Regulatory control of fuel design and manufacturing

This Guide is in force as of 1 November 1993, until further notice. It replaces Guide YVL 6.3, issued on 15 February 1983.

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Authorisation

By virtue of section 55, second paragraph, point 3 of the Nuclear Energy Act (990/87) and section 29 of the Council of State Decision (395/91) on the General Regulations for the Safety of Nuclear Power Plants, the Finnish Centre for Radiation and Nuclear Safety issues detailed regulations concerning the safety of nuclear power plants.

The YVL Guides are rules an individual licensee or any other organisation concerned shall comply with, unless the Finnish Centre for Radiation and Nuclear Safety has been presented with some other acceptable procedure or solution by which the safety level laid down in YVL Guides is achieved. This Guide does not change decisions made by STUK before the entry into force of this Guide, unless STUK states otherwise.

Translation. Original text in Finnish.

1 General

Regulatory control of the design and manufacturing of nuclear fuel and of control rods aims to ensure conformance to set requirements during normal operating conditions, anticipated operational transients and postulated accident conditions. General licencing and approval procedures are described in Guide YVL 6.1.

The Council of State Decision (395/91) lays down general safety regulations for nuclear power plants. These regulations also contain requirements for fuel. Detailed requirements for the design, quality assurance, control of operation, handling, storage and transport of fuel are presented in Guides YVL 6.2, 6.4, 6.5, 6.6, 6.7 and 6.8.

This Guide deals with the regulatory control of design, manufacturing, receiving inspections and of the start of operation of fuel. Fuel means an assembly of fuel rods with its fixed upper and lower tie-plates and the channel in which the assembly is encased. The regulatory control procedure presented here also applies to control rods and shield elements.

2 Pre-inspection of fuel and control rods

2.1 Initial core loading, new type of fuel or control rod or new manufacturer of fuel

According to Section 15 of the Council of State Decision (395/91)

- the probability of significant degradation of fuel cooling or, of a fuel failure due to other reasons, shall be low during normal operational conditions and anticipated operational transients
- during postulated accidents, the rate of fuel failures shall be low and fuel coolability shall not be endangered
- the possibility of a criticality accident shall be extremely low.

Detailed safety requirements for fuel design are given in Guide YVL 6.2.

General safety-related information concerning fuel and control rods shall be presented in a plant-specific safety analysis report, as stated in Guides YVL 1.1 and 2.2. Fuel and control rod pre-inspection documentation shall state detailed design criteria, design and manufacturing data, fuel and control rod operating experience, experimental studies and analyses of fuel behaviour plus assumptions and correlations, with background data, which relate to fuel and control rods and which are to be used in accident analyses.

Pre-inspection documentation concerning initial core loading, new type of fuel or fuel supplied by a new manufacturer shall be submitted to the Finnish Centre for Radiation and Nuclear Safety (STUK) for approval not later than one year before fuel manufacturing is commenced. Apart from a detailed description of fuel, the pre-inspection documentation shall then contain at least the clarifications required in sub-sections 2.1.1, 2.1.2, 2.1.3 and 2.1.4 of this Guide. For the purposes of this Guide, new supplier means a supplier to whom the fuel type in question is new or who supply their first batch of fuel to Finland. As regards other requirements, the pre-inspection documentation shall be complemented not later than three months before fuel manufacturing is commenced. Pre-inspection documentation may be drawn up separately for fuel assemblies, fuel channels and control rods.

Requirements for the contents of the pre-inspection documentation are presented below.

2.1.1 Quality assurance

Guide YVL 1.4 presents general requirements for quality assurance and Guide YVL 6.7 gives detailed requirements for fuel.

The fuel supplier's quality assurance programme and the manual for its

implementation shall be delivered to STUK for information with the pre-inspection documentation. The licensee's own fuel quality assurance manual shall be submitted to STUK for approval separately from the pre-inspection documentation, not later than one year before fuel manufacturing is commenced.

2.1.2 Design criteria

Fuel and control rod design bases and the design limits for the prevention of fuel failure, and concerning coolability, shall be presented, taking into account the requirements presented in Guide YVL 6.2. Fuel failure means that fission products are released from fuel rods into coolant (fuel leakage) or that deformation limits set as a design-basis for any section of the fuel assembly, including the fuel channel, are exceeded. Loss of fuel coolability means such failures in fuel assembly structure that the assembly looses its coolable geometry.

The design bases shall also state the requirements for the use of fuel and restrictions on e.g. the mean and maximum linear heat rating or heat flux, power ramp rate, burn-up plus the chemical and physical properties of coolant. The following shall also be stated: design-basis internal and axial power peaking factors for fuel assemblies, and power histories which subject fuel to the maximum loads.

The structure and components of fuel and control rods shall be so designed that their condition can be inspected to sufficient extent at specified intervals.

2.1.3 Experimental studies and analyses of fuel behaviour

Analyses, experimental studies and operating experience shall demonstrate that fuel and control rods conform to design-basis requirements. I.a. the following matters shall be clarified:

- fuel pellet and fuel rod cladding maximum temperature and temperature distribution under normal operating conditions, and during transients which increase reactor power
- impact of the densification of fuel pellets on linear heat rating, power peaking and heat transfer
- fission gas release (rod internal pressure) and its dependence on burn-up and on power histories subjecting fuel to the maximum loads
- fuel rod bowing and its impact
- fuel rod corrosion and formation of corrosion product layers, and their effect on heat transfer
- pellet-cladding interaction
- fuel cladding wear, corrosion and hydriding
- fuel cladding stresses, deformations and buckling, and fuel rod vibrations
- interactions between coolant and structural parts of fuel
- fatique of structural parts of fuel
- structural stability of fuel under various conditions
- changes which occur in the dimensions of the fuel assembly during service life
- behaviour of leaking fuel rods
- control rod dimensions and stability under various conditions
- manoeuvring of control rods under various conditions
- temperature and temperature distribution of control rods under various conditions
- control rod corrosion and build-up of corrosion product layers, and rod wear-off
- changes which occur in control rod dimensions during service life
- behaviour of absorbing material.

Accident analyses shall also clarify the following aspects:

- interactions between fuel components during accident conditions
- temperature and oxidation of fuel cladding during various accidents
- ballooning and rupturing of fuel rods, and blocking of assemblies
- propagation of metal/water-reaction in zirconium-based alloys
- fuel rod maximum enthalpy
- effect of fuel burn-up on various failure mechanisms

- number of fuel failures during postulated accident conditions.

The methods of calculation to be used in the analyses, their validation and factors contributing to uncertainty shall be stated. Sufficient input data, the test conditions and results shall be presented of experimental studies carried out under reactor conditions and under simulated laboratory conditions.

If accident analyses and calculations pertaining to the power peaking factor and to safety margins have been contained in the plant's safety analysis report, the pre-inspection documentation shall state the final results relating to fuel of these analyses and also the necessary references to respective points in the safety analysis report.

2.1.4 Operating experience

The operating experience relating to fuel and to control rods shall be presented with attention paid to the meeting of design-basis requirements. The clarification shall also specify the service life, the conditions for cooling, the mean and maximum linear powers, the burn-up, and the failures with their causes of the fuel type in question, and also, where applicable, the power histories and the coolant activity concentrations of the reactors in question.

Any significant modifications in the types of fuel assembly and control rod shall be described and the causes of the modifications presented.

A general follow-up programme for the use of fuel, drawn up by the fuel designer, shall be presented.

2.1.5 Item list for each delivery batch

A list shall be presented of each delivery batch, giving specifications and drawings, part by part, of accomplished products, semi-manufactured products and materials.

2.1.6 Technical specifications

Technical specifications of all components in each fuel assembly, fuel channel and control rod, and also of all base materials and welding filler materials shall be given. The specifications are intended to present unambiguous approval criteria and limits for accomplished products, semi-manufactured products and their materials and methods of manufacture.

The specifications of uranium dioxide pellets shall present the methods of fabrication, the identification of manufacturing batches, the requirements to be set for the pellets' properties and the inspection requirements. STUK reviews the specification of uranium dioxide powder during the manufacturing plant inspection referred to in sub-section 3.2.

The specifications of the fuel assembly and channel and of the structural parts and materials of control rods shall give the method of fabrication, the identification of manufacturing batches, the requirements to be set for materials properties, testing and inspection.

2.1.7 Drawings

Drawings concerning fuel and control rods and their components shall be presented, specifying i.a. the following aspects:

- dimensions and geometries required for analyses, and the allowable tolerances
- assembly data with parts and materials lists
- types of joint, their locations and dimensions.

2.1.8 Quality control programme

The quality control programme shall present, or the pre-inspection documentation shall specify, the quality control measures planned and the inspection procedures applicable to the measures.

The quality control measures shall contain inspection plans for the following: uranium

dioxide pellets, structural parts and their base materials and welding filler materials, semi-manufactured products and accomplished products.

The inspection plans shall describe the quality control measures, specifying the following aspects:

- identification of parts on the basis of drawings
- specification marking of uranium dioxide pellets, structural parts and their base material and welding filler materials
- inspection instructions for quality control measures.

The inspection plan shall show the following aspects as regards each inspection step:

- fabrication phase during which the inspection is conducted
- place of inspection
- conductor of inspection
- supervisor of inspection.

Instructions shall be drawn up for every inspection step relating to fabrication and assembly. The instructions shall state the method and scope of, and the requirements and reporting for the inspection.

2.1.9 Description of manufacturing

The document shall present, or the pre-inspection documentation shall otherwise specify, the fabrication methods of fuel, control rods and their various components and the implementation of quality control during the various phases of fabrication.

2.2 Delivery batches for reloads

The pre-inspection documents of fuel and control rod delivery batches for reloads shall be submitted to STUK for approval, not later than three months before manufacturing of the batch in question is commenced.

Requirements in sub-section 2.1 are concerned with the contents of pre-inspection documents. Documents delivered to STUK earlier may be referred to, and no re-delivery will be necessary.

Updated operating experience shall be presented and reference shall be made to the operating experience data delivered to STUK in connection with the operational surveillance control programme of fuel.

New data and methods of analysis pertaining to analyses of fuel behaviour and to experimental studies shall be presented.

A summary of any changes made to design and manufacturing shall be presented. The changes shall be supported by experimental results and analyses, where necessary. Any changes to manufacturing or quality control methods shall also be substantiated.

If the designer or manufacturer changes, the entire pre-inspection documentation shall be presented in accordance with sub-section 2.1.

3 Control of manufacturing

Control of the manufacturing of fuel and control rods by the Finnish Centre for Radiation and Nuclear Safety is intended to assure that the products in question conform to applicable requirements. The inspections mentioned in sub-sections 3.1 and 3.2 shall have been conducted and pre-inspection documentation shall have been approved before manufacturing is commenced. STUK's inspector draws up a protocol of the manufacturing inspections. For the purpose of arranging the inspections, the licensee shall deliver the manufacturing schedules to STUK well in advance of the inspections.

The control of manufacturing comprises the inspections mentioned in sub-sections 3.1- 3.4.

3.1 Implementation of quality assurance

The Finnish Centre for Radiation and Nuclear Safety reviews the implementation of the quality assurance of design and manufacturing before the manufacturing of an initial core loading batch and of a new type of fuel and control rod is commenced. The implementation of quality assurance by a new manufacturer will be similarly reviewed.

The licensee shall see to it that STUK can schedule the inspections so that sufficient time will be left for potential corrective measures and re-inspections. An inspection may comprise several steps.

As a general rule, if a reload batch is supplied by the same designer and manufacturer, STUK reviews the implementation of quality assurance once a year.

3.2 Methods of manufacturing and quality control

The Finnish Centre for Radiation and Nuclear Safety reviews fabrication and quality control methods before the manufacturing of an initial core loading batch and new types of fuel and control rod is commenced. A new manufacturer's fabrication and quality control methods will be similarly reviewed.

When a new batch is delivered by the same manufacturer as before, STUK reviews the methods of fabrication and quality control mainly during the manufacture of the batch.

STUK reviews any significant changes in the manufacturing and quality control methods of delivery batches ordered to Finland before the methods in question are taken into use.

The licensee shall schedule the inspections in such a way that sufficient time will be left for potential corrective measures and re-inspections.

3.3 Sub-contracting

The Finnish Centre for Radiation and Nuclear Safety inspects the quality assurance functions of sub-contractors and their methods of manufacturing and quality control at its discretion. The inspections are focused on the suppliers of the most important components and structural materials.

3.4 Quality control documentation of delivery batches

Before a reload batch is taken into operation, STUK reviews the quality control documentation and potential deviation reports either at the factory or at the licencee's premises. A report shall be drawn up of any significant deviations affecting safety, justifying the acceptability of each deviation. The report shall be submitted to STUK for approval. A repair plan of deviations affecting safety, which are intended to be corrrected, shall be submitted to STUK for approval in advance. The plan shall indicate, as appropriate, the information presented in point 6.

A list of deviation reports concerning fuel and control rods and their certificates of manufacturing shall be delivered to STUK for information before the batches in question are taken into operation. A statistical summary report shall be drawn up of the quality control documentation of each batch and it shall be delivered to STUK for information not later than three months after the operation of the fuel batch has started.

4 Receiving inspections

An inspection programme covering receiving inspections at the nuclear power plant shall be drawn up and submitted to STUK for approval. The Centre shall be notified in advance of the date of each batch's receiving inspection.

A summary report of the results of the receiving inspections shall be delivered to STUK for information. The report may also be delivered to STUK in connection with the application for operation of the delivery batch, as referred to in point 5.

Deviations detected during the receiving inspections shall be contained in a deviation report which is submitted to STUK for approval and contains a plan for potential repairs or an assessment of the acceptability of the deviation.

STUK oversees the receiving inspections at its discretion.

5 Application for operation of delivery batches

The utility shall apply for STUK's approval of the operation of the initial core loading batch of fuel and control rods and of each delivery batch. In the application, the following shall be listed: documents which have been sent to STUK concerning the batch, decisions made by STUK, and the manufacturing and receiving inspections conducted by both STUK and the utility.

The pre-requisites for a positive commissioning decision are as follows:

- STUK has approved of the batch's pre-inspection documentation
- during control of manufacturing and receipt, no such matters have surfaced as would prevent the taking into operation of the batch
- potential deviation reports and the certificate of manufacturing have been delivered to STUK.

Any potential unaccomplished matters shall be mentioned in the application and a plan for corrective actions shall be presented. The application shall also contain the identification markings of fuel assemblies, fuel channels and control rods of the reload batch in question.

6 Repairs of fuel

Fuel repairs on site shall be carried out according to a written plan. STUK's approval of the plan shall be obtained in advance. The plan shall contain the following data:

- an overall description of the work, specifying the cause, object and method of repair, previous experience of the repair method and the inspection methods to be used
- qualification and experience requirements for staff supervising, managing and carrying out the work
- replacement parts to be used
- list of instructions to be used in performing the work.

There shall be written instructions for repairs, inspections, supervision and reporting. These can be work-specific procedure instructions or - particularly, as regards supervision, reporting and documentation - guidelines of a more general nature, applicable to various work assignments. The new instructions and procedure descriptions shall be delivered to STUK for information before the work in question is commenced.

Inspection of fuel and of control rod repair and modification work, as referred to in Guide YVL 1.8, shall be requested from STUK. During the inspection, it will be ensured that the work has been implemented according to plan and that the documentation for the work is acceptable. For the purpose of the inspection, the following items shall be presented:

- work order
- procedures
- list of special equipment required in the work and related drawings
- copies of documents that have been delivered to STUK.

On the basis of a separate application, STUK may grant the licensee's inspectors the right to inspect repetitive work which is of minor significance to fuel assembly integrity.

The fuel spare parts to be used shall have been inspected and approved according to chapter 3 of this Guide, and shall have passed the nuclear facility's receiving inspection.

Handling instructions for fuel and fuel rods shall comply with Guide YVL 6.8. Instructions for handling and storage equipment shall comply with the requirements of Guide YVL 6.8. Detailed drawings or equivalent data of the new handling and storage equipment required during repairs shall be submitted to STUK for approval, allowing sufficient time for repairs and modifications.

STUK shall be given advance notice of any work to be done on fuel. The notice shall determine the work to be done, specify the fuel in question, mention the date of work and the plans according to which the work will be done.

Repaired fuel may be introduced into service after the quality of repair work has been inspected and STUK has approved the taking into use of the fuel batch in question. A leak test of fuel that has already been in the core, and that has been significantly repaired, shall be conducted before the fuel is taken into use.

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General guides

YVL 1.0 Safety criteria for design of nuclear power plants, 1 Dec. 1982

YVL 1.1 The Finnish Centre for Radiation and Nuclear Safety as the regulatory authority in control of the use of nuclear energy, 27 Jan. 1992

YVL 1.2 Documents to be submitted to the Finnish Centre for Radiation and Nuclear Safety concerning the regulation of nuclear facilities, 22 May 1991 (in Finnish)

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YVL 1.5 Reporting nuclear power plant operation to the Finnish Centre for Radiation and Nuclear Safety, 18 Aug. 1989

YVL 1.6 Nuclear power plant operator licensing, 3 March 1989

YVL 1.7 Duties important to nuclear power plant safety, personnel qualifications and training, 28 Dec. 1992 (in Finnish)

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YVL 1.9 Quality assurance during operation of nuclear power plants, 13 Nov. 1991

YVL 1.13 Regulatory inspections related to shut-downs at nuclear power plants, 9 May 1985

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Systems

YVL 2.1 Safety classification of nuclear power plant systems, structures and components, 22 May 1992

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YVL 2.3 Preinspection of nuclear power plant systems, 14 Aug. 1975

YVL 2.4 Over-pressure protection and pressure control during disturbances in the primary circuit and steam generators of a PWR plant, 19 Sept. 1984

YVL 2.5 Pre-operational and start-up testing of nuclear power plants, 8 Jan 1991

YVL 2.6 Provision against earthquakes affecting nuclear facilities, 19 Dec. 1988

YVL 2.7 Failure criteria for the design of a light-water reactor, 6 April 1983

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YVL 3.7 Pressure vessels of nuclear facilities. Commissioning inspection, 12 Dec. 1991

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YVL 4.1 Nuclear power plant concrete structures, 22 May 1992 (in Finnish)

YVL 4.2 Steel structures for nuclear facilities, 19 Jan. 1987

YVL 4.3 Fire protection at nuclear facilities, 2 Feb. 1987

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YVL 5.7 Pumps at nuclear facilities, 23 Nov. 1993 (in Finnish)

YVL 5.8 Hoisting appliances and fuel handling equipment at nuclear facilities, 5 Jan. 1987

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YVL 6.1 Control of nuclear fuel and other nuclear materials required in the operation of nuclear power plants, 19 June 1991

YVL 6.2 Fuel design limits and general design criteria, 15 Feb. 1983

YVL 6.3 Regulatory control of fuel design and manufacturing, 15 Sept. 1993

YVL 6.4 Supervision of nuclear fuel transport packages, 1 March 1984

YVL 6.5 Supervision of nuclear fuel transport, 1 March 1984

YVL 6.6 Surveillance of nuclear fuel performance, 5 Nov. 1990 (in Finnish)

YVL 6.7 Quality assurance of nuclear fuel, 23 Nov. 1993 (in Finnish)

YVL 6.8 Handling and storage of nuclear fuel, 13 Nov. 1991 (in Finnish)

YVL 6.9 The national system of accounting for and control of nuclear material, 23 Nov. 1993 (in Finnish)

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YVL 7.14 Action levels for protection of the public in nuclear power plant accidents, 26 May 1976

YVL 7.18 Radiation protection in design of nuclear power plants, 14 May 1981

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YVL 8.1 Disposal of reactor waste, 20 Sept. 1991

YVL 8.2 Exemption from regulatory control of nuclear wastes, 19 March 1992

YVL 8.3 Treatment and storage of radioactive waste at the nuclear power plants, 1 July 1985

The YVL-guides without any language marking are available both in English and Finnish.