STUK

GUIDE **YVL 8.5** / 23 DECEMBER 2002

OPERATIONAL SAFETY OF A DISPOSAL FACILITY FOR SPENT NUCLEAR FUEL

This Guide remains in force as of 1 June 2003 until further notice.

First edition
Helsinki 2003
Dark Oy

ISBN 951-712-700-6 (print)
ISBN 951-712-701-4 (pdf)
ISBN 951-712-702-2 (html)
ISSN 0783-246X

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Authorisation

By virtue of the below acts and regulations, the Radiation and Nuclear Safety Authority (STUK) issues detailed regulations that apply to the safe use of nuclear energy and to physical protection, emergency preparedness and safeguards:

- Section 55, paragraph 2, point 3 of the Nuclear Energy Act (990/1987)
- Section 29 of the Government Resolution (395/1991) on the Safety of Nuclear Power Plants
- Section 13 of the Government Resolution (396/1991) on the Physical Protection of Nuclear Power Plants
- Section 11 of the Government Resolution (397/1991) on the Emergency Preparedness of Nuclear Power Plants
- Section 8 of the Government Resolution (398/1991) on the Safety of a Disposal Facility for Reactor Waste
- Section 30 of the Government Resolution (478/1999) on the Safety of Disposal of Spent Nuclear Fuel.

Rules for application

The publication of a YVL guide does not, as such, alter any previous decisions made by STUK. After having heard those concerned, STUK makes a separate decision on how a new or revised YVL guide applies to operating nuclear power plants, or to those under construction, and to licensees' operational activities. The guides apply as such to new nuclear facilities.

When considering how new safety requirements presented in YVL guides apply to operating nuclear power plants, or to those under construction, STUK takes into account section 27 of the Government Resolution (395/1991), which prescribes that *for further safety enhancement, measures shall be taken which can be regarded as justified considering operating experience and the results of safety research as well as the advancement of science and technology.*

If deviations are made from the requirements of a YVL guide, STUK shall be presented with some other acceptable procedure or solution by which the safety level set forth in the guide is achieved.

Translation. Original text in Finnish.

1 General

This Guide applies to the operation of a disposal facility for spent nuclear fuel. A disposal facility comprises of a facility for the encapsulation of spent fuel elements and an underground facility in bedrock with waste emplacement and auxiliary rooms. The operation of the disposal facility begins when an authorization to bring nuclear waste into the facility is granted and ends when the Radiation and Nuclear Safety Authority (STUK) has stated that the nuclear waste has been disposed of in a permanent manner. This Guide specifies the requirements given in Government Resolution (478/1999) on the safety of disposal of spent nuclear fuel, hereafter referred as the Government Resolution. The Guide concentrates on operational safety issues important during the design phase of the facility. This Guide also includes references to other YVL Guides applicable to the disposal facility. The requirements concerning the long-term safety of spent fuel disposal are given in Guide YVL 8.4.

2 Radiation safety

The radiation protection objectives for the design of the disposal facility and for the planning of the operation of the facility are given in Section 4 of the Government Resolution. According to the principle of optimisation which is included in Section 2 of the Radiation Act (592/1991) and the principle of continuous improvement of safety contained in Section 12 of the Government Resolution, all practicable measures need to be taken in striving for further radiation exposure reduction, even if the the pertinent target values have been achieved.

According to Section 4 of the Government Resolution, *the disposal facility and its operation shall be designed so that:*

1) *as a consequence of undisturbed operation of the facility, discharges of radioactive substances to the environment remain insignificantly low;*
2) *the annual effective dose to the most exposed members of the public as a consequence of anticipated operational transients remains below 0.1 mSv; and*
3) *the annual effective dose to the most exposed members of the public as a consequence of postulated accidents remains below 1 mSv.*

Environmental discharges of radioactive substances from the undisturbed operation of the disposal facility may be deemed insignificantly low if the average annual effective dose to the most exposed members of the public from the discharges is not more than 0,01 mSv. The annual effective dose comprises of the sum of external effective dose accrued during one year and the dose from intake of radionuclides during the same period, integrated over the period of fifty years.

Anticipated operational transient is a safety-related incident with estimated average occurrence of less than once a year but having a significant probability to occur at least once during the operational period of the facility. As a consequence of an anticipated operational transient, spent nuclear fuel may be damaged, radiation dose rates or concentrations of radioactive substances may increase within the disposal facility, or radioactive substances may be released to the environment.

Postulated accident is a safety-related incident, used as a design base for the safety functions of the facility, which has a low probability to occur during the operational period of the facility. As a result of a postulated accident, spent fuel may be severely damaged, large quantities of radioactive substances may be released within the facility or significant quantities of radioactive substances may be released to the environment.

Radiation doses resulting from the undisturbed operation, anticipated operational transients and postulated accidents of the facility shall be assessed. These doses shall be assessed to an individual belonging to the maximally exposed group, the so-called critical group, exposed to external radiation, and to radioactive substances trough inhalation or ingestion. The radionuclide transport and dose analyses shall be based on Guides YVL 7.2 and YVL 7.3 as applicable.

Occupational exposures at the disposal facility shall be limited in accordance to Section 2 of the Radiation Act (592/1991) and Chapter 2 of the Radiation Degree (1512/1991). The requirement to keep occupational exposure as low as reasonably available shall be taken into account in the design of the layout, structures and systems of the disposal facility and in the planning of operations at the facility.

Occupational exposure to natural radiation shall be taken into account especially in designing the underground rooms and planning the activities in them. Guide ST 12.1 applies to limitation of exposure to natural radiation.

3 Technical design requirements

3.1 Limitation of occupational exposure to radiation

Working areas and passageways in regular use in the disposal facility shall be designed and located so that the external dose rate is low and the risk for internal exposure to radiation is small. Radiation dose rates and concentrations of radioactive substances within the disposal facility shall be estimated. Objects emitting intensive radiation shall be shielded effectively or placed in rooms which can be provided with remote handling equipment. Adequate safety margins shall be incorporated in the design of radiation shielding.

The areas in the disposal facility shall be classified based on estimated radiation conditions. Rooms requiring radiation control shall be placed within a specified area to allow appropriate control of access. In setting the protective measures and safety provisions for the underground controlled areas, the specific features concerning work in those areas may be taken into account. Such conditions and premises shall be ensured, by design and planning, for the operation, inspection and maintenance of equipment that the need for and duration of work under radiation is limited. In the design of structures and systems, the feasibility of their dismantling due to maintenance, plant modifications and decommissioning shall be taken into account.

For radiation monitoring purposes the disposal facility shall have available:

- equipment for individual monitoring of radiation doses
- fixed and portable monitoring equipment for external dose rate
- measuring equipment for detecting airborne radioactive material, surface contamination and radioactive materials in systems
- appropriate laboratory facilities for the analysis of samples.

Devices with an alarm function shall be employed for radiation monitoring so that, during the operation of the disposal facility, significant unintentional exposure to radiation will not occur.

The disposal facility shall be designed so that the radiation protection arrangements of the facility are in accordance with the Guides YVL 7.9 and YVL 7.18 as applicable. Guide YVL 7.11 applies to the radiation monitoring systems and equipment in the facility.

3.2 Limitation of radioactive releases

According to Section 17 of the Government Resolution *the dispersion of radioactive substances inside the disposal facility as a consequence of handling of spent fuel shall be limited to the minimum. The released solid, liquid and particulate airborne radioactive matter shall be collected and treated as radioactive waste.*

The operation of the disposal facility shall be planned and its structures and systems designed so that the release of radioactive substances within the facility and to the environment will be prevented or restricted with all practicable means. The facility shall be equipped with systems for the recovery of radioactive residues released into process rooms, for the decontamination of surfaces from radioactive substances and for the treatment and conditioning of radioactive waste arisings.

Such areas of the facility where significant amounts of airborne radioactive materials can exist shall be equipped with ventilation and filtering systems which:

- reduce the concentration of radioactive substances in these areas

- prevent the spread of radioactive substances to other areas within the facility
- limit the release of radioactive materials to the environment.

These ventilation and filtering systems shall be designed to be operated on their rated capacity also during an anticipated operational transient or a postulated accident.

The applicable requirements of Guide YVL 5.6 shall be followed in the design of ventilation systems of the disposal facility.

3.3 Radiation monitoring

In accordance with Section 18 of the Government Resolution, *compliance with operational radiation protection constraints shall be ensured by means of continuous or regular monitoring, focused on the potential discharge routes at the disposal facility and on the activity concentrations in the surroundings of the disposal facility.*

Systems that measure and record the amounts of released radioactive substances shall be designed to monitor the potential discharge routes from the disposal facility. Monitoring of discharges shall be designed to be feasible also during an anticipated operational transient or a postulated accident. For each discharge pathway, a constraint shall be defined, the exceeding of which will activate actions to limit the releases.

Measuring stations for external radiation and meteorological equipment for monitoring radionuclide transport parameters shall be installed in the vicinity of the disposal facility. An environmental surveillance programme shall be implemented in the vicinity of the facility to detect potential releases of radioactive substances.

Guides YVL 7.5, 7.6 and 7.7 include specific requirements concerning meteorological measurements, discharge measurement and environmental radiation monitoring which pertain to the disposal facility, as applicable.

3.4 Safety classification

According to Section 13 of the Government Resolution, *the systems, structures and components of the disposal facility shall be classified on the basis of their importance to the operational safety and to the long-term safety of the disposal facility. Their quality level and the inspections and tests required to ascertain and verify the quality level shall be adequate considering the importance to safety of the item concerned.*

Systems, structures and components important to safety and subject to safety classification include:

- handling systems for containers of spent nuclear fuel
- equipment and cells for handling of spent fuel bundles with the related instrumentation and control systems
- handling systems for the canister of spent fuel with the related instrumentation and control systems
- other systems containing significant quantities of radioactive materials
- fire protection systems in safety relevant compartments
- controlled zone ventilation and filtering systems
- radiation monitoring systems.

Systems, structures and components important to long-term safety and subject to safety classification are:

- the waste canister and its handling systems
- the buffer surrounding the waste canister.

Guide YVL 2.1 shall be followed, as applicable, in the safety classification of the systems, structures and components in the disposal facility. Guide YVL 5.8 applies to the design of hoisting equipment. In the design of instrumentation and control systems, Guide YVL 5.5 and in the design of electrical systems, Guide YVL 5.2 shall be followed as applicable.

3.5 Ensuring the safety functions

According to Section 14 of the Government Resolution, *the functions at the disposal facility that are important to the maintenance of the integrity of fuel bundles and waste canisters, prevention of radioactive releases and to the radiation protection of the personnel shall be ensured.*

Safety systems that shall be ensured against single failure include:

- systems needed to prevent overheating of spent nuclear fuel bundles
- radiation monitoring systems needed for accident follow-up and mitigation and the radia-

tion monitoring system in the hot cell for handling of spent fuel elements
- underpressurising and filtration systems in rooms into which large quantities of airborne radioactive substances may be released
- monitoring systems for discharges of radioactive substances
- fire alarm and extinguishing systems in areas where a fire could cause a significant release of radioactive substances within the facility or to the environment.

The handling systems of spent fuel elements shall be designed so that a single equipment failure can not cause a drop accident or another kind of accident where spent fuel bundles could be severely damaged. The handling systems for spent fuel transport casks and waste canisters shall be designed so that a single equipment failure cannot cause a drop accident or another kind of accident where significant amounts of radioactive substances could be released from the cask or canister. A radiation hazard shall not be caused as a consequence of the loss of driving power of these systems.

Applicable requirements of Guide YVL 2.7 shall be followed in ensuring the safety functions of the disposal facility.

3.6 Prevention of criticality accidents

According to Section 19 of the Government Resolution, *the formation of such spent fuel configurations that would cause an uncontrolled chain reaction of fission shall be prevented by means of structural design of systems and components.*

The transport casks, storage rooms and handling equipment for spent fuel as well as the waste canisters shall be designed so that no critical fuel configurations may be formed in any operational situations, including any anticipated transient or postulated accident.

The emplaced canisters shall retain their subcriticality also in the long term, when the canisters may have lost their integrity and been subject to mechanical or corrosion induced deformations. In the criticality analyses, fuel enrichment and burn-up, the safety margin for the effective multiplication factor and other assumptions shall be selected so that a high degree of confidence in criticality safety is achieved.

3.7 Prevention of fire and explosion hazards

According to Section 20 of the Government Resolution, *the disposal facility shall be designed so that the likelihood of a fire is low and its consequences are of minor importance to safety.*

The disposal facility shall be designed so that explosions that would jeopardise the integrity of spent fuel bundles, waste canisters, or the components or chambers containing radioactive substances, are reliably prevented.

The objective for the design of fire safety of the disposal facility shall include:
- prevention of the ignition of fires
- rapid detection and extinguishing of fires
- prevention of the propagation of fires into areas where a fire could compromise the safety of spent fuel handling or storage
- minimisation of explosion hazards.

The prevention of fires and explosions in the disposal facility shall be primarily based on its layout and on the design of fire cells, which shall fulfil the fire class requirement EI 60 at the minimum. The materials in the facility shall be predominantly incombustible and heat resistant. No materials or equipment that could increase the fire load or cause the hazard of fire ignition or explosion shall be placed within fire cells important to safety or in their immediate vicinity. Separate fire cells shall be formed of rooms or areas with significant fire load concentrations.

The disposal facility shall be equipped with an automatic fire alarm system designed so that a fire can be located with sufficient accuracy. Furthermore, rooms in the disposal facility shall be equipped, as necessary, with suitable fire fighting and first-hand extinguishing equipment. The fire alarm and fighting systems shall be effective also during an anticipated operational transient or a postulated accident.

In the design and planning of fire safety arrangements, Guide YVL 4.3 shall be followed, as applicable.

3.8 Consideration of external events

According to Section 21 of the Government Resolution, *the disposal facility shall be designed so that the impacts caused by potential natural*

phenomena and other external events are taken into account.

Natural phenomena to be considered include at least strikes of lightning, earthquakes, storm winds, floods and exceptional outdoor temperatures. Other external events to be considered include electromagnetic interferences, aeroplane crashes, wildfires and explosions.

The applicable requirements concerning the concrete and steel structures of a nuclear facility in Guides YVL 4.1 and 4.2 and those concerning earthquakes in Guide YVL 2.6 shall be followed in the design of the aboveground facilities.

3.9 Control of nuclear materials

According to Section 23 of the Government Resolution, *the design, construction, operation and closure of a disposal facility shall be implemented so that control of nuclear materials can be arranged in accordance with pertinent regulations.*

Control of nuclear materials shall be taken into account in the design of the disposal facility. The transport routes, buffer stores, handling processes and the control measures for nuclear materials shall be designed and planned so that the continuation of knowledge is assured at every step. Control of material flows in and out of the underground rooms shall be feasible. The fuel elements and waste canisters shall be identifiable.

The nuclear material data of all fuel bundles shall be verifiable by non-destructive methods to check the authenticity and completeness of information. The comprehensive verification of nuclear material data may be performed either in the encapsulation facility or prior to transfer of the fuel bundles there. In the latter case, the fuel bundles shall be individually identified in the encapsulation facility. Also, the uninterrupted continuation of knowledge and the fact that the spent fuel containers remain sealed during the transfers, shall be ensured. If the continuation of knowledge is lost after the verification, nuclear material data shall be reverified.

The aim of the nuclear material control in the disposal facility is also to ensure that, the facility, especially in its underground part, has no rooms, materials or operations outside the system of nuclear material accounting and that the waste canisters remain in their declared positions during the operation and after the closure of the facility.

The information on nuclide composition of the fuel bundles inferred from safeguards measurements can also be used for ensuring that the requirements concerning subcriticality and heat generation of a waste canister are met. The measurements of releases of radionuclides and environmental monitoring data can also be used for the purpose of ensuring that no undeclared activities take place in the disposal facility.

When planning the nuclear material accounting and reporting system, the requirements of Guides YVL 6.1, YVL 6.2 and YVL 6.10 shall be followed as applicable. The basic technical data required by European Union Decree 3227/76/ Euratom shall be furnished to the Radiation and Nuclear Safety Authority and to the European Commission not later than 200 days before the start of the construction of the disposal facility.

3.10 Construction and operation of the underground facilities

According to Sections 24 and 25 of the Government Resolution, *at the planned disposal depth, blocks of bedrock with adequate size and intactness shall exist for the construction of the emplacement rooms. For the design of the emplacement rooms and for the acquisition of data needed for the safety analysis, the host rock shall be adequately characterised by means of investigations performed at the planned disposal depth.*

The design, excavation, other construction and closure of the underground facility shall be implemented in the best manner with regard to retaining the characteristics of the host rock that are important to long-term safety.

During the construction of the waste emplacement rooms and other underground rooms, a geological investigation, testing and surveillance programme shall be executed to ensure the suitability of the rooms for disposal and to determine the characteristics of the rock important to safety. This programme shall include:

- characterisation of the rock volumes intended to be excavated
- monitoring of rock stresses, deformations and displacements
- characterisation of rock types and fracture

zones
- hydrogeological monitoring of rock and monitoring of groundwater characteristics
- observation of effects on rock caused by the heat generation of the disposed waste.

Changes in the layout of the underground facility shall be considered if the quality of the rock surrounding the planned excavations proves to be significantly inferior to the original design base.

To maintain rock characteristics favourable to long-term safety:
- one criterion in choosing the excavation methods shall be to minimise the disturbance caused by excavation in the surrounding rock
- reinforcement and injection of host rock shall be done so that no significant amounts of substances detrimental to the performance of barriers enter the waste emplacement rooms
- introduction of organic and oxidising substances to the waste emplacement rooms shall be minimised
- emplacement rooms shall be backfilled and closed as soon as disposal activities and related monitoring activities allow.

According to Section 26 of the Government Resolution, *excavation works related to enlargement of the underground facility shall not be performed in the vicinity of disposed waste canisters and even otherwise the operations in the underground facility shall be designed with regard to efficiently prevent damages to waste canisters. Regarding underground excavation and construction works, transfers of rock masses or other comparable extensive transfers shall not be performed in the same areas which might simultaneously be used as transport routes for waste packages.*

Enlargement of the disposal facility or other activities requiring large-scale transfer operations shall not compromise the safety of the disposal. Consequently, the layout of the disposal facility shall be drawn up so that disposal operations and the transport of excavated rock, backfilling materials and heavy machinery are appropriately separated. Rock collapses and slides in rooms with waste canister emplacements in progress or completed shall be prevented by keeping these rooms at a sufficient distance from the excavation activities.

The waste canisters shall be transported from the encapsulation plant to their emplacement positions and backfilled in such a manner that no the canisters damages compromising their long-term integrity will occur.

4 Demonstration of compliance with safety requirements

According to Section 27 of the Government Resolution, *if compliance with the requirements for the operational safety of the disposal facility cannot be directly ascertained, it shall be demonstrated by experimental or computational methods or their combination. The computational methods shall be selected so that the detriment or risk likely to occur, with high degree of certainty, remains below the results of analyses. The applied computational methods shall be reliable and well validated for dealing with the events of interest.*

Compliance with the safety requirements concerning the undisturbed operation of the disposal shall be demonstrated by analyses and verified during the commissioning tests of the facility. Also, the performance of safety systems designed for operational transients and accidents shall be, whenever practicable, tested during the commissioning of the facility. The applicable requirements of Guide YVL 2.5 shall be followed in the commissioning of a disposal facility.

Compliance with the safety requirements concerning anticipated operational transients and postulated accidents shall be demonstrated with analyses that cover potential transients and accidents of different nature and severity at the disposal facility. With regard to the representativeness of these analyses, it is essential to consider the cases which are the most limiting ones to the performance and dimensioning of each safety system.

Compliance with radiation protection requirements shall primarily be demonstrated by

a deterministic safety analysis. Such an analysis shall be attached to the decision in principle, in the preliminary safety analysis report and the final safety analysis report. The technical designs of the disposal facility affecting the operational safety shall be additionally justified with probabilistic safety analysis. In accordance with Section 36 of the Nuclear Energy Decree (161/1988), a probabilistic safety analysis shall be included in the material that shall be furnished to STUK in connection with the operation license application. The preliminary safety analysis report, which is included in the material attached to the construction license application, shall contain a design phase probabilistic safety analysis, which includes the assessment of the probabilities of the most significant disturbances and of the magnitudes of the consequent releases of radionuclides as well as the assessment of occupational doses.

The potential causes for anticipated operational incidents to be considered include at least:

- handing of a severely leaking or mechanically deteriorated fuel bundle
- equipment failure or a malfunction with safety significance
- loss of power of a system for handling radioactive substances or of a safety system
- fire in an area or of an object significant to safety
- unforeseen water leakage or flooding in the underground facility.

The potential causes for postulated accidents to be considered include at least:

- drop of a spent fuel bundle, drop of a cask or canister containing spent fuel or other handling accident resulting in a severe damage to the fuel
- substantial degradation of the performance of an important safety system
- significant overheating of spent fuel
- explosion or rock collapse in the underground facility
- external event causing a significant damage, such as a major earthquake or an aeroplane crash.

A description of the methods to be used in the operational safety analysis of the disposal facility shall be presented. It shall contain an explanation of the general principles of the adopted methods, a description of the physical models and numerical methods as well as an account of the experimental data on which the parameters used in the calculation are based on. The methods shall be adequately validated for use in the analysis of the relevant events. Physical models may be validated either against a set of experiments covering the relevant phenomena or by utilising already validated models. Numerical methods may be validated against reference calculations.

Parameter values with a significant impact on the result of the safety analyses shall be selected within their range so that the final result is likely, with high degree of confidence, to overestimate the actual exposure or other detriment. The sensitivity of the results of analyses to the variations of parameter values important to safety shall also be demonstrated.