirements 4110–4112. The purpose is not to apply the regulations

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for the transport of dangerous goods to these transfers. Section 2(2)(2) of the Act on Transport of Dangerous Goods excludes from the scope of application of the Act the transfers of nuclear fuel referred to in Guide YVL D.3.

### 3 Justifications of the requirements

Section 3 of Guide YVL D.3 presents requirements for the demonstration of compliance with safety requirements for the nuclear fuel storage facility and encapsulation plant. Safety assessments shall be carried out for the facilities at all licensing stages, demonstrating that the nuclear facility has been designed and implemented in accordance with the safety requirements. The assessments shall cover the operation of the facility in accordance with the Operating Limits and Conditions as well as any anticipated operational occurrences and accident situations.

The above matters are presented in STUK Regulations STUK Y/1/2018 and STUK Y/4/2018, which are referred to in paragraph 309b of Guide YVL D.3. As concerns nuclear fuel storage facilities and encapsulation plants, events such as the following may be addressed as operational occurrences as mentioned in the paragraph:

- a cladding failure of a nuclear fuel rod or significant mechanical deformation of a nuclear fuel assembly
- a handling error of a transfer cask, nuclear fuel assembly or disposal canister
- a leak of cooling water due to, for example, degraded leak-tightness of the liner of a nuclear fuel storage pool, a pool gate or piping connected to the pool
- a leak in a gas-tight transfer cask, storage container or handling cell
- a component failure or malfunction and the resulting non-operability of a non-redundant system
- loss of power in a nuclear fuel handling system or a related safety system
- a contained fire in a safety-significant location.

As concerns nuclear fuel storage facilities and encapsulation plants, events such as the following may be addressed as postulated accidents as mentioned in paragraph 309b:

- dropping or other handling errors involving a nuclear fuel assembly or a transfer cask, storage container or disposal canister containing fuel assemblies
- non-operability of a redundant system (e.g. the cooling system of a nuclear fuel storage pool or the under pressure and filtration system of a handling cell) due to component failures or malfunctions
- a significant external event, such as a design basis earthquake or a crash of an aircraft.

#### 3.1 Section 4.3 Considering human factors relating to safety

HFE (Human Factors Engineering) requirements 451–453 have been added to section 4.11. The previous version of the Guide referred to section 5.3 of Guide YVL B.1, which included the instructions concerning control rooms and the requirements concerning the HFE programme. These requirements have now been incorporated into Guide YVL D.3 and revised to better suit KPA storages and encapsulation plants.

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### **3.2 Section 4.5 Safety functions and provisions for ensuring them**

The subsections of this section discuss the safety functions of the nuclear fuel storage facility and encapsulation plant and the related requirements. The safety functions discussed in this Guide include the handling of nuclear fuel (section 4.13.1), nuclear fuel cooling (4.13.2), prevention of the dispersal of radioactive material (4.13.4) and criticality safety (4.13.5).

#### **3.2.1 Section 4.5.1 Handling of nuclear fuel**

This section presents requirements for fuel handling. The requirement level is the same as in the previous version of the Guide.

In requirement 472, it is specified that the single-failure tolerance requirement applies to systems used for handling nuclear fuel that might cause spent nuclear fuel damage or other significant radiation exposure in the event of a failure.

Requirement 473 concerns situations in which the handling system itself fails. The purpose is to ensure that the assembly or its container does not drop.

Requirement 476 concerns situations outside this system, such as manual transfers in SBO in a manner that the assembly is not uncovered. A safe position can be different for different storage types and situations.

#### **3.2.2 Section 4.5.2 Nuclear fuel storage pools and nuclear fuel cooling**

Section 4.13.2 of Guide YVL D.3 presents requirements for the cooling of stored nuclear fuel. The section considers the changes made to STUK Regulation Y/1/2018 concerning nuclear fuel. The requirement level of the requirements concerning nuclear fuel storage pools has remained the same. The requirements have been formulated to be more general to be as independent of the pool design solutions as possible.

In Guide YVL D.3, cooling refers to the entire cooling function including the actual cooling function and its supporting functions, such as power supply and cooling-related measurements.

In requirements 478–480 of Guide YVL D.3, the word “stored” has been added in front of “nuclear fuel”. This specifies that the requirements concern nuclear fuel in pools as opposed to nuclear fuel in the reactor.

Requirement 477 mentions an on-site and an off-site electrical power supply system. More detailed requirements concerning this are set forth in Guide YVL B.1.

Items a–f of requirement 423 of the previous version (2013) of Guide YVL D.3 have been divided into separate requirements and regrouped: some into section 4.13.2 and others into section 4.14. In the previous version of the Guide, item c of requirement 423 included a requirement for compensating for a loss of any coolant water in a storage pool due to an operational occurrence by a make-up water system. This requirement is now included in requirement 479, according to which it shall be possible to cool nuclear fuel with a cooling system that operates on the diversity

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principle. In accordance with item d of requirement 423 of the previous version of the Guide, it shall be possible to feed water into the storage pools from external sources. This requirement is also included in requirement 479, according to which the pool shall be cooled with a system that operates on the diversity principle. Item e of requirement 423 of the previous version of the Guide required measurement data on the water level and temperature of the storage pool. This requirement is now included in requirements 478, 479 and 480, which set forth requirements for the cooling function also covering the measurements contained in it.

Requirement 477a (previously 422) contains a compilation of requirements related to the dimensioning of pools and cooling. In the previous version of the Guide, items a and b of requirement 423 presented requirements concerning cases where the water level of the storage pool could drop. These requirements are now included in item c of requirement 477a, according to which storage pools shall be designed so that inadvertent discharge of the storage pool or excessive water level drop to a level that would endanger nuclear fuel cooling, or the necessary radiation protection is not possible.

In accordance with requirement 483, residual heat removal of nuclear fuel shall be ensured even during a severe reactor accident. This also covers the power supply and instrumentation required by residual heat removal. The design shall also consider the possibility of sky shine and that cooling is arranged, nevertheless.

According to requirement 485, enough cooling of nuclear fuel shall be ensured in rare external events (DEC C) so that the fuel is not severely damaged. According to the requirement, measures related to ensuring the cooling and conducted at the plant site shall not require the use of vehicles during the first eight hours. Components designed for use shall be accessible even if any individual route or hatch is blocked by an external obstacle. The systems ensuring the cooling of stored nuclear fuel do not need to accomplish the single-failure criterion. The requirement contains requirement 426 of the previous version of the Guide (2013), divided into two. Requirement 485 also contains requirement 452 of the previous version of Guide YVL B.1 "Safety design of a nuclear facility". Contrary to requirement 450a of the current version of Guide YVL B.1, systems needed in the events need not be stationary. Requirement 485 also covers support functions related to cooling, such as cooling-related measurements and power supply.

Requirement 486 specifies that the cooling of stored nuclear fuel shall be ensured in the event of loss of the plant's internal electricity distribution in accordance with requirement 451 of Guide YVL B.1. This requirement shall be followed if the plant has been designed so that the loss of internal electricity distribution is possible.

### 3.2.3

#### **Section 4.5.4 Prevention of the dispersal of radioactive material**

Section 4.13.4 contains a compilation of references and requirements related to the prevention of the dispersal of radioactive material. The previous version of Guide YVL D.3 (2013) presented requirement 417 for the application of the redundancy principle in the handling and storage of nuclear fuel and required that it shall be (N+1). Section 15(2) of STUK Regulation Y/4/2018 now presents the requirement for ensuring the functions of an encapsulation plant. Guide YVL D.3 has therefore been updated so

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that paragraph 489 presents a reference to the STUK regulation and requirement 490 specifies the STUK regulation by requiring a redundancy principle level of (N+1) for functions whose failure could result in a significant release of radioactive materials or radiation exposure of personnel at the facility.

### **3.2.4 Section 4.5.5 Criticality safety in the handling and storage of nuclear fuel**

Requirement 494 is connected to application decision 65/0002/2016. If a fuel position in a canister is to be left empty to ensure subcriticality, the analysis may be based on this placement. In this case, the placement of fuel in such position in the canister shall be structurally prevented. The possibility of, for example, misplacing nuclear fuel assemblies in the wrong canister positions due to identification errors shall be taken into consideration in the criticality analyses.

### **3.2.5 Section 4.5.6 Monitoring**

Requirement 497 requires that systems that provide information on the state of the fuel and operate without external power supply shall be available for monitoring the progress of design extension conditions. The monitoring of the state of the fuel may include temperature and radiation or activity measurement, providing information on whether the fuel cools sufficiently, whether it leaks and whether its location is what it should be.

### **3.3 Section 4.6 Safety of the storage and encapsulation of nuclear fuel**

Section 4.14 presents requirements related to the storage of nuclear fuel. Of the requirements related to this topic, the so-called evacuation requirement has been moderated.

Guide YVL D.3 previously required nuclear fuel storage facilities and their use to be designed so that any storage pool or reactor core could be emptied of nuclear fuel in order to perform repair work. In this Guide update, the requirement has been specified so that it shall be possible to empty the reactor core (requirement 4100) and repair the pools (requirement 4101). In addition, pool leaks shall be monitored (requirement 4102). The requirement level has been moderated because, based on operating experience, small leaks of storage pools, such as weld leaks, are common and leak monitoring is essential in locating the leaks. Repairing small leaks is technically possible under water, so it may be enough to partly drain the pool of fuel. In that case, it would be unjustified to drain the entire pool.

For large and fast leaks, the transfer of fuel assemblies is of no help because it is slow to transfer nuclear fuel assemblies. The possibility of an extensive damage to the nuclear fuel pool shall be extremely low (STUK Y/1/2018, Section 12[5]), which means that large damage to the pool shall not be possible.

Requirement 4101 for the reparability of the nuclear fuel storage pool gives the licensee the opportunity to assess and plan repair measures for a potential pool leak situation and the amount of extra pool space required in such a situation.

Requirement 4102 requires any leak of nuclear fuel storage pools to be detected and localised. Item f of requirement 423 of the previous version of the Guide has



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remained unchanged, but it has been moved to requirement 4102 and a requirement for the localisation of the leak point has been added.

The plan for the encapsulation of nuclear fuel assemblies deviating from the design bases referred to in requirement 4106 shall be presented at a general level in the construction licence application documentation and at a more detailed level in the operating licence application documentation.

### **3.4 4.7 Transfers of spent nuclear fuel**

New requirements concerning transfers of nuclear fuel have been added to the Guide. Transfers refer to transfers made using a nuclear fuel transfer cask within the facility site or between two facility sites without using roads under the Road Traffic Act.

Transfer events were previously monitored separately in different fields of technology. The purpose of requirement 4112 is to collect the information related to transfers so that it can be confirmed that the safety of transfers is at a enough level as a whole.

Requirement 4110 previously required the transfer cask to fulfil the requirements for the BF type transport package presented in the transport regulations for dangerous goods. A more moderate level of the transport regulations for dangerous goods has been considered, but the level is not enough with regard to criticality requirements. Requirement 4110 now includes the possibility to license the transfer cask as a facility system if the transfer cask is not used for nuclear fuel transport on roads specified in the road Traffic Act.

Requirement 4111 concerns transfers from one licensee to another. According to the requirement, the transfer of responsibility from one licensee to another shall be determined.

Requirement 4112 specifies what the plan concerning transfers of nuclear fuel shall present.

### **3.5 Section 4.8 Monitoring and control of a nuclear waste facility**

In place of requirements 4114–4121, the previous version of the Guide D.3 (2013) included a reference to the requirements specified in section 5.3 of Guide YVL B.1, which should be complied with where applicable. That section presents requirements for the control room of a nuclear power plant. These requirements have now been revised to suit the nuclear fuel storage facility and encapsulation plant and added as new requirements to Guide YVL D.3.

HFE requirements 451–453 added to section 4.11 are also related to the monitoring and control of the nuclear waste facility.

### **3.6 Chapter 8 Regulatory oversight by the Radiation and Nuclear Safety Authority**

Requirement 801 refers to the separate construction of a new facility and the decision-in-principle required for such facility. The KPA storages of currently operating plants already have valid operating licences. When facilities are made

independent, an operating licence revision procedure will probably be applied instead of a decision-in-principle procedure.

#### **4 International provisions concerning the scope of the Guide**

- WENRA, Working Group on Waste and Decommissioning (WGWD), Waste and Spent Fuel Storage Safety Reference Levels Report, version 2.2
- SSG-27 Criticality Safety in the Handling of Fissile Material (DS407), 6/2014
- DS489 - Storage of Spent Nuclear Fuel (SSG)
- DS487 - Design of Fuel Handling and Storage Systems for Nuclear Power Plants (SSG)
- DS478 - Safety of Nuclear Fuel Cycle Facilities (SSR).

#### **5 Impacts of the Tepco Fukushima Dai-ichi accident**

Guide YVL D.3 does not include requirements directly resulting from the Fukushima accident, but such requirements, some of which also concern the KPA storage, have been added to Guide YVL B.1. These include, for example, requirement 424 of Guide YVL B.1 regarding events to be eliminated and requirement 452, which is now included in requirement 485 of Guide YVL D.3.

#### **6 Needs for changes considered in the revision**

When the STUK Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2016) came into force, several general principles related to the handling and storage of nuclear fuel were moved to STUK's regulatory level. For example, the possibility of fuel damage shall be as low as possible in the handling and storage of nuclear fuel. The definitions of operational occurrence and accident classes and the related radiation dose limits were also moved to the regulation and the Nuclear Energy Act.

In the YVL Guide update, the idea is to avoid presenting overlapping requirements in the guidelines. The requirements to be complied with in the design of nuclear facilities are presented in Guide YVL B.1, and the previous version of Guide YVL D.3 referred to the design requirements on several occasions. The reference to design requirements is now presented once in an application item in the Guide.

The change proposals made in connection with the preparation of the YVL Guide implementation decisions mostly overlapped with other Guides, and they have been considered in the Guide update.

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

The requirement level changes made to the Guide concern the transfer of nuclear fuel and the moderation of the evacuation requirement. The structural changes relate to the fact that many of the requirements of the previous version were moved to STUK Regulation STUK Y/4/2016. The changes to the requirements concerning the storage of spent fuel in STUK Regulation STUK Y/1/2018 have also been considered in this update.