In the event of any differences in interpretation of this guide, the Finnish version shall take precedence over this translation.

SUPERVISION OF FUEL DESIGN AND MANUFACTURE

CONTENTS

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1. GENERAL

The general principles for the design of fuel and control rods are presented in Guide YVL 1.0 "Safety Criteria for Design of Nuclear Power Plants". The supervision of design and manufacture ensures that the fuel and the control rods meet the requirements set for them in normal operation, in anticipated operational occurrences and in postulated accident conditions.

General requirements and procedures for the licensing and acceptance of fuel are presented in Guide YVL 6.1 "Licensing of Nuclear Fuel and Other Nuclear Material". This guide deals with the supervision of the design, manufacture, receiving inspections, and commissioning of fuel (including the boxes surrounding the fuel bundles). The supervisory procedure is also applied to control rods.

Limits and design requirements concerning fuel damage and coolability are given in Guide YVL 6.2. "Fuel Design Limits and General Design Criteria". Requirements for quality assurance, supervision of operation, and handling and storage are presented in other YVL Guides.

2. PRE-INSPECTION OF FUEL AND CONTROL RODS

2.1. Initial loading of the nuclear power plant

The general premise in the design of fuel and control rods is to ensure that:

- the fissile material is distributed in the reactor in a suitable manner,

- the heat released in the fission is removed in a controlled manner into the coolant,
- the fuel and the control rods do not become damaged during normal operation and in anticipated operational occurrences,
- fuel and control rod damages do not prevent the insertion of control rods into the reactor even in postulated accident conditions,
- the fuel remains in a coolable form in postulated accident conditions,
- the properties and behaviour of the fuel and the control rods are well known, so that reliable safety analyses can be performed, and
- the structure and parts of the fuel and the control rods can be inspected periodically to an adequate extent.

Requirements concerning fuel coolability and prevention of fuel damage are dealt with in more detail in Guide YVL 6.2.

The general information concerning the safety of the fuel and the control rods are presented in accordance with Guide YVL 1.1 "The Institute of Radiation Protection as the Supervising Authority of Nuclear Power Plants" in the safety analysis report of the plant unit, which also includes the analyses dealing with disturbance and accident situations at the plant unit. The pre-inspection documents of fuel and control rods present detailed design bases, design and manufacturing specifications, operating experience of the fuel and control rod type, experimental studies and behaviour analyses, and background data for the assumptions and correlations used in accident analyses for the fuel and the control rods.

The pre-inspection documents are submitted to the Institute of Radiation Protection (IRP) for approval not later

than one year before the commencement of manufacture. The documents dealing with quality assurance can be submitted to the IRP, even if they require approval, separately from the pre-inspection documents. The pre-inspection documents may be prepared separately, for instance, for fuel bundles, fuel boxes and control rods.

Requirements for the contents of the pre-inspection documents are set forth below.

2.1.1.
Quality assurance

The document presents the supplier's quality assurance program concerning the design and manufacture of the fuel and the control rods. The general requirements for quality assurance are given in Guide YVL 1.4 "Quality Assurance Program for Nuclear Power Plants".

The manual on the execution of the quality assurance program is submitted separately, but at the same time, to the IRP for information.

The power company's manual on the quality assurance of fuel is submitted separately to the IRP for approval not later than one year before the commencement of the manufacture of fuel.

2.1.2.
Design bases

The document presents the design bases for the fuel and the control rods. The design bases, including the design limits for fuel coolability and for prevention of fuel damage, shall be presented taking into account the requirements set forth in Guide YVL 6.2. A fuel damage means a situation in which fission gases are released from fuel

rods into the coolant (fuel leakage) or the deformations determined as a design basis are exceeded. The loss of coolability means such damage in the fuel that the fuel consequently loses its coolable form.

The design bases also set requirements for operating conditions, such as the average and maximum linear power or heat flux, power change rate, burn-up, and the chemical and physical properties of the coolant. In addition, the hot channel factors for the internal and axial power distribution of the fuel bundle, used as a design basis, and the most severe power histories are accounted for.

2.1.3.
Behaviour analyses and experimental studies

By means of analyses, experimental studies and operating experience, it shall be demonstrated that the fuel and the control rods meet the design basis requirements. At least the following items shall be reported.

- the highest temperature of the fuel pellets and the cladding and temperature distribution in normal operation and in disturbances increasing the reactor power,
- effects of the densification of fuel pellets on linear power, power distribution and heat transfer,
- bowing of fuel rods and the effects of bowing,
- the effect on heat transfer caused by the corrosion and crud layer on the surface of a fuel rod,
- internal pressure of the fuel rods,
- interaction between fuel pellets and cladding,
- amount of fission products in fuel rods,
- wear and corrosion of the fuel cladding,
- stresses, strains and collapse of the fuel cladding and vibrations of fuel rods,

- fatigue of the structural parts of the fuel,
- integrity of the fuel structure in various conditions,
- chemical reactions between various parts of the fuel and the coolant and fission products,
- dimensional stability of various parts of the fuel during operation,
- interactions between various parts of the fuel in accident conditions,
- behaviour of leaking fuel rods,
- dimensioning and integrity of control rods in various conditions,
- movability of control rods in various conditions,
- temperature and temperature distribution of control rods in various conditions,
- corrosion of control rods, formation of crud layer and wear,
- dimensional stability of control rods during operation,
- behaviour of absorber material,
- temperature and oxidation of the fuel cladding in loss-of-coolant accidents (as part of accident analyses),
- ballooning and rupture of the fuel rods and blockage of the flow channels (as part of accident analyses),
- metal/water reaction (as part of accident analyses),
- increase in the enthalpy of the fuel rod (as part of accident analyses), and
- number of fuel damages in postulated accident conditions (as part of accident analyses).

The calculation methods to be used in the analyses, their verification and the uncertainty factors are presented. Adequate input data, test conditions, and the final results of experimental studies that have been made in reactor

and laboratory conditions shall be presented.

As far as the analyses, as described above, are included in the safety analysis report of the plant (accident analyses, calculations concerning the power distribution and safety margins), the final results in regard to fuel and necessary references are presented in the pre-inspection documents.

2.1.4.
Operating experience

The operating experience of the fuel and the control rods are presented paying extra attention to the fulfilment of the requirements given as the design basis. In addition, the document shall provide information on the operating time, cooling conditions, and average and maximum linear power of the fuel design in question, on fuel burn-up and damages and their causes, and, as applicable, on the power history of the reactors in question and on the activity of the coolant. Significant modifications made on the fuel and control rod design are described and the causes for the modifications are given.

An account is given of the general fuel behaviour surveillance program of the fuel designer.

2.1.5.
Material specification

The purpose of the material specification is to demonstrate the applicability of the materials to their intended use and to provide unambiguous acceptance criteria and limits for the materials.

Control rods and parts of the fuel bundles are provided with a specification on base materials and welding filler

materials, which shows the numbers of the parts in question, codes (reference to drawings and inspection plan), and standard symbols for the base materials and welding filler materials.

In addition to the specification, an account is given of the fabrication method of the uranium dioxide powder, identification and enrichment level of the fabrication batches, chemical and physical requirements set for the powder, and inspection requirements of the powder, As concerns finished pellets, also their fabrication method, identification of the fabrication batches, requirements set for the properties of the pellets, and inspection requirements are described.

With respect to the zirconium-based tube, rod and plate alloys that are used in fuel rods, in grid structures of the bundle and in fuel boxes, an account is given of the fabrication method, identification of the fabrication batches, requirements set for the properties of the materials, testing and inspection requirements, code numbers of the parts in question, and references to drawings and inspection plans.

The other parts of the control rods and the fuel, with each construction material specified, are further provided with a description of the standard symbol and type of the base material or the welding filler material, the fabrication method of the base material, its state of delivery, fabrication processes significant to the properties of the final product (forming, heat treatment, etc.), properties of the construction materials required of the finished product, and testing and inspection requirements.

As concerns raw materials and products that are supplied by sub-contractors used by the manufacturer, their material certificate class is also presented.

The experimentally measured properties of the fuel and control rod materials in various conditions are presented taking also into account the effects of radiation. The properties are presented to such an extent that the behaviour of the fuel rods, bundles and boxes as well as control rods in normal operation, in anticipated operating disturbances and in postulated accident conditions can be estimated.

2.1.6.
Description of manufacture

The document presents the manufacturing processes of the fuel and the control rods and their parts as well as the implementation of quality control in the various phases of manufacture.

2.1.7.
Quality control program

The purpose of the quality control program is to give a systematic presentation of the planned quality control measures and the inspection procedures applied in them.

The quality control program includes

- definitions,
- inspection plans for uranium oxide powder and pellets, zirconium-based alloys, other base materials, welding filler materials, semi-finished products and finished products, and
- inspection instructions.

The inspection plans present quality control measures and provide the following information

- numbering of each part and welded joint according to drawings,
- name and quantity of the part,
- standard and specification symbols of uranium oxide powder and pellets, zirconium-based alloys, and other base materials and welding filler materials, and
- division of quality control measures according to inspection instructions.

Each inspection measure that is included in the plan shall answer the questions: where the inspection is performed (manufacturer, sub-contractor, etc.) and which parties perform the inspection or supervise it.

All inspection measures that relate to manufacture and assembly shall be provided with inspection instructions. The instructions shall reveal the procedure, extent, requirements and reporting of the inspection. Part of the inspection instructions may be included in other documents, e.g. material specifications.

2.1.8.
Drawings

The drawings describing the fuel and the control rods and their parts are presented. The drawings shall be unambiguous and clear. They shall show, for instance:

- dimensions and forms needed for analyses, and allowable tolerances
- assembly data with part and material lists,
- types, locations and dimensions of joints,
- as for welded joints, a description of the welding method and the requirements set for welding, and
- references to the quality control program and inspection instructions.

2.2.
Subsequent batches needed for reloading

The pre-inspection documents concerning subsequent fuel batches are submitted to the IRP for approval not later than six months before the fabrication of the batch in question is begun.

The requirements presented in section 2.1 are applicable to the contents of the pre-inspection documents. Reference can be made to documents that have already been submitted to the IRP, and they need not be submitted again.

The data on operating experience are updated, so that they are in keeping with the present time. Reference is made to the data on operating experience that have been submitted to the IRP in connection with the supervision of the use of fuel.

All new information on behaviour analyses and on experimental studies and developed analysis methods are introduced.

A summary of the modifications made in design and manufacture is presented and the modifications are justified separately by means of experimental results and analyses. Also the reasons for the modifications to be made in fabrication or quality control procedures are given.

If the designer or the manufacturer is changed, the pre-inspection documents are presented in their entirety in accordance with section 2.1.

3.
CONTROL OF MANUFACTURE

The purpose of the control of the fuel and control rod

manufacture is to ensure that these products meet the requirements set for them. The inspections mentioned in sections 3.1 and 3.2 and an approval granted for the pre-inspection documents are prerequisites for the commencement of the manufacture.

The inspections concerning the manufacture are recorded in an inspection memorandum, which is delivered to the power conpany either in connection with the inspection or separately. For the arrangement of the inspections, the power conpany shall submit the manufacturing schedules to the IRP well before the work is begun.

The control of manufacture performed by the Institute of Radiation Protection comprises the following inspections.

3.1.
Audit of the implementation of quality assurance

The audit concerning the implementation of quality assurance in design and manufacture is made, as far as products belonging to the first core batch are concerned, before the commencement of manufacture.

The power company shall take care of the timing of the audit so that there is enough time for repairs and re-inspections considered to be necessary. The audit can also consist of several part-inspections.

If the same designer or manufacturer is the supplier of the subsequent batches, audits concerning the implementation of quality assurance are as a rule carried out annually. If the designer or the manufacturer is changed, the audit is performed before the manufacture of the first batch is commenced.

3.2.
Inspection of manufacturing and quality control methods

The inspection of the manufacturing and quality control methods is made, as far as products belonging to the first core batch are concerned, before the commencement of manufacture. The power company shall take care of the timing of the inspection so that there is enough time for repairs and re-inspections considered to be necessary.

When the same manufacturer supplies new batches, the inspections concerning manufacturing and quality control methods are as a rule carried out annually. If the manufacturer is changed, the inspection is performed before the first batch is manufactured.

Significant changes in manufacturing and quality control procedures are inspected before the procedures are applied to deliveries coming to Finland.

3.3.
Audit of subcontracting

Inspections concerning the subcontractors' quality assurance and quality control methods are performed to the extent deemed necessary by the IRP. The audits are concentrated on the suppliers of the most important construction materials and parts.

3.4.
Inspection of the final documentation concerning the quality control of manufactured batches

The final documentation of quality control and any deviation reports that may have been made are inspected either at the manufacturing site or at the plant site before the batch in question is commissioned. Deviations affecting

safety shall be recorded in a report, in which the grounds for accepting the deviation are given. The report is submitted to the IRP for approval. If it is intended that some deviations affecting safety be removed by repairing, a repair plan including, as applicable, the information presented in section 6 shall be submitted to the IRP beforehand for approval. The IRP informs of the supervision of the repair work in its resolution on the plan.

A statistical summary report shall be prepared of the final documentation of the fuel quality control. The summary report, a list of deviations and a certificate of manufacture is submitted to the IRP for information before the batch in question is commissioned.

4. RECEIVING INSPECTIONS

An inspection plan for receiving inspections at the nuclear power plant shall be drawn and delivered to the IRP for approval. The IRP shall be notified in advance of the date of the receiving inspection for each batch.

A summary report of the results of the receiving inspections shall be submitted to the IRP for information. The report can be delivered to the IRP also in connection with the application for commissioning referred to in section 5.

All significant deviations that are detected shall be reported in a deviation report which is submitted to the IRP for approval. The report includes a plan for an eventual repair or grounds for the acceptability of the deviation.

The Institute of Radiation Protection supervises the receiving inspection to the extent deemed necessary.

5. COMMISSIONING

The power company shall apply to the IRP for approval of the use of the first core and each subsequent batch. The application shall include a list of the letters sent to the IRP concerning the charge in question, the decisions made by the IRP, and the inspections carried out by the IRP and the power company with respect to fabrication and receiving.

The following conditions shall be met if a positive decision on the use of the fuel is to be reached:

- the pre-inspection documents are accepted as a whole,
- no matters constituting a hindrance to commissioning have come up in the control of manufacture and reception, and
- the summry report of quality control, eventual deviation reports and the certificate of manufacture have been reviewed by the IRP.

If there are still some unfinished matters, they are mentioned in the application and a plan for finishing them is presented. The application shall also contain the identification symbols of the fuel bundles, boxes, and control rods that are included in the batch that the application deals with.

6. FUEL REPAIRS

Fuel repairs at the plant site shall be performed according to a written plan. This plan shall be accepted by the IRP. If possible, an application for the acceptance shall be made to the IRP one month before the repair work is plan-

ned to be started. The plan shall include the following information:

- reason for repair,
- object to be repaired,
- repair method and earlier experience gained of it,
- descriptions of the function of special instruments used in the repair and drawings of these instruments,
- competence of the persons participating in the repair and in its supervision,
- instructions for the repair work,
- instructions for the inspection and control of the repair work,
- design documents of new parts needed in the repair or reference to pre-inspection documents that have already been accepted,
- instructions for the reporting and recording of results,
- description of the safety of the repair work and radiation protection (in regard to spent fuel), and
- evidence to prove that the fuel properties are not impaired in the repair.

The repair work can be started after a representative of the IRP has ascertained that the equipment to be used in the repair corresponds with the approved documentation and that the preparedness for performing the repair is sufficient also in other respects. The final documents of the quality control of any new parts as well as their material certificates shall be presented to the representative of the IRP before the repair work is commenced.

The repaired fuel can be taken into use after the representative of the IRP has reviewed the documents on the repair or the modification and has ascertained that the fuel is

in an acceptable condition and after the IRP has accepted the use of the batch in question. If significant repairs are made on spent fuel, a leakage test shall be performed for the fuel before it is again taken into use.

7.
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