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NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

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REGULATORY INSPECTION PRACTICES ON FUEL ELEMENTS AND CORE LAY-OUT AT NPPs

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article I of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral. non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of all OECD Member countries except New Zealant and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international committee made up primarily of senior nuclear regulators. It was set up in 1989 as a forum for the exchange of information and experience among regulatory organisations and for the review of developments which could affect regulatory requirements.

The Committee is responsible for the programme of the NEA, concerning the regulation, licensing and inspection of nuclear installations. The Committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them or avoid disparities among Member Countries. In particular, the Committee reviews current practices and operating experience.

The Committee focuses primarily on power reactors and other nuclear installations currently being built and operated. It also may consider the regulatory implications of new designs of power reactors and other types of nuclear installations.

In implementing its programme, CNRA establishes co-operative mechanisms with NEA's Committee on the Safety of Nuclear Installations (CSNI), responsible for co-ordinating the activities of the Agency concerning the technical aspects of design, construction and operation of nuclear installations insofar as they affect the safety of such installations. It also co-operates with NEA's Committee on Radiation Protection and Public Health (CRPPH) and NEA's Radioactive Waste Management Committee (RWMC) on matters of common interest.

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ABSTRACT

The basic description of the reactor core of a nuclear power plant (NPP) is an important part of the Safety Analysis Report in all countries. Due to increased interest by regulatory authorities in the Member countries, in 1996 WGIP proposed looking at inspection aspects on fuel elements and core lay-out at nuclear power plants. The CNRA subsequently approved proceeding with this report.

The report deals primarily with inspection practices and inspection requirements during nuclear power plant (NPP) operation with special emphasis on refuelling procedures. All license related topics, such as fuel and core design (mechanical, neutronic, thermal-hydraulic), as well as inspection philosophy and practices on fuel fabrication are included as appropriate serving as background information and may not be completely described.

INTRODUCTION

Scope of the report

The report deals primarily with inspection practices and inspection requirements during nuclear power plant (NPP) operation with special emphasis on refuelling procedures. All license related topics, such as fuel and core design (mechanical, neutronic, thermal-hydraulic), as well as inspection philosophy and practices on fuel fabrication are included as appropriate serving as background information and may not be completely described.

Preparation of report

WGIP members describe their country's inspection programme according to the structure of a questionnaire (see appendix 1). The individual contributions are contained in the appendix 2 and are compiled within the main chapters (1 through 3).

Report Structure

1. **Licensing and Quality Assurance (QA) requirements for nuclear fuel**
2. **Regulatory inspection programme during NPP operation and refuelling outages**
3. **Procedures for inspection practices and inspection programme**

Appendix: Questionnaire and Country specific contributions

Contributions are presented by Belgium, Finland, France, Germany, Hungary, Italy, Japan, Mexico, The Netherlands, Spain, Sweden, Switzerland, United Kingdom, USA.

The authors would like to thank all those members of WGIP and their associated colleagues who helped in compiling this report. Additionally, WGIP wishes to extend its appreciation to Dr. H. Klonk and the other members of the task group, for all their efforts.

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

The basic description of the reactor core of a nuclear power plant (NPP) is an important part of the Safety Analysis Report in all countries. The main neutronic, mechanic and thermo-hydraulic characteristics and properties of the core and the corresponding operational limits based on a reference core are laid down in the construction and operation licences and the technical specifications of the NPP.

1.2 Licensing of fuel design

Within the safety envelope of the core design the design of the individual fuel elements is either individually licensed or described in the Safety Analysis Report, in special Safety Reports, Safety Cases, Vendor's Topical Reports or similar documents. These documents are then assessed by the regulatory body. In Belgium, Finland, Sweden and Switzerland, new type of fuel is accepted or licensed on the basis of experimental results, demonstration projects and lead test assemblies respectively.

1.3 Modifications of core and fuel design

In all countries modifications of core and fuel design need regulatory approval for the calculation methods and for operation conditions. Full licensing procedures for modification of core lay-out and significant modification of fuel and control-rod design respectively are required in Belgium, Finland, Germany, Hungary, Italy, Japan, The Netherlands, Spain, Sweden, and in Switzerland. In France, the Safety Report is to be updated. In the USA, only major modifications are reviewed by the regulator.

In the UK, modifications of fuel, core and core design are dealt with as all other modifications and require formal procedures with involvement of the regulatory body. In Belgium, for new calculation methods and codes an audit of the designer is performed by the regulatory body.

1.4 Quality Assurance of nuclear fuel

The fabrication of nuclear fuel is covered in all countries by a quality assurance programme. These QA-programmes, in Hungary, Italy, Japan and The Netherlands based on or in close conformity to the IAEA Safety Series 50-QA documents, are within the licensee's responsibility. Also, requirements from ISO 9000 have been used, e.g. in Hungary. The regulatory bodies analyse or inspect the QA programmes and perform audits. QA-documentation is approved in Finland and Germany. The fuel fabrication itself is inspected regularly (Finland, Germany, Japan, Spain, Sweden), or only on special occasions, e.g. in following up concerns arising from particular reactor fuel incidents, (Belgium, UK), for new type of fuel (The Netherlands, Japan, Switzerland) or once per year for qualification of products, processes and documentation (France).

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of new fuel

In all countries the licensee inspects fresh fuel on delivery. This is mainly a visual inspection; the regulatory body inspects the programmes. Direct involvement of the regulatory inspectors is found in Finland, Germany, Italy and Mexico (once per delivery campaign or batch), in the USA (by the resident inspector), and in Belgium, Hungary, Spain, and UK (occasionally).

2.2 Composition of new core in the next operating cycle

The following description is based on the operation of Light Water Reactors, where fuel exchange is performed on refuelling outages leading to a new core composition.

In all countries the parameters of the new core after fuel exchange and reload are to be calculated in advance and a corresponding Safety Evaluation Report submitted to the regulatory body or the resident inspector (USA) for review. Timing requirements range from one to three months before refuelling. The regulator verifies the validity of the used computer codes (Belgium, The Netherlands, Spain, Switzerland) or conducts independent calculations by himself or by expert organisations on each reload (Germany, Japan). In the USA, independent calculations are carried out for new design fuel. In Finland, Hungary and Switzerland, control analyses of the calculation code or strategy or on special occasions are performed by independent experts in case of modifications.

In the UK, where most of the NPP have Gas Cooled Reactors with fuel reload procedures during operation, it is part of the operators absolute responsibility for the safety of operation to specify and justify the composition of the core against pre-set criteria. This justification is subject to peer review.

2.3 Inspection of nuclear fuel operation

For verification of the calculated core properties, tests and physical measurements during start-up are required in all countries. The start-up and testing programmes normally are included in the Safety Evaluation Report of the reload and reviewed by the regulator. The tests will be carried out by the licensee and verified or observed by regulatory inspectors (Italy, Mexico, Spain, USA). In other countries, the results are checked by the regulatory body (Belgium, Hungary, The Netherlands, UK), or the regulatory body or its experts directly supervise these tests as part of the Periodic Inspection Programme (Germany, Japan, Switzerland).

2.4 Operating NPP with fuel defects

In all countries specified contamination limits for the reactor coolant are laid down in the technical specifications. These limits are calculated for accident conditions and normally not intended to regulate operation with fuel defects. As a common policy, NPPs need not to be shut down as a fuel defect occurs, as long as other safety considerations are not affected or evidence of systematic failures is not obvious. In Finland, limiting conditions for operation for the reactor coolant contamination are derived from the permissible amount of untight (1%) or failed (0,1%) fuel elements. In Switzerland, a maximum allowable activity concentration of I-131 in the reactor coolant has been specified; operation with defective fuel is permitted below these limits; also, an intermediate shut-down must be considered in cases, where an increase of Np-239 reactor coolant activity indicates fuel failures with significant Uranium wash-out. On the other hand, in most countries leaking or mechanical damaged fuel must not be reloaded. In France, fuel elements may be reloaded, if the equivalent leak diameter is less than 35 µm.

In the UK, Gas Cooled Reactors are allowed to return to power with known failed fuel present in the core provided that the release is within specified limits. Regulatory inspection on this is within the routine work by the site inspector.

2.5 Fuel inspection after unloading the core

Sipping tests are conducted regularly, if the contamination of the reactor coolant or pre-sipping measurements during unloading give suspect for fuel defects. Regulatory prescribed limits for the reactor coolant contamination to mandate a full core sipping test are given in Japan (based on Iodine isotopes).

In most countries, the regulatory body reviews any fuel inspection programmes and current results, difficulties or problems and may prescribe additional tests if necessary. In some countries, an extensive fuel inspection programme (including e.g., visual inspections, oxide layer measurements, eddy current tests of control rods), is carried out regularly and supervised by the regulatory body or its experts as part of the Periodic Inspection Programme (Germany, Japan).

Repair or refurbishment of fuel elements, depending on the facilities available, is reviewed and approved by the regulatory body in most countries. In the UK, some selected Gas Cooled Reactor fuel is subjected to extensive in-cave Post Irradiation Examination in line with an agreed programme.

2.6 Fuel handling

In all countries fuel handling by the licensee follows written operational procedures. These fuel handling procedures are inspected by the regulatory body as are all other relevant operational procedures. Important modifications need regulatory approval, e.g. in Hungary.

The handling itself including storage of new fuel is spot-checked or observed occasionally by the regulatory body or the resident inspector. Problems during unloading or loading the fuel (e.g., tractive force measurements) are to be discussed with the regulator’s expert for additional inspection needs (Belgium, Germany, Hungary). Functional tests of the fuel handling machine or of other handling equipment are required, in some countries as part of the Periodic Inspection Programme (Germany, Italy, Japan). In some countries, inspection of shipment of spent fuel is conducted by the regulatory body or its experts (Belgium (spot-checks), Germany, Italy, UK).

Note: Nuclear safeguards inspections by IAEA or EURATOM are not covered within this report.

2.7 Policy of evaluations of inspection findings

Safety related inspection findings are considered reportable events in most countries. Core anomalies and fuel defects or anomalies related to fuel manipulations have to be reported to the regulatory body in Belgium, Finland, Hungary, Italy and Spain. In Finland, Germany and Japan, massive fuel defects, systematic failures of fuel bundles or mechanical damage of the fuel skeleton and spacer grids are to be reported and evaluated for corrective actions. It is common to all regulatory inspection authorities to require root cause analyses and appropriate corrective actions depending on the safety significance of inspection findings.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

The following questions relate to the operation of Light Water Reactors, where fuel exchange is performed on refuelling outages leading to a new core composition.

3.1 Is the reloading plan /core composition approved or endorsed by the inspection authority on each refuelling outage?

Yes, in Belgium, Finland, Germany, Hungary, Italy, Japan, The Netherlands, Sweden, Switzerland. Independent calculations by the regulatory body are carried out in Germany and Japan using computer codes different from those used by the licensee.

In the UK, the regulatory body does not specifically approve or endorse the reloading plan.

3.2 What happens, if the reloading plan must be changed during refuelling outage due to defect fuel elements foreseen for reloading?

Any proposed changes to the reloading plan must be discussed with the regulatory body in Belgium, Finland, Germany, Hungary, Italy, Japan, The Netherlands and Switzerland for full or partial recalculation.

APPENDIX 1

QUESTIONNAIRE

Regulatory Inspection Philosophy and Inspection Practices on Fuel Elements and Core Lay-out at Nuclear Power Plant Operation

Please describe your country's inspection programme according to the following structure. Sub-topics are given as suggestions for the contents of the different sub-chapters and may be used as applicable. Other relevant topics and information should be included, as appropriate.

1. Licensing and Quality Assurance requirements for nuclear fuel

1.1. Licensing of core design

- safety analysis report
- specifications of safety margins
- operation limits

1.2. Licensing of fuel design

- specifications, quality of material

1.3. Modifications of core and fuel design requiring licensing

- licensing procedures for modifications

1.4. Quality Assurance of nuclear fuel

- licensee's QA programme
- manufacturer's QA programme
- regulatory inspection on fuel fabrication

2. Regulatory inspection programme during NPP operation and refuelling outage

2.1. Pre-inspection of each delivery batch of new fuel

2.2. Composition of new core after fuel exchange and reloading

- safety related values and margins
- required calculations by the operator

- independent calculations by the inspector or the inspection authority
- use of computer codes

2.3. Inspection of nuclear fuel operation

- fuel operation parameters
- verification of calculated core properties during start-up, required testings and measurements
- periodic testings
- inspection on these testings and measurements
- verification of results
- obtaining reference data

2.4. Operating NPP with fuel defects

- contamination limits for reactor coolant
- policy and requirements for continued operation or shut-down
- radiological limits

2.5. Fuel inspection after unloading the core

- visual inspections
- tests for fuel defects
- inspection of spacer grids
- measurements of oxide layer of zircaloy tubes
- requirements for storing defect fuel rods on site
- inspection of repair of defect fuel elements

2.6. Fuel handling

- inspection of storage of new fuel
- loading and unloading the core
- wet storage
- inspection of spent fuel shipment

2.7. Policy of evaluations of inspection findings

- abnormal occurrences, reportable events
- follow up of corrective actions

3. Procedures for inspection practices and inspection programme

3.1. Is the reloading plan /core composition approved/endorsed by the inspection authority?

3.2. What happens, if the reloading plan must be changed during refuelling outage due to defect fuel elements foreseen for reloading?

3.3. Other procedures

Note: If possible, give man-hours for inspectors, use of computer codes, formal procedures for each step, number of people involved for inspections

APPENDIX 2

The following contributions are presented in this appendix:

Belgium
Finland
France
Germany
Hungary
Italy
Japan
Mexico
The Netherlands
Spain
Sweden
Switzerland
United Kingdom
United States

Contribution from:

J. J. Van Binnebeek, AVN-AIB, Belgium

1. LICENSING AND QA REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

The Safety Evaluation Report (SAR) of the plant provides historically the characteristics of the first three reloads (including so-called equilibrium cycle), with primary and secondary criteria, calculation methods, as well as operation limits. It covers the mechanical, neutronic and thermal-hydraulic aspects.

As the licensees introduced new fuel types and new operation strategies (low leakage, long stretch-outs (up to three months), extended operation at reduced power, extended cycles (up to 18 months), power up-rating, MOX Fuel, … the SAR has been revisited to include only general criteria and methodological approaches.

The details on secondary criteria and calculation methodologies are in specific documents for each reload designer.

A specific procedure of the Licensed Inspection Organisation (LIO), which is referred to in the licences, describes the information to be supplied to the Regulatory Body for approval of core reload, new fuel, new operating conditions, new calculation methods and codes.

1.2 Licensing of fuel design

New fuel design is licensed on the basis of geometrical, mechanical, neutronic & thermal-hydraulic criteria.

For each new fuel, a compatibility document is prepared. This document shows that the new fuel does not violate any criterion (geometrical, mechanical, neutronic and thermal-hydraulic), neither for a full new fuel core as well as for transition reloads.

To demonstrate the thermal-hydraulic compatibility of a new fuel design, statistical methods are used by most of the designers. Specific penalties related to some non rigorous aspects of the approaches, additional verifications when statistical combinations of the uncertainty on the DNB correlation is used, and generic margins to guarantee defence in depth are imposed by the LIO.

All these elements and more particularly the "Belgian Licensing Requirements for mixed cores" have been presented during the "CSNI/PWG1 Specialists' Meeting on Nuclear Fuel and Control Rods: Operating Experience, Design Evolution and Safety Aspects", Madrid, November 1996.

Special attention is devoted to the assembly design (stresses, fatigue, vertical load,…) and to the rod design (pressure, maximal heat flux, power capacity, transient behaviour,…). A fuel rod thermal-mechanical design report is submitted for approval to the LIO: it must demonstrate the adequate behaviour of the fuel rod in normal operation and during class II transient conditions.

When new materials are introduced in the fuel assemblies (Zirlo, M5, MOX, gadolinium,…), experimental feedback results are required for the licensing.

1.3 Modification of core and fuel design requiring licensing

Specific information concerning fuel design, core calculation methodology and codes, or core operation conditions is to be submitted to the Regulatory Body for approval:

- Six months before the planned date of the beginning of the core loading, for the modifications related to the fuel design, or core calculation methodology and codes;

- Before the implementation of the modifications related to new operating conditions. For new calculation methods or codes, an audit of the designers is performed by the LIO.

1.4 QA of nuclear fuel

The licensee's QA programme must cover the fuel fabrication. Usually the manufacturer's QA programme is audited by the licensee's QA, and a systematic follow-up of the fabrication process is performed by the licensee.

The Regulatory Body restricts itself to inspections of the licensee's QA programme. At some occasions (fuel fabrication potential problems), the Regulatory Body may perform independent audit at the manufacturer's workshop.

2. REGULATORY INSPECTIONS PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGE

2.1 Pre-inspection of each delivery batch of new fuel

The licensee performs a systematic visual inspection of the fuel batches at their arrival on site (including shock detection during transportation).

The Regulatory Body verify the licensee's programme and spots check some inspections.

2.2 Composition of new core after fuel exchange and reloading

The safety related values and criteria are given in the FSAR or in the reference documents for reload calculation and compatibility analysis of the specific fuel.

A Core Safety Evaluation Report (CSAR) - preliminary version - dealing with the whole cycle length must be submitted to the Regulatory Body for approval one month before the beginning of the core loading.

- If a Stretch-out is foreseen, it shall be covered by this evaluation. If the Licensee has not yet decided on a potential stretch-out,

  - either, the study shall cover a conservative stretch-out period, enveloping any actual stretch-out period

  - or, a complementary study covering the real cycle stretch-out shall be transmitted to the Regulatory Body one month before the end of the period covered by a Core Safety Evaluation Report.

- In case of serious technical problems, the different technical options will be discussed between the Licensee and the Regulatory Body. The required delays might then be modified by common agreement.

No independent calculation is normally made by the Regulatory Body (no code used), as it is felt that a very detailed knowledge of the core history is needed to perform meaningful calculations.

2.3 Inspection of nuclear fuel operation

2.3.1 Start-up tests

One month before the beginning of the core loading, the programme of the start-up tests is submitted to the Regulatory Body for approval.

That programme is supposed to verify that there is a good coherence between core calculation and actual core properties.

It is a standard programme, possibly augmented or modified in special conditions (replacement of control rods, introduction of MOX fuel, use of gadolinium).

The performance of the tests are spot-checked by the LIO experts. The results must satisfy acceptance criteria before power increase is authorised by the LIO.

2.3.2 Periodic tests

A standard periodic test programme is included in the technical specifications, verifying a.o. flux maps, hot channel factors, moderator temperature coefficient, and foreseeing specific test according to the actual core features.

These tests are inspected in the same way as other periodic tests (spot-check attendance by the Regulatory Body). However all the flux maps are received by the Regulatory Body for evaluation, comments and approval.

2.4 Operating NPP with fuel defects

The contamination of the reactor coolant is limited by the radiological consequences of the accidents or by ALARA considerations (see SAR). The limits are incorporated in the technical specifications.

Normally the policy and requirements for continued operations are governed by the technical specifications. However some additional constraints may results of specific situations (e.g. the quality of the steam generators). Leaking fuel elements are not reloaded.

2.5 Fuel inspection after unloading the core

Most of the time the unloaded fuel assembly are sipping tested in the refuelling machine mast itself. If a leak is detected, additional measurements are performed off-line.

Defected fuel assemblies are completely inspected by utility and manufacturer. The manufacturer participates also to more systematic fuel assembly inspections (including inspection of spacer grids, potentially, but not systematically, measurement of oxide layers). The Regulatory Body is informed of the results of these inspections.

The defective fuel elements are recorded and stored in the wet pool. No specific conditions are required.

When economically suitable the utility requested to repair defective fuel elements. In that case, the repair process and procedures are reviewed and approved by the Regulatory Body, who also controls the correct character of the operations.

2.6 Fuel handling

The inspection of the new fuel is performed by the licensee; the Regulatory Body participates on a spot-check basis.

The procedures for core loading and unloading are developed by the licensee. They are inspected by the Regulatory Body who spot-checked its correct implementation. If problems during unloading or loading of fuel elements are encountered, they have to be discussed with the Regulatory Body inspectors.

The Regulatory Body verifies that the wet storage is kept adequate, especially that no activities are threatening the fuel integrity (heavy loads manipulations,…).

The licensee’s procedure for spent fuel shipment are inspected by the Regulatory Body, who spot-checked some shipments.

2.7 Policy of evaluation of inspection findings

During the ongoing irradiation cycle, flux maps results are analysed by the Regulatory Body, and any core anomalies or fuel leakage is reported to the inspector.

Three months after the beginning of the new irradiation cycle, the Regulatory Body holds a meeting with the utility, the architect-engineer and possibly the fuel manufacturer/ core designer. During the meeting the following aspects are covered:

a) The final version of the Safety Evaluation Report provided it differs from the preliminary version submitted before connection to the grid.

b) The final report of the physical start-up tests.

c) The follow-up report of the previous cycle.

d) The operating experience of the previous cycle for which the Licensed Organisation has received all the data.

e) A comparison between the values measured during the start-up of the cycle and the values calculated during the safety evaluation.

f) The conclusions to be drawn for the subsequent behaviour of the fuel and for the validity of the safety evaluations.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Is the reloading plan/core composition approved/endorsed by the Regulatory Body?

The reloading plan/core composition is approved by the Regulatory Body on basis of the safety reports issued for the cycle. No independent computer code calculations are performed.

The Regulatory Body issues a formal approval before going to nominal power (after the start-up tests and the flux map at 85% power).

Before operating above 85% of the nominal power, The licensee submits to the Regulatory Body for approval the preliminary results of the physical start-up tests and of the flux and temperature measurements performed at the various intermediate power levels, including the interpretation of these tests and measurements, as well as an analysis of the conformity of the results with respect to the safety limits and acceptance criteria mentioned in the test procedures.

3.2 What happens if the reloading plan must be changed during refuelling outage due to defective fuel elements foreseen for reloading?

When the reloading plan has to be modified during the refuelling outage due to unforeseen problems, the core modifications have to be notified within 72 hours following their implementation and their implications have to be discussed between the Licensee and the Licensed Inspection Organisation before the vessel head closure.

3.3 Other procedures

NA

4. RESOURCES

Reloads activities required about 400 man-Hr per reactor and per irradiation cycle, taking into account the numerous requests by the licensee for new methods, new fuel or changes in operating conditions.

Contribution from:

Pekka Liuhto, STUK, Finland

1. LICENSING AND QUALITY ASSURANCE REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

Safety analysis report of the core and fuel designer is submitted to STUK for approval.

Utility calculations for safety margins and operation limits will be checked. Own independent calculations will be also made if necessary.

1.2 Licensing of fuel (or control rod) design

STUK's Acceptance of fuel occurs always by delivery batches.

Licensing procedure will occur take three steps:

Step 1 (initial core, new type or manufacturer of fuel)

In case of new type of fuel or major changes to previous one lead test assemblies will be used. Pre-inspection documentation is submitted to STUK for approval 1 year before manufacturing is commenced. including:

- manufacturers QA-programme and QA-manual (for information)
- design criteria
- experimental studies and analyses of fuel behaviour
- operating experience

Step 2 (old type of fuel)

All other pre-inspection documents shall be complemented not later than 3 months before manufacturing is commenced, including:

- item list
- specifications
- drawings
- QC-programme
- description of manufacturing

Step 3

Before manufacturing is commenced:

- documents above (Step 1 and 2) shall be approved by STUK
- implementation of manufacturer's (and designer's) QA is reviewed by STUK (usually a separate QA-audit)
- fabrication and QC-methods are reviewed by STUK

1.3 Modifications of core and fuel design requiring licensing

All modifications require licensing. For major modifications (e.g. new type of fuel) the utility shall submit documents to STUK for acceptance according to Steps 1,2 and 3 above. For minor modifications (old type of fuel) documents according Step 1 above are not needed and the utility shall submit documents to STUK for acceptance according Step 2 above. In that case all new fabrication and QC-methods (Step 3) will be reviewed by STUK during manufacturing inspection.

Pre-inspection documentation for the next fuel delivery batch shall be approved by STUK even if there are no changes compered to previous delivery batch. All changes of the pre-inspection documentation shall approved by STUK. If there are no changes at all part list and common drawings is enough to submit to STUK for approval.

1.4 Quality assurance of nuclear fuel

Licensee’s QA programme is submitted to STUK for approval. STUK’s QA audits are mostly carried out annually. Manufacturer’s QA programme is submitted to STUK for information. STUK’s QA audit is done before manufacturing starts and afterwards during manufacturing inspection (QC-inspection). STUK’s inspection on fuel fabrication (QC inspection) will be carried out for each delivery batch (approx. 3-6 inspections 2 days each during manufacturing of the batch).

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Inspection of each delivery batch of fresh fuel

2.1.1 Receiving inspection

Inspection programme shall be submitted to STUK for approval. Inspection is carried out by utility.
At least the following items are to be inspected:

- the documentation for the consignment, and the transport protocol
- the transport package which shall be inspected visually
- visual and dimensional inspections for fuel

A summary report of the results of the receiving inspection results shall be delivered to STUK for information (usually in connection with the application for operation of the delivery batch). STUK oversees the receiving inspections at its discretion.

2.1.2 Application for operation

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. 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

2.2 Composition of new core after fuel exchange and reloading

2.1.1 Core loading application

Core loading application shall be submitted to STUK for approval 2 weeks before start of loading shutdown. It shall include:

- loading plan
- all inspections/work concerning fuel and control rods
- detailed plan for works concerning reactor core

STUK's approval of the loading application is a prerequisite for the opening of the reactor pressure vessel lid and the loading operation.

2.2.2 Behaviour of the reactor and fuel

The documentation for the behaviour of the reactor and fuel during the next operating period shall be submitted to STUK for approval at least one week before closing of the reactor pressure vessel lid. It shall include:

for previous period:
- fulfilling of the maximum linear heat rating for fuel rods
- fulfilling of the maximum burnup for fuel rods or bundles

for next period:
- amount of the different fuel bundle types in the core
- estimated maximum power history for rods and bundles
- axial and radial power distribution for bundles
- thermal margins and shut down margins
- burnup for rods and bundles
- thermo-mechanical analysis for fuel
- operating experience of fuel

2.3 Inspection of nuclear fuel operation

Fuel operation parameters will be followed by STUK at start up and during operation.

2.4 Operating NPP with fuel defects

The limiting conditions for operation permit activity levels of the primary coolant below specified limits which are derived from the permissible amount of untight (1%) and failed (0,1 %) fuel elements.

In the primary coolant of PWRs (VVER-440) the maximum allowed concentrations are for noble gases 4 x 10 EXP 8 Bq/kg, iodines 1x 10 EXP 8 Bq/kg and total gamma-activity 7x10 EXP 8 Bq/kg.

In BWRs the highest allowed specific activity of iodines in reactor water is 2,2 x 10 EXP 6 Bq/kg in 131-I equivalents.

If those limits will be exceeded shut-down should follow if the values are not returned to the specified ones during a given period of time.

2.5 Fuel inspection after unloading the core

Visual inspections are carried out according to utility annual programme.
Reasons causing defects on fuel must be investigated.
For new structural materials a follow-up program will be issued.
Heavily defected rods will be stored in separate vessels.
Fuel repairs shall be carried out according to a written plan. STUK's approval of the plan shall be obtained in advance. All repaired bundles (if they included defective rods) shall be sipped before loading back into core.

1. TVO inspects annually 4 to 5 bundles, including:
   - visual inspection of the bundles and channels
   - sipping if leaking fuel
   - separate programme for leaking bundles

2. IVO makes special pool-side inspections for leakers and also for bundles with changed design. No annual visual inspections for Loviisa fuel because of compact design of the bundle (To inspect the rods the channel shall be removed. And if the channel is removed reload of the bundle into the core is not acceptable.)

2.6 Fuel handling and storage

STUK controls the handling and storage of fuel at the NPP. This control contains:

- a review of the plans for and analyses of the handling and storage systems
- a review of the pre-inspection documentation for components and structures
- supervision of the components and structures manufacturing and performance of structural and commissioning inspections
- witnessing of the start-up tests of the handling and storage systems
- a review of the handling and storage instructions
- inspections of the handling and storage systems and their use at discretion and as part of the periodic inspection programme of nuclear power plants.

2.7 Policy of evaluations of inspection findings

Inspection and examination reports shall be submitted to STUK not later than four months from the accomplishment of each examination. However, the STUK must be informed without delay about any exceptional observations. Follow-up of possible comments occurs by date or during next inspection.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 The reloading plan including fuel inspection plans is approved by authority.

3.2 Utility will send to STUK a revised documentation for the behaviour of the reactor and fuel (item 2.2.2) for approval

Contribution from:

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1. GENERAL

1.1 Supervision (reminder)

The French regulatory authorities mainly check that the utilities fully entrust their responsibility of plant operation, as far as safety (and security) are concerned. Therefore, their supervision is an external one, and does not interfere with the implementation of plant activities. Such supervision mainly consists in carrying out safety assessments of the plant at certain statutory commissioning stages (and associated regulatory inspections), as well as other inspections during plant life

Fuel inspection is a very important matter, since it deals with the first barrier in the defence in depth concept for PWRs, and represents bout 25 inspections, among the overall number of inspections carried out in France (in power reactors, fuel manufacturing plants and other facilities), which amounts roughly to 700 per year.

1.2 The role of DRIRE-Rhône-Alpes

The DRIRE-Rhone Alpes, located in Lyon, has a specific role in the field of fuel inspection. This role is due to its geographical position, most of the fuel manufacturing plants being located in this area, and, besides, most of EDF and Framatome central services dealing with fuel being located in Lyon. Fuel inspections are carried out by two inspectors spending 1/3 of their time on this topic.

They cover fuel design, manufacturing and in reactor operation. They perform 15 to 20 inspections per year. Besides, other inspections are carried out by inspectors belonging to other DRIREs. The corresponding reports are sent to these dedicated two inspectors, which produce a summary report each year, with a proposal of follow up letter, to be formally sent by the Director of DSIN. These two inspectors also propose to DSIN a yearly inspection program on fuel.

1.3 General documentation

1.3.1 Fuel licensing for power reactors

For a NPP reactor, fuel licensing starts at the very beginning of the facility life, at the stage of the so called “authorisation decree” which authorises the EDF plant operator to create a NPP. This decree prescribes, for PWRs, the following;

- the type of fissile material (U,Pu),
- the close monitoring of primary water radioactivity in order to detect possible fuel rod leakages,
- conservative margins for fuel integrity in all situations (normal, accidental),
- type of cladding material, primary water composition required to prevent corrosion,
- influence of mechanical phenomena, such as vibrations, requirements for fuel handling to avoid criticality and overheating.

1.3.2 Basic Safety Rules

In addition to these general prescriptions, more specific licensing guidelines can be found in the Basic Safety Rule RFS No. V.2.e, applicable to fuel elements. Its main requirements are

- to apply the Design and Construction Rules (RCC-C:), for design and manufacturing of the fuel elements,
- to inform the DSIN about deviations from these codes and associated corrective actions

1.3.3 PWR Safety report (for each PWR type)

It gives a detailed description of both fuel and core design, together with:

- the basis for design and analyses
- the core mechanical design
- the description of the fuel and control rods (and RCC-As, Rod Cluster Control Assemblies)
- the system of reactivity control
- the neutronic design
- the thermohydraulic design

Whenever a new kind of fuel element is to be loaded, or a new fuel management type is envisaged, the EDF central services send to DSIN the corresponding updated reports.

1.3.4 Test files

For each type of reactor and each type of fuel management (including MOX fuel), EDF central services issue a general procedure for physical tests to be performed when restarting the reactor (verification of calculated core parameters), to be approved by DSIN; it is called DGE.

1.3.5 Specific documents for reloadings, after refuelling shutdowns

For each reload, EDF must send to DSIN the two following documents:

- The safety analysis of the reload (DSS)
- The test specific package (DSE), which gives the calculated core parameters for the physical tests, and which is based on the DGE procedure.

DSIN does not formally approve these documents but can make any comments or ask questions if necessary.

Furthermore, EDF presents a report on manufacturing non-conformance’s of the reload.

2. REGULATORY INSPECTIONS FOR THE FIRST REACTOR CRITICALITY

After being constructed, any PWR may go into operation if fully authorised by DSIN, through three different steps. Basically, one inspection is required for each of these steps: before initial fuel delivery, before first loading, and before criticality.

During life time of the reactor, each reactor restart after refuelling shutdown is subject to authorisation for criticality, mostly based on compliance of maintenance works with regulations; there is always one outage inspection devoted to that subject, performed by DRIRE inspectors, but no systematic inspection for each fuel reloading (see para. 3).

2.1 In fuel building inspections before the first fuel delivery

2.1 Supervision of acceptance, handling and storage of fuel elements

The inspectors mainly check or review

- type of storage (wet or dry)
- works in the fuel building, and their influence on safety
- examination of fuel delivery planning
- criteria of acceptance and of storage of fuel elements
- access of personnel to fuel building
- procedures and instructions for equipments used for acceptance, handling and storing:
  - pool integrity and cooling system
  - monitoring of pool parameters (water level, boron concentration, temperature, cleanliness)
  - ventilation (cleanliness of ventilation ducts, iodine filters)
  - radiological measurements
  - fire detection and protection

- Results of quality controls performed in the manufacturing plant, list of non-conformance’s. Are these non-conformance’s known by the EDF plant management ?
- What are their consequences for reactor control ?
- Training of personnel
- Communication equipments between fuel building, reactor building and control room

2.1.2 Main issues

The inspectors ensure that:

- the conditions of access in the fuel building are adequate; are they known and applied by the security guards ? Are there suitable doors, cameras, radars, telephones ?
- the buildings and rooms are clean (especially those involved in handling and storage)
- the fuel examination device is in good condition and properly qualified
- the surface appearance of the pool is correct (clean, no leak)
- the wall or floor openings are correctly closed
- siphon breakers are installed so as to avoid risks of pool emptying
- incoming pipes of non boricated water are blocked

- wet cells for storage are clean and locked
- fire detectors are installed and tested, fire instructions in place
- anti seismic cylinders are installed
- it is possible to shift from normal ventilation to special ventilation with iodine filters

2.2 In reactor building inspections before first loading

2.2.1 General appearance of the different rooms

- general appearance of reactor building: floors cleanliness, pool cleanliness, reactor penetrations appearance (instrumentation, pipings, electrical, ..), containment sumps;
- fire detection and protection, results of tests.

2.2.2 Operability of equipments

- operability of fuel handling system, results of qualification tests
- blocking of all non boricated water incoming pipes
- examination of certain equipments (safety valves for example)
- examination of the boronmeter calibration
- examination of modifications to be completed before loading, and their qualification
- operability and calibration of source range channels

2.2.3 Quality and operability of documents

- sampling review of reactor operation instructions, taking into account the load specificity's (from the DSS report)
- sampling review of instructions and alarm sheets which are necessary from the very beginning of the loading (incidental water dilution, etc.)
- examination of personnel accreditation

2.2.4 Examination of personnel training

By questioning the control room operators and operators dealing with the handling system.

2.2.5 Examination of the different access controls

2.3 Inspections before first criticality

The general program of such an inspection is very similar to the previous ones.

2.3.1 General appearance of rooms and equipments

- reactor building . see 2.3.1
- nuclear auxiliary building
- electrical rooms
- fire detection and prevention
- operability of radiological measurement channels

2.3.2 Operability of equipments (tests results)

- operability of equipments which are required by the technical specifications during criticality
- operability of equipments necessary for physical tests (ex: control rod worth, reactimeter, sensitivity of neutron flux range channels.)
- examination of the indication of the control rod level and of boronmeter calibration
- examination of modifications to be performed before criticality
- examination of alarms and alarm sheets in the control room
- examination of blocked circuits
- examination of the operability of iodine filters and corresponding ventilation
- results for pressure measurements in the reactor building.

2.3.3 Documents quality

- instruction and alarm sheets
- blocking certificates
- accreditation of personnel

3. INSPECTIONS DURING REFUELLING

As said previously, this type of inspection is not carried out for each refuelling, but at a frequency of one every 2 or 3 years for each PWR site. It is either a routine one, or oriented towards:

- new equipments such as new fuel handling machines for the 900 MWe or assisted loading devices for the 1300 MWe,
- new procedures such as rapid loadings
- new kind of fuel such as MOX (mixed oxide) which requires special procedures for radiological protection,

A special inspection guide was written for this kind of inspection. The following points are examined:

3.1 Preparation of unloading/reloading

Before these operations, the different systems are checked by the operators, some of them with a dummy assembly. The inspector's questions deal with:

- modification of the different equipments, handling machines, sipping test equipment, and associated quality control (quality plans, procedures, non-conformance's)
- new operations which can be performed with these machines and their qualification, training and accreditation of operators.

3.2 Review of unloading operations

- review of procedures: sequence of assembly unloading, neutron counting in source range channels, comments from the operators;
- review of any difficulty and/or problem: twisted assemblies, broken grids,...
- check results of mast qualitative sipping tests, which are performed when the primary circuit fluid is not clean (>185 MBq/ton): calibration procedures and sipping results.

- check results of complementary quantitative sipping tests: these are performed on fuel elements which have been identified as leaking elements during the mast sipping test.

When the equivalent diameter of the defect is less than 35 microns, the element may be reloaded. If the defect is larger, the element will be stored in the spent fuel pool for possible future repair.

When the skeleton is damaged (torn grids for example), it can be replaced, this operation is called "refurbishment".

3.3 Examination of reloading operations

The most appropriate time for fuel inspections is during reloading operations.

The inspectors review:

- delivery files: compliance certificates of new elements and eventually new RCCAs;
- reload safety analysis reports (DSS) and any specific or temporary reactor operating instruction;
- reloading lay out and particular attention to prevent errors (the inspector can have a look on videos which are taken at the end of refuelling);
- list of all applicable documents: these are to be stored near the chief fuel handling operator;
- examination of some particular points such as: source range channels and their associated alarms, indications of boronmeter, radioprotection channels and associated alarms;
- two important procedures are systematically reviewed and the operators are questioned on them:

  - IPMC-1: it deals with accidental damage to fuel element
  - IPMC-3: it deals with sudden decrease of water level in the pools

Sometimes, inspectors interview the control room operators to check the safety devices related to on-going operations (ventilation system for example).

4. OTHER KINDS OF REGULATORY FUEL RELATED INSPECTIONS

4.1 On PWR site

In addition to inspections described in §3, at least two kinds of inspections can be carried out:

4.1.1 Repair or examination of fuel elements

EDF periodically sends to DSIN the list of elements to be inspected, repaired or "refurbished", on the different PWR sites Whenever new kinds of operations, equipments, or assemblies are encountered, a regulatory inspection is to be scheduled.

The following topics are examined during these inspections:

- Quality of operations: programs (ultrasonic, eddy current inspections, visual inspections, oxide layer inspection...); qualification in air and in water of equipments; non conformance analysis.
- Safety aspects ; safety report for these operations which take place in the fuel building, and pool.
- Any special or temporary reactor operating instructions.

These operations are performed by the fuel supplier who makes his own safety analysis. Besides, the EDF site management has to make his overall own safety analysis, including "environmental" matters and Q/C of supplier operations.

4.1.2 Physical tests (neutronics)

When a new DGE (see § 1.3.5) is in application (new kind of fuel, new fuel management...) regulatory inspections are to he scheduled in order to supervise the DSE plant application of this DGE and the quality control of the operations.

The following points are specially examined:

- operators training and understanding of the operations documentation conditions for each test phase (power, reactivity, RCCAs level, boron concentration, reactor stability...)
- calibration of special equipments, particularly the reactimeter
- ongoing tests results and interpretation, in connection with central services, comparison with DSE predictions

The best time for carrying out these inspections is at beginning of physical tests and checking the interfaces between different teams (physical tests technicians, control room operators, chemical analysis specialists) is an important issue.

4.2 Inspections at EDF central services

The EDF central services dealing with fuel are:

D.A.C.: Délégation Aux Combustibles (fuel service), in charge of contracts for all kinds of fuels (nuclear and non nuclear) and RCCAs, and of the accreditation of suppliers.

G.C.N.: Groupe Combustible Nucléaire (nuclear fuel group), in charge of fuel management core computings and fuel handling machines development.

S.Q.R.: Service Qualité des Réalisations (manufacturing quality control), with a group in charge of fuel assembly and RCCAs manufacturing.

Each of these services is inspected every 3 years or so.

4.3 Inspections on fuel design and manufacturing

The main supplier is Framatome, but there are three others for EDF PWRs. EDF has recently widely diversified its procurements: ANF, ENUSA and ABB elements are now loaded in EDF reactors.

This diversification leads to a large variety of regulatory inspections. These are carried out at the supplier engineering department (fuel design) and in manufacturing plants. Moreover, the sub-contractors, for example the cladding or nozzle manufacturers, and even sub-sub contractors (TREX manufacturers for example) are also inspected. These inspections are systematic for new important components. For the main plants supplying EDF, one inspection per year is scheduled, because there are constant improvements in the manufacturing process and evolution of designs.

The main documentation for these inspections is the RCC-C, with its associated requirements to be fulfilled.

The main questions examined during these fuel design inspections are:

- data base quality
- computer codes quality
- in reactor experience feed back
- documentation

The main questions raised during an inspection dealing with fuel manufacturing are:

- qualification of products (pellets, claddings, rods, assemblies, RCCAs...)
- qualification of special processes. pressing, sintering, grinding of pellets, plugs weldings, automatic control processes such as image recognition or gammascanning.
- qualification of operators and sub-contractors
- quality organisation, quality assurance, recording capacity
- non-conformance's, analyses and reports
- procurements
- review of end of manufacturing reports

Contribution from:

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ABSTRACT

In Germany, inspection and supervision of nuclear power plants (NPP) is a duty of the governments of the different states called „Länder“. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit - BMU) issues general regulations and may give directives to the regulatory authorities. The different regulatory authorities of the Länder supervise the NPP operators in accordance with the German Atomic Energy Act. They use the German regulatory framework as a uniform basis for licensing and inspection activities. This regulatory framework contains, e.g. the guidelines for pressurised water reactors of the Reactor Safety Commission (Reaktor-Sicherheitskommission - RSK) and the regulations of the Nuclear Safety Standards Committee (Kerntechnischer Ausschuß - KTA). BMU is supervising the licensing and inspection activities of the Länder to be in consistency with the regulatory framework.

All regulatory authorities involve independent experts or expert organisations for technical support and assessment. In the following, TÜV stands for the competent Technical Inspection Agency (Technischer Überwachungsverein). In special cases, other expert organisations are contracted with inspection tasks.

The following summary describes the basic procedures common to the individual Länder. Inspection details are given on the basis of a NPP with PWR.

1. LICENSING AND QUALITY ASSURANCE REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

For a NPP reactor, licensing of the core design includes the determination of the safety-related core characteristics, which is an essential part of the safety analysis report (SAR). Corresponding to the rule KTA 3101.2, the core characteristics contain parameters as reactor power, power density distribution, departure from nucleate boiling, effectiveness of control rods, reactor shut-down system effectiveness, poison injection system effectiveness and reactivity, shutdown reactivity, average burnup, local burnup distribution, reactivity coefficients of coolant temperature, coolant density (void effect), fuel temperature (Doppler effect) and concentration of neutron poisons as well as the neutron lifetime. Normally the operational licence covers the first core, containing the main parameter limits for fuel assemblies, e.g. the maximum fuel enrichment, the maximum number of MOX assemblies, the maximum of the core fission product inventory as well as the maximum of thermal power generation.

All later core loadings satisfying those conditions are considered to be equivalent to the first core (with respect to safe operation and handling of incident and accident situations). Therefore, they do not need further licensing.

1.2 Licensing of fuel design

The German Atomic Energy Act does not require special licence for the different types of fuel assemblies. Because of broad spread variations of fuel assembly design and construction details, type testing is not common for fuel design. Instead of a fuel design licence, the fuel design parameters are considered for the determination of the core characteristics in detail. Therefore, the NPP design basis analysis and respective the NPP operational licence is essentially based on the fuel design parameters. Main safety-related parameters of the fuel design are:

- type and enrichment of fissile material (Pu, U)
- central temperature and inner pressure of fuel rod
- limiting values for oxide layer thickness and cladding hydration
- tension in cladding, fuel structure and control rod guiding tube.

Fuel assemblies for recharging have to suit a general description specifying

- type of material of spacer grids, guiding tubes, and fuel cladding
- general design of fuel rods and fuel pellets.

Considering all inserted fuel assemblies, these parameters have to be by TÜV before the authority approves the reactor start-up.

1.3 Modifications of core- and fuel design requiring licensing

According to the German Atomic Energy Act, essential modifications of the core- or fuel design require licensing. Modifications are classified to be essential when they imply more than a negligible impact on the safety level of the facility. The above-mentioned criteria for core and fuel design represent the frame of safe operation. A modification is considered to be essential when it leads to values exceeding the safety margins.

In this case, the licensee submits a detailed description of the planned modification including a safety analysis report particularly analysing whether the modification will influence the plant safety functions. TÜV comments this material particularly regarding the questions, whether the modified design still satisfies the corresponding regulations and whether the modified design still allows safe operation and controlling of incident and accident situations. For quantitative analyses, TÜV normally use different calculational programs than the applicant. The regulatory authority evaluates expert’s statement and formally approves or rejects the modification.

If the modification is not considered essential, the licensee informs the regulatory authority and competent expert. TÜV checks the criteria for classifying the modification as non-essential in order to ensure the correct handling. Evaluating expert’s statement, the authority decides about the approval to the modification.

Normally, a licensing procedure will be started if the proposed fuel enrichment, the number of MOX assemblies or burn-up as well as the maximum of thermal power generation is higher than the maximum values provided by the present NPP operating licence.

1.4 Quality assurance of nuclear fuel

During fabrication, the compliance of the fuel design parameters has to be strictly surveyed by the manufacturer using an appropriate quality assurance (QA-) program. The NPP licensee who intends to insert the fuel assemblies and TÜV become early involved in this program.

In a first step, the specifications and drawings, describing the fuel layout of a reload in detail, are checked by TÜV, whether the design characteristics of the licence as well as the parameters coming out from design analysis are met.

The quality assurance program for nuclear fuel production is mainly based on inspections on the product certifying the requirements of specification and drawings. The results of the inspections are documented in QA-certification. If the fuel manufacture is new on the marked or the fuel design has been changed significantly, TÜV inspection activities will become intensified.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of new fuel

The documentation has to be checked by TÜV in detail for each fuel assembly that enters the NPP. Before the new fuel assemblies are stored into the dry fuel storage facility, inspections of new fuel assemblies are carried out by the licensee and consist of checking manufacturing and transport documentation, transport cask (acceleration indicators, dosimetry, contamination...), fuel rods (visible damages, regular spacing), spacer grids (visible damages, regular geometry), bottom and top boreholes for centring, bottom and top connections, and fuel elements (general appearance, alien elements). TÜV occasionally takes part.

Weather outside or inside the NPP, the licensee has to announce each fuel transport to the authority. Once per delivery campaign TÜV and regulatory body personnel control these inspections. Together with inspection of storage.

2.2 Composition of new core after fuel exchange and reloading

Core layout calculation:

The safety-related criteria for a new core loading are specified according to the operational licence. At least one month prior to the planned refuelling outage, the licensee has to submit the characteristics of the new core layout with following calculation results:

- maximum value of power and burn-up of fuel rods
- mean values of expected power and burn-up of fuel assemblies
- maximum change in power of fuel rods due to rearrangement of fuel assemblies
- maximum number of defective rods in the case of LOCA
- for each fuel assembly type, past and anticipated power history of the assembly
- with the highest burn-up
- corrosion
- DNB-ratio
- efficiency of control rods and reserves for shut down
- critical boron concentration and reactivity coefficients

- proof of long-term sub-criticality
- proof of sufficient capacity for residual heat removal, and
- data basis for calculations during operation (distribution of power density, DNB-ratio, production of radionuclides)
- reactor vessel fluence.
- damage rate analysis for selected design basis accidents.

All inspection findings of the outage (particularly the fuel inspection results) and the associated changes in the reloading plan have to be considered by the licensee or contractor/vendor in the frame of the new core design calculations - they are main prerequisite for the approval to reactor restart. It is common, that the licensee has delivered the results of the final core layout calculations before the reloading starts. After checking these results, TÜV gives recommendation to the reloading plan.

Usually, the core reloading calculation results of the licensee or contractor/vendor are based on a computer code system like SAV-90 in which the following codes are implemented:

- FOXS (calculation of power density distribution)
- MEDIUM3 (burn-up distribution)
- PINPOW2 (local flux, burn-up and relative power)
- FDELTAH80 (integrated in PINPOW2; min. DNB-ratio) and
- FCOMO (integrated in PINPOW2; oxide layer thickness).

On behalf of the regulatory body, TÜV performs independent calculations for selected reactor states (e.g. begin and end of cycle as well as end of Gadolinia burn-out) using computer codes like CASMO-3/ NODXY/ SIMULATE-3/ INTERPIN CS/ ORIGEN/ TORT. This takes roughly 450 to 550 man-hours depending on whether a reloading plan modification is necessary during outage.

Inspection during as well as after reloading:

TÜV checks the main characteristics again, before loading the fuel assemblies into the core. TÜV checks the fuel reloading scheme and the fuel assembling in the pool before the licensee starts the reloading procedure. Occasionally, the reloading procedure is on-line inspected by TÜV. After reloading, TÜV visually inspects the new core in-vessel via TV-camera and investigates the fuel handling records with respect to tractive power.

2.3 Inspection of nuclear fuel operation

During start-up (reactor goes critical and first zero-power operation) several tests, measurements and calibrations are required:

- measurement of critical boron concentration without any and with one control rod cluster completely inserted at zero power
- linearity and overlapping of neutron flux range channels at zero power
- calibration of inner and outer system of neutron flux detection at 30%, 70%,
- 95% rated power
- measurement of minimum hot channel factor at 95% power, repeated at 100%
- power when Xe-equilibrium is attained
- to calibrate and measure the distribution of power density at 95% and to verify at
- 100% power

- evidence of negative coolant temperature reactivity coefficient, and
- measurement of falling times for each control rod.

The obtained start-up values are compared to the ones previously calculated. TÜV regularly supervises those tests (roughly 10 to 20 man hours per outage), while the regulatory authority does so occasionally.

During the reactor power operation, the distribution of reactor power density is controlled continuously by the inner and outer neutron flux detection devices. The coolant temperature at the core outlet is taken as well. Considering these values the minimum DNB-ratio and the maximum power density are evaluated and limited. Inner and outer flux detection systems regularly need calibration. Therefore, an aero ball measurement is carried out every week. It allows calibration and, supplementary, the calculation of hot channel factor, burn-up distribution and balance of radionuclides. Once per month, the boron concentrations for shut-down states (zero power and hot as well as cold) are newly calculated and calibrated. Once per day the reactor coolant contamination is investigated.

The above mentioned actions during the reactor operation are left to the responsibility of the licensee and rarely inspected by the regulatory authority. TÜV checks occasionally the licensees' self-supervision records with respect to completeness and deepness.

The reactor shut-down experiments of the licensee are also accompanied by TÜV.

2.4 Operating NPP with fuel defects

Operation of the NPP with defective fuels is allowed as long as certain limits are not exceeded:

- specified contamination of reactor coolant, and
- limits for radioactive releases.

These values are included in the plant operational licence. The limits of the reactor coolant contamination are taken into account in the design basis analysis for accidental situations and are based on the assumption that no more than 10 per cent of fuel assemblies are damaged.

After considering the radiological and safety impact, a temporary shutdown and identification, examination and correction of the specific problem may be ordered. If the radioactive release limits are exceeded, the facility has to be shut down until precautions are taken to eliminate the cause or at least diminish the emissions below the licensed limits.

Defective fuel assemblies will not be reloaded, independent of the defect's magnitude, although operation continues when some defects occur. There is no criterion for reactor shut-down in the case of minor fuel defects. Nevertheless, an indication of systematic defects may lead to an unforeseen outage even if no radiological limit is reached.

2.5 Fuel inspection after unloading the core

Fuel inspection after unloading the core generally includes

- complete visual inspection of 5 to 10 % of the fuel assemblies
- investigation of oxide layer thickness of 30 to 90 fuel rods out of several fuel assemblies
- eddy current examination of 15 to 16 control rods (regarding the minimum of

- cladding thickness), and
- visual inspection of 5 to 10% (i.e. 2) of the control rod clusters.

Depending on systematic problems there may be complementary examinations:

- visual inspection of spacer grid corners when there has been major damage in previous cycles
- sipping test of all assemblies if the reactor coolant contamination has increased significantly during the previous cycle of operation
- visual inspection of all assemblies with positive sipping result or with mechanical problems during unloading, for example, and
- measurement of fuel assembly dimension changes (assembly bow or length growth)
- measurement of hold-down spring-forces.

Depending on the amount of supplementary inspections during outage, TÜV supervises the inspections during 2 to 8 hours.

Defective assemblies will not be reloaded again. Because of radiation protection, repair starts 100 days after unloading at the earliest. The defective fuel rods are identified, inspected and stored in a quiver. Special interest is paid to radiation protection during repair, accreditation of the supplier's staff, qualification of the equipment, stepwise action according to the authorised papers, documentation (positioning of fuel rods, eddy-current and eventually oxide layer thickness results), and video films of the visual inspection and their interpretation (size and possible cause of the defect).

2.6 Fuel handling

Inspection of fuel handling within the NPP mainly deals with the same questions as mentioned for fuel repair. The regulatory authority as well as TÜV inspect once per year the storage of new assemblies, loading, and unloading. This amounts to approximately 8 to 12 man hours per year (4 to 8 hours for loading/unloading, 4 hours for inspection and storage of new assemblies, see chapter 2.1).

When a new type of fissile material or a special procedure is newly introduced, the amount of inspection is extended. TÜV controls routine fuel handling at random, whereas new procedures are completely reviewed.

Spent fuel shipment has to be announced to the authority and is inspected by the regulatory authority without exception. Special points of interest are radiation protection, transport documentation, accreditation of transport company and driver, licence for shipment as well as sealing and correct labelling of the load and checking the load temperature.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Procedures concerning reloading plan

Prior to start-up, the regulatory authority checks if all planned safety related actions have been carried out during the outage. The proposed reloading plan is not formally approved by the regulatory authority, but assessed by TÜV. Demands concerning core composition generally are taken into account because of the need of permission for start-up.

3.2 Procedures concerning modifications of the reloading plan during refuelling outage

If abnormal events or inspection results occur during the outage, they have to be assessed by TÜV and the authority. Occurrences and associated changes in the reloading plan have to be considered by the licensee in the frame of his final reactor core design calculations. TÜV assesses the calculation results. Mostly it is sufficient to calculate the effect of the differences between the first and the modified plan. The authority gives finally the permission for start-up if the recommendation of TÜV is positive.

3.3 Procedures concerning evaluation of inspection findings

Inspection findings can lead to different procedures depending on their safety implications. Findings with any safety relevance are to be reported to the regulatory authority according to a unified national reporting scheme. By this scheme, the events are categorised in accordance with the urgency to report the event (immediately, quick, normal) and are forwarded to the Incident Reporting Office at the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz - BfS).

The regulatory authority asks for TÜVs' suggestions and recommendations and supervises any necessary corrective actions.

Contribution from:

G. Fichtinger, Hungary

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

The basic description of the reactor core is an important part of the Safety Analysis Report (SAR). The main neutronic, mechanic and thermo-hydraulic characteristics and properties of the core and corresponding operational limits are laid down in the construction and operation licences and the technical specification of the NPP.

In the constructing and commissioning period of the WWER-440 units the Nuclear Safety Inspectorate (NSI) accepted the core design and the SAR of the vendor, the former USSR without any important licensing procedure. At the beginning NSI also accepted the calculation method with the computer code (BIPR-5M) for the design of the fuel loading, without any licensing procedure.

1.2 Licensing of fuel design

The fuel design of the nuclear reactors WWER-440 type is the original core design. From this reason NSI accepted the fuel design with the core design of the vendor in the constructing and commissioning period.

1.3 Modification of core and fuel design

The modifications of core and fuel design need regulatory approval. From the starting period of nuclear units some small modifications of fuel and fuel loading strategy occurred with full NSI licensing procedures.

1.4 Quality Assurance of nuclear fuel

The licensee is responsible for the QA of nuclear fuel. The licensees QA programmes on the nuclear fuel are based on IAEA 50-C-QA documents and related Safety Guides. In addition the utility follows some ISO 9000 requirements also. The main activities in this field are as follows:

- written procedures for the QA of nuclear fuel
- quality requirements for the fuel
- control of manufacturing company on the spot
- incoming inspection of the fuel
- supervision of refuelling and other manipulations
- control of transportation of the fresh and the spent fuel
- spent fuel handling
- QA of the modifications
- documentation of the nuclear fuel

NSI periodically makes inspections and audits on the QA performance of the licensee including its QA activity on the nuclear fuel.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of fresh fuel

The licensee inspects the fresh fuel on delivery. In practice the licensee audits the Russian supplier every 3 years. In the case of an agreed non-conformance the supplier shall correct or change the fuel assembly. Occasionally NSI inspects also the fresh fuel on delivery.

2.2 Composition of new core in the next operating cycle

NSI requires the preliminary calculations and cartograrnme of the new core with the safety parameters about a month before refuelling. Generally NSI does not perform any control calculations. In case of any modification of the core calculation code or strategy NSI orders control analyses at independent expert organisations.

2.3 Inspection of nuclear fuel operation

NSI does not take part directly in the start-up and testing programmes of the new core. A week after re-start the licensee submits a detailed report about the measured core properties comparing to the calculated properties. In the operating phase NSI occasionally inspect the core parameters and the activity concentration of the reactor cooling water.

2.4 Operation with fuel defects

In Hungary fuel leakage during operation has not occurred up to now. The Limiting Conditions for Operation permit an activity level of the primary coolant below a prescribed limit which is derived from the permissible amount of untight (1%) and failed (0.1%) fuel elements. The reactor have to be shut down in the case of the failure of the above limitation. Failed fuel assemblies selected during refuelling periods are excluded from further operation. It corresponds also to non-leaking fuel assemblies having mechanical damage.

2.5 Fuel inspection after unloading the core

At the unloading of the core the first step is the visual control of the fuel bounds with underwater TV-cameras. Partly sipping tests are conducted when the activity of primary coolant is higher comparing to usual values. The fuel defects have to be reported to NSI. NSI pays attention also to the fuel part of the control rods and to their clutching mechanism.

2.6 Fuel handling

Fuel handling procedures are inspected by the NSI as are all other relevant operational procedures. The NPP has written procedures for the fuel handling:

- fresh and spent fuel transport
- fresh and spent fuel storage
- refuelling machine and crane requirements
- operational tests
- safety rules and radioprotection

- fuel safeguard

NSI regularly and occasionally inspects all this safety related procedures. Problems during refuelling are to be discussed with the regulator's expert for additional inspection needs. In the case of any important modification NSI requires full licensing procedure with safety analysis.

2.7 Policy of evaluations of inspection findings

All anomalies related to the nuclear fuel manipulation have to be reported to the regulatory body. Normally the inspection findings are treated with the NPP management. Sometimes NSI issues a decision for the regulation of the fuel procedures. In the case of any incident the NPP must analyse the circumstances of the event and submit the results to NSI.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1

NSI approves all the refuelling plan/core composition on each refuelling outage

3.2

Also all unexpected changes related to refuelling plan must be approved by the NSI.

Contribution from:

P. Manzella, ANPA, Italy

INTRODUCTION

After the Chernobyl accident the development of nuclear energy in Italy became even more of a political issue which resulted in the Referendum of November 1987 and, finally, in a long time moratorium with a halt to all nuclear power plants, both under construction and in operation.

Because of this particular situation, the report deals with practices carried out in Caorso (BWR) and Trino (PWR) nuclear power plants about ten years ago.

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

The Safety Analysis Report includes the basic description of the reactor core as well as the main neutronic, mechanic and thermo-hydraulic characteristics of the core.

The operational limits are specified in the technical specifications enclosed in the operation license of the NPP

1.2 Licensing of fuel design

Fuel Design Manufactures (Ansaldo for Caorso and Agip Nucleare for Trino) submit the application for permission of fuel design to Regulatory Body. The design of the fuel elements is described in the vendor's Safety Report

1.3 Modification of core and fuel design requiring licensing

Licensees submit the application for permission of modification of core and fuel design to Regulatory Body.

1.4 Quality assurance of nuclear fuel

Licensees and Manufactures establish their QA Programme based on "ENEA Technical Guide n° 8; Guideline of QA for NPP" which is almost in conformity to the IAEA Safety Series 50-QA documents. The Regulatory Body analyses the QA programme.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of new fuel

Before the refuelling the Regulatory Body and the licensee QA branch make a pre-inspection of each delivery batch of the new fuel; it consists of visual review of the cladding, spacer grids and channels.

2.2 Composition of new core after fuel exchange and reloading

Regulatory Body inspects the new core parameters after fuel exchange and reloading. The parameters are calculated in advance by licensees and submitted to Regulatory Body in a special Safety Report at least three months before refuelling.

2.3 Inspection of nuclear fuel operation

During the start-up the licensees verify the required tests and measurements, as follows:

(BWR)

- Reactivity Shutdown Margin at one-rod stuck
- Max. Linear Power Density
- Max. Medium Power Density
- Max. Critical Power Ratio

(PWR)

- Reactivity Shutdown Margin at one-rod stuck
- Max. Linear Power Density
- Max. Burn-up Ratio of Fuel Assembly
- Critical Boron Density
- Moderator Temperature Factor

The start-up testing programme is included in a Safety Report, that is reviewed by the Regulatory Body. The tests are carried out by the licensee and verified by Regulatory inspectors

2.4 Operating NPP with fuel defects

There is no regulation for the operation with defected fuel. Regulatory Body stipulates criteria of operation with defected fuel, in particular specified contamination limits are contained in the technical specifications. NPPs don't need to be shut down if a fuel defect occurs. Anyway, leaking fuel must not be reloaded for another cycle of operation.

2.5 Fuel inspection after unloading the core

After unloading the core the licensee conducts visual inspection for fuel assembly, if the contamination of the reactor coolant gives suspect for fuel defects. The Regulatory Body reviews the fuel inspection programme and if it is necessary prescribes to the licensee extensive tests for fuel defects.

2.6 Fuel handling

As a part of the periodic inspection programme, the Regulatory Body verifies the fuel handling procedures about storage of new fuel, loading and unloading the core. Moreover functional tests of the fuel handling machine are required.

The inspections of shipment of spent fuel are carried out directly by the Regulatory Body.

2.7 Policy of evaluation of inspection finding

Core anomalies and fuel defects have to be reported to Regulatory Body and discussed about the adopted countermeasures.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Is the reloading plan/core composition approved/endorsed by the inspection authority?

Yes, it needs Regulatory approval for the calculation methods and for the operation conditions.

3.2 What happens if the reloading plan must be changed during refuelling outage due to defect fuel elements foreseen for reloading?

The licensee must submit to the Regulatory Body any proposed changes of the reloading plan.

Contribution from:

H. Koizumi, Japan

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

Utilities submit the Application for Permission of Reactor Installation to the regulatory body according to the Law for Regulation of Nuclear Source Materials, Nuclear Fuel Material and Reactors (RNNR Law). Overall plant design including core design is reviewed in accordance with the following Guidances by Nuclear Safety Commission as well as regulatory body with double check systems.

- Safety Design Criteria for Light Water Nuclear Power Plant
- Guideline for Examination of Safety Evaluation of Light Water Nuclear Power Plant
- Guide for Evaluation of Reactivity Insertion Events
- etc.

1.2 Licensing of fuel design

Fuel Design Manufacturers submit the Application for Permission of Fuel Design to the regulatory body according to the Electric Utilities Industry Law (EUIL).

1.3 Modification of core and fuel design requiring licensing

Licensees submit the Application for Permission of Modification again in similar way of 1.1 and 1.2 when Licensees modify the design.

1.4 Quality Assurance of nuclear fuel

Licensees and Manufacturers establish their QA Programme based on JEAG 4101 ‘Guideline of QA for NPP’ which refers to IAEA QA code, Safety Guideline.

Concerning Fuel Quality Management, they also establish QA programme based on JEAG 4204 ‘Guideline of Nuclear Fuel Inspection for NPP’ which stipulates inspection items & method and Quality Management in manufacturing of Nuclear Fuel.

Inspection conducted by regulatory body is stipulated in the EUIL and Criteria is in the Ministerial Ordinance ‘Technical Standard of Nuclear Fuel Material for NPP’ and mentioned items of application for permission of fuel design stipulated in the enforcement of the EUIL. New fuels in NPP shall be inspected in each manufacture stage for fuel rods, each parts, pellets composing fuel assembly. Manufacturers have to have Chief Engineer of Nuclear Fuel qualified by RNNR Law.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of new fuel

Imported new fuels are regulated by EUIL and shall be inspected by regulatory body at the site. Concerning new home-made fuels after carrying into the site, the self safety management manual stipulated by RNNR Law obliges Licensees to inspect new fuel by themselves at receiving and pre-loading.

2.2 Composition of new core after fuel exchange and reloading

Regulatory body inspects the new core after fuel exchange and reloading in the core lay-out inspection, the shutdown margin inspection and visual inspection as a part of Periodical Inspection regulated by EUIL.

In the review of application for permission of reactor installation, Regulatory Body examines the safety of reloaded core as well as first-load core based on guidelines. Main parameters and nuclear thermal limitation for safety check can be listed as follows:

(BWR)

- Reactivity Shutdown Margin at one-rod stuck
- Max. Line Power Density
- Critical Power Ratio
- Max. Burn ratio of Fuel Assembly
- Void Factor
- Doppler Factor

(PWR)

- Reactivity Shutdown Margin at one-rod stuck
- Max. Line Power Density
- Max. Burn Ratio of Fuel Assembly
- Max. Reactivity adding ratio
- Peaking Factor F-n. xv
- Moderator Temperature Factor
- Worth of Control Rod Cluster dropping and F-n. ΔH
- Worth of Control Rod Cluster jumping out and F-q

Licensees calculate these values and inspection authority also evaluates these values by using computer again.

2.3 Inspection of nuclear fuel operation

In pre-use inspection, Regulatory Body conducts following inspections:

(BWR)

Fuel Loading Inspection, Shutdown Margin Inspection, First Critical Inspection, Moderator Temp. Factor Measurement Inspection and Full Power Inspection.

(PWR)

Fuel Loading Inspection, Min. Shutdown Margin Inspection (Boron density measurement), Moderator Temp. Factor Measurement Inspection, Control Rod Cluster bank Inspection, Critical Boron Density Measurement Inspection and Full Power Inspection.

In periodical inspection, Regulatory body conducts Shutdown Margin Inspection. Full Power Inspection and check the parameters of fuel operation. In plant operation, Senior Specialists for NPP Operation (Resident Inspector) check the plant daily condition including core operation.

2.4 Operating NPP with fuel defects

Self Safety Management Manual regulated by RNNR Law stipulates criteria of operation with defected fuel.

2.5 Fuel inspection after unloading the core

In periodical inspection, Regulatory Body conducts visual inspection for fuel assembly in order to confirm the soundness of fuel in use of next cycle. If the plant is not satisfied with the following conditions, sipping inspection which finds the leaked fuel shall be conducted.

(BWR)

- Iodine 131 density in Moderator is less than 3.7x10 Bq/cc and indicates no significant deviation in plant operation
- Increase of iodine 131 at shutdown is less than $3.7x1^{09}$ Bq/cc
- Radiation Monitors of exhaust gas indicate no significant deviation in plant operation

(PWR)

- Iodine 131 density in Moderator is less than 3.7x10 Bq/cc in plant operation and indicates no significant deviation during plant operation and up to opening the coolant system
- Increase of Iodine 131 at shutdown is less than $3.7x10^{9}$ Bq/cc

2.6 Fuel handling

In Periodical Inspection, Regulatory Body conducts Fuel Handling Machine Inspection. In addition, Self Safety Management Manual regulated by LRR stipulates Fuel Handling such as storage, loading, spent fuel shipment.

2.7 Policy of evaluation of inspection finding

If Regulatory Body finds discrepancy in pre-use inspection or periodical inspection, Inspector directs licensee to satisfy the criteria. In Shipping Inspection, for example, if there finds leak fuel, the cause of leakage is examined and it will not be used anymore. Significant fuel leakage is reported to Advisory Committee of Regulatory Body and discussed about causes and countermeasure.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Is the reloading plan/core composition approved/endorsed by the inspection authority?

See 2.2

<u>Contribution from:</u>

José Luis Delgado, Luis Miguel Gutiérrez Ruiz, CNSNS, Mexico

General Electric is the principal vendor of nuclear fuel to Laguna Verde using the GESTAR-III methodology by agreement between the regulatory body and the licensee three months before the refuelling, GE sends the "Nuclear Design and Cycle Management Report". In this document the vendor settles the operational limits' the most limiting transients for this cycle and the new composition of the core.

The GESTAR-III methodology is includes the fuel design specifications and materials.

The licensee made an independent review of this document using the fuel managements and power codes.

During the third cycle the licensee loaded four bundles which belong to other vendor so the licensee had to make a core compatibility analysis to demonstrate to the regulatory body that the core behaviour didn't change.

Before the first cycle the regulatory body and the licensee quality assurance branch made some inspections to verify the manufacturer's QA programme and to the fuel fabrication installations.

Before the refuelling the regulatory body and the licensee QA branch make a pre-inspection of each delivery batch which consists of visual review of the cladding, spacer grids and channels.

During the outage operations the resident inspector verifies the loading and unloading of the core, checking if the licensee's personnel follow the procedures and the Technical Specifications.

During the start-up the resident inspector verifies the required tests and measurements:

- Shutdown margin
- Reactivity Anomalies
- PC10MR

If there are some leaking fuel assemblies the activity release could be detected by the plant off-gas and coolant activity measurements systems, the basic faulted bundles management plan is (1) quickly to determine the leaker core location through power suppression testing (2) to suppress the leaker power level by the full insertion of control blades in/around the leaker cell, as required, and (3) minimise subsequent leaker fuel duty by either the avoidance of leaker power increases or the performance of leaker power increases at a slow power ramp rate and in the subsequent outage, the licensee shall sip all reinsert bundles to ensure that failed fuel assemblies are not returned to the core for another cycle of operation.

Contribution from:

E. des Bouvrie, KFD, Netherlands

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 / 1.2 Licensing of core design/Licensing of fuel design

The safety analysis report which is submitted in support of the license application describes the core and fuel design and spells out the specific characteristics. The typical controlling characteristics and limiting conditions are laid down in the Technical Specifications (TS) for plant operations.

1.3 Modification of core and fuel design requiring licensing

If core or fuel characteristics for design and operations deviate from the described limits in the safety analysis report, a license renewal application has to be submitted (e.g. when the enrichment deviates from the specified range). This encompasses a complete licensing procedure with possible public participation.

Some characteristics of core and fuel design are only described with typical values; the corresponding limiting conditions are given in the TS. Modifications in this particular case have to be reviewed by the competent regulatory body (KFD) and -if necessary- the changes in TS need to be approved by KFD.

1.4 Quality Assurance of nuclear fuel

General regulatory QA requirements are specified in the Dutch version of the IAEA Code on Quality Assurance, Safety Series No.50-C-QA (Rev. l) and further guidance on nuclear fuel can be found in guide No.50-SG-QA-ll. The licensees QA programme will as a minimum follow this and prescribe the applicable requirements for the manufacturer QA programme.

For new types of fuel regulatory inspections are held at the fuel manufacturing plant.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

No routing regulatory inspection of each delivery batch of new fuel. Routine inspection is responsibility of the operating organisation.

For each new core load the operator (or fuel vendor) has to perform the physics and thermal hydraulic calculations in order to show the new configurations meets the specified limits. The authority verifies if the computer code has been validated for specific application. Typical input parameters for the calculations are checked and calculated results are compared with limiting conditions. The authority does not perform independent verifications.

2.3 Inspection of nuclear fuel operation

According to license requirements the operator has to verify the predicted flux distribution with local flux distribution measurements during start-up. Power ascension is only allowed when prediction and measurements do not significantly deviate. The 50% power test results are routinely checked by the authority KFD.

2.4 Operating NPP with fuel defects

The TS prescribe contamination limits, for the reactor coolant, and dictate plant shutdown if specified concentration limits for certain isotopes are exceeded during a prescribed period.

2.5 Fuel inspection after unloading the core

Fuel elements are routinely sipped for leakage when during operation one or more leaking rods/elements are suspected.

The spent fuel storage has a limited capacity to store leaking fuel elements in canisters.

There are provisions for repair of fuel elements (exchange of defective rods)

2.6 Fuel handling

Inspections of dry, wet and spent fuel storage are carried out routinely by the operator and occasionally by the authority.

2.7 Policy of evaluation of inspection finding

Fortunately, there is not much experience with leaking fuel

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Is the reloading plan/core composition approved/endorsed by the inspection authority?

Each reloading plan has to be approved by the authority prior to fuel loading and start-up.

3.2 What happens if the reload plan must be changed during refuelling outage due to defect fuel elements foreseen for reloading?

On an ad hoc basis it will have to be determined if the similarity of the substitution (typical burn-up) will require a full or partial recalculation before reloading.

3.3 Other

No other procedures are applied.

Contribution from:

J. Gil, CSN, Spain

1. LICENSING AND QUALITY ASSURANCE REQUIREMENTS FOR NUCLEAR FUEL

1.1.*Licensing of core design*

The licensees must submit for the operation licence the preliminary core design characteristics according with NRC Standard Format (FSAR). The licensing of core design is included in the overall licensing programme following the NRC Standard Review Plan (NUREG-0800). The regulatory body also review includes the specifications of safety margins and operation limits described in the technical specifications proposal by the licensees.

All later core loadings satisfying these conditions are considered to be equivalent to the first core design. Therefore, they do not need further licensing.

1.2.***Licensing of fuel design***

The Spanish Nuclear Energy Law and the Nuclear and Radioactive Installations Rule (RINR) do not require special license for the different types of fuel assemblies.

The Spanish nuclear fuel facility (ENUSA) submits to the regulatory body and the Ministry of Industry all the facility characteristics, processes, and operation procedures, as the fuel maker and as other Nuclear Installations according to the RINR. The operation license of ENUSA includes the types of fuel authorised to manufacture. Major changes in the fuel manufactured are reviewed by the regulatory body but not necessarily authorised. The fuel design parameters are considered for the determination of the core characteristics in detail.

1.3.***Modifications of core and fuel design requiring licensing***

Essential modifications of the core or fuel design require licensing process by the regulatory body and a specific licence by the Ministry according RINR might be needed.

In these cases, the licensee submits a detailed description of the planned modification including a safety analysis report.

In the CSN organisation there is an Area, included in the Nuclear Technology Subdirection, named Core Engineering, which is involved in reviewing fuel and core characteristics (nuclear and thermohydraulical aspects.).

Design criteria, code results, fuel parameters etc. are reviewed by the regulatory body using independent code calculations if needed.

If the modification does not involve safety significance the regulatory body is informed by the main changes but not for licensing.

1.4.*Quality Assurance of nuclear fuel*

The QA programme of the licensees is included in the FSAR and licensed as other official operational document. All changes of this approved program must be submit to the regulatory body.

The QA program of the manufacturer is also approved by the regulatory body in the case of the Spanish fuel maker.

If the fuel is not from a Spanish fuel maker the licensees are responsible for the overall QA program, including fabrication processes.

The regulatory body checks compliance of the QA program through periodical inspections programmed to the Spanish fuel facility. In the case of non Spanish facility the licensees provides to the regulatory body the opportunity to carry out inspections by agreement between the licensee and the fuel maker, according to the Spanish law.

The QA programs for the licensees and Spanish fuel facility are in accordance with the QA IAEA guidelines and the US 10CFR50 appendix B.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1.Pre-inspection of each delivery batch of new fuel

Before the new fuel assemblies are stored into the dry fuel storage facility, inspections of new fuel assemblies are carried out by the licensee.

Each new fuel transport has to be announced to the Ministry of Industry and the regulatory body by the Spanish fuel maker or the licensee. In some cases special inspections of transport conditions are carried out by the regulatory body.

The licensee inspections in the NPP are usually observed by the resident inspectors.

2.2.*Composition of new core after fuel exchange and reloading*

The licensees must submit to the regulatory body a refuelling safety report prior to the planned refuelling outage with the characteristics of the new core layout, code calculations results, etc., according to the operational licence. The CSN safety guide G.S. 1.5 (1990) provides licensees information about the regulatory body requirements for this report.

This report has to include at least core layout, safety related values and margins, code calculations results made by the licensees and all safety significant values.

The reloading safety report is reviewed by the regulatory body and approved before loading the fuel assemblies into the core.

An informal licensing process has to be carried out before loading, including independent calculations if needed.

Inspections of the fuel assemblies are carried out by the licensees before refuelling with the site inspector as observer. In some special cases inspections for the CSN staff may be programmed.

2.3. ***Inspection of nuclear fuel operation***

Tests and measurements are required for verification of calculated core properties during start-up.

The test activities are performed by the licensee and monitored by resident inspector an core engineering trained inspectors from the CSN.

Core parameters measured are critical boron concentration, calibration of inner and outer system of neutron flux detection and measurements of distribution of power density at different power rates, measurement of falling times for each control rod, moderator temperature coefficient and other test included in an standard star-up test program.

The differences between measured and calculated parameter values must not exceed specified tolerances and recalculations are made by the licensee if needed.

The start-up tests provide the reference data for the test required by technical specifications during the reactor power operation related to the performance of the core monitoring systems.

2.4. ***Operating NPP with fuel defects***

Operation of the NPP with fuel defects is allowed within limits on coolant activity required by technical specifications.

The contamination limits for reactor coolant and policy and requirements for continued operation or shut-down are included in technical specifications approved by the regulatory body for the licence.

We do not have specific limits for number or type of fuel defects.

The radiological limits are reviewed and approved during the licensing process according standard review plan.

2.5. ***Fuel inspection after unloading core***

A complete visual inspection of a small part of the fuel assemblies is carried out by the licensee.

If due to coolant activity there is evidence of fuel defects a fuel sipping on site is made.

Additional test to selected fuel such eddy current examination of control rods (cladding thickness), investigation of oxide layer thickness of fuel rods, visual inspection of spacer grids are carried out taken into account the fuel experience, burn-up grade, historical fuel events etc.

The tests are carried out by licensee and monitored by the resident inspector or specific trained inspectors from the CSN if some problems appear or presumed.

The defective assemblies may be reloaded or stored in the spent fuel pool depending on defects, according technical requirements for vendors and licensees. Therefore may be stored in special conditions due to radiological protection criteria.

2.6. ***Fuel handling***

Inspections of fuel handling within the NPP are carried out usually by resident inspectors during the refuelling outages including storage of new fuel, loading and unloading the core and wet storage.

The activities of fuel handling are made following operational procedures approved by the regulatory body. Changes in the fuel handling procedures are reported to the regulatory body mainly when a special procedure is needed.

2.7. ***Policy of evaluations of inspection findings***

Policy about fuel defects and reportable events criteria is the same that other operational subject.

Reportable events criteria is included in the CSN safety guide GS 1.6 and required by technical specifications.

The inspection and enforcement activities of the CSN are important in the fuel area due to the safety significance of the fuel on the operation requirements.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

The proposed reloading plan is not formally approved by the regulatory body if significant changes of the first operational authorisation are not made (see 2.2).

The information related to reload outage activities that the licensees must submit to the regulatory body for reviewing is included in the CSN safety guide GS 1.5. (1990).

If the reload plan must be changed due to defect fuel elements the safety impact must be evaluated by the licensee and in some cases reviewed by the CSN. If the changes are significant a reviewed reload safety report may be sent to the CSN.

The Core Engineering Area from the CSN has 8 specialists in fuel nuclear and thermohydraulics aspects. The fuel mechanical aspects are reviewed by other Area in the Engineering Subdirection.

There are in the CSN computer codes for core and fuel design different than the fuel maker codes.

The CSN inspection procedures for fuel and core aspects have detailed agendas for each activity monitored by CSN.

Contribution from:

Staffan Forsberg, SKI, Sweden

1. LICENSING AND QUALITY ASSURANCE(QA) REQUIREMENTS FOR NUCLEAR FUEL

Nearly all major fuel vendors are represented in Swedish cores. The policy of utilities is that two or three fuel vendors at all times should be qualified for fuel deliveries to Swedish plants.

1.1 Licensing of core design

Preliminary core designs are normally submitted to the Inspectorate in good time before the reload and the Inspectorate approves the safety limits which are applicable. The detailed core designs are generally done by the fuel vendors or the utilities. The Inspectorate requires that the core design is approved by so called 'free standing audit'. After such approval their application for reload core design is sent to the Inspectorate for information or if there are essential changes, for approval.

1.2 Licensing of fuel design

Three types of fuel design licensing processes are used for Swedish reactors.

1. Licensing of a full reload: this normally requires that demonstration projects has been conducted on the fuel type and that lead test fuel assemblies have been in use in the reactor and that an approval certificate for the fuel type has been issued.

2. Demonstration projects: A limited number of lead test fuel assemblies are licensed for loading prior to full reload or for maintaining a vendor's capability to deliver approved fuel to a specific reactor. This is in principle equivalent to a full reload and all handling procedures, paperwork, quality assurance routines etc. should be in place. The objective is to streamline the procedures before a new reload arrives. A demonstration project is normally concluded by an approval certificate for the fuel type. Such fuel is usually not accepted in a limiting position of the core.

3. Experimental fuel: The fuel vendors often want to test fuel development potential, in terms of economy and safety, under reactor conditions. The licensing procedure for such fuel is meant to be slightly more relaxed than for a full reload. Instead, appropriate penalties on thermal limits are used.

1.3 Modification of core design and fuel design requiring licensing

Renewed licensing is required if there are essential differences in design conditions. Permission from the Inspectorate is always required if the fuel integrity is broken e.g. for fuel reconstitution or replacement of fuel rods.

1.4 Quality assurance of nuclear fuel

The Inspectorate's regulations require that the fuel manufacturers have a QA programme in place. The licensee is required to perform audits of the manufacturers QA programme. The Inspectorate does formal inspections only in the domestic fuel factories. However, the Inspectorate has the practice to visit also fuel factories abroad which delivers fuel to Swedish power plants. The prime responsibility for regular audits of such facilities lies with the Swedish utilities.

2. REGULATORY INSPECTIONS PROGRAMMES DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each delivery batch of new fuel

The inspection that the delivered fuel is according to specifications is the responsibility of the utility. Amount and composition of nuclear material are audited and inspected by international agencies and the Inspectorate.

2.2 Composition of new core after fuel exchange and reloading

The safety limits for the new core has been approved by the Inspectorate as well as the Technical Specifications used by the utility during reloading and verification of a new core. In addition to verification of the safety limits and correct loading, the Inspectorate often requires additional checks, such as for instance verification of axial location, to be performed.

2.3 Inspection of nuclear fuel operation

The core limits are inspected during operation. Data are stored during operation and transients so that it can be verified that fuel limits are not violated.

2.4 Operation of NPP with fuel defects

The objective is to have zero fuel leak. The Inspectorate has set the goal that leak frequency should be less than 1 of 100 000 pins during a normal pin lifetime. The Inspectorate requires that the utility consider insertion of adjacent control rod to shut down the affected fuel element. There are no specific regulations on reactor water contamination in terms of Bq or Curies. The safety aspects of fuel leaks are mostly associated with radiation dose to maintenance and testing personnel. If many fuel elements are leaking the reactor will be taken down for reload.

If safety functions are challenged by fuel defects, the normal procedure would be to shut the reactor down for reload. This happened in a Swedish PWR when prolonged control rod drop times were observed because of S-shaped fuel in a PWR.

2.5 Fuel inspection after unloading the core

The fuel is normally visually inspected by the utility after discharge. Since most fuel failures have been caused by foreign objects it has been usual to search the fuel for such objects.

2.6 Fuel handling

There has been a number of incidents with fuel loading machines an new equipment for fuel handling has been introduced for the Swedish BWRs. The incidents were often man-machine related, and the Inspectorate has had special projects to cope with the problems.

2.7 Policy of evaluations of inspection findings

The objective is to use the inspection results in order to reduce or eliminate fuel failures. If a fuel failure has occurred, the Inspectorate requires that the utility makes serious attempts to identify the root cause of the failure by for instance, examining the failed fuel in a laboratory.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMMES

3.1 Is the reloading plan or core composition approved or endorsed by the inspection authority?

The safety limits for the reloaded core and the fuel types must be approved by the Inspection Authority.

3.2 What happens if the reloading plan must be changed during refuelling outage due to defective fuel elements foreseen for reloading?

Loading of defective fuel is not allowed. They have to choose other fuel elements or reconstruct the fuel.

3.3 Other procedures

Contribution from:

H. Wand, HSK, Switzerland

1. LICENSING AND QUALITY ASSURANCE REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core

The basic safety analyses of a nuclear power plant are usually described in special reports and summarised in the safety analysis report. These safety analyses are based on a reference core whose key safety parameters have been varied within certain limits. The verified limits of these safety parameters are contained in the list of the so-called "safety-related boundary conditions". The reload cores which meet these boundary conditions are regarded as acceptable with respect to safety. If the reload core does not meet the safety-related boundary conditions, a special analysis is needed (see Section 1.3).

1.2 Licensing of fuel design

For the introduction of a new type of fuel element a fuel rod and/or a fuel element structure design report have to be presented to HSK. In these reports it must be shown that all relevant fuel design criteria are fulfilled during normal operation and operational transients. Usually, HSK accepts the fuel design criteria that are valid in the country of origin of the fuel vendor. If large modifications on a fuel element have been performed, the satisfactory operational behaviour of the modified element must be shown by means of lead test assemblies.

1.3 Modifications of core and fuel design requiring licensing

According to the HSK Regulatory Guide HSK-R-15 a HSK-permit is required for modifications of the reactor core, fuel elements, control rods and of installations used for core supervision.

The HSK-permit for plant operation after a refuelling outage is based on the results of a safety evaluation, which is submitted by the licensee in the Reload Licensing Submittal. This safety evaluation must show that the key safety parameters of the reload core are within their verified limits. Alternatively, additional safety considerations or analyses must be performed to show that the basic safety criteria for the reactor core are fulfilled.

The permit for a modification of the fuel design is given on the basis of revisions to the fuel rod or the fuel element structure design report.

1.4 Quality assurance of nuclear fuel

Fuel fabrication is inspected by the regulatory body of the fuel vendor country. So far, HSK accepts the quality assurance (QA) of the fuel vendor country inspection team.

Usually, HSK performs an inspection of the fuel fabrication plant when a new fuel vendor has been chosen by a Swiss utility. During this HSK inspection the QA procedure of the vendor is presented to HSK. In some cases the QA manual of a fuel vendor has been submitted to HSK for information purposes.

The licensees of the Swiss nuclear power plants have their own quality assurance procedures for controlling the fabrication of new fuel elements. The corresponding QA measures are not supervised by HSK.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-inspection of each Delivery Batch of New Fuel

The new fuel elements that are delivered to a nuclear power plant are inspected by the plant personnel when arriving at the plant. Usually, the results of these inspections are not presented to HSK. However, HSK must be informed by the NPP operator, if problems arise or fuel element defects have been detected.

2.2 Composition of a new core after fuel exchange and reloading

For a reload core the NPP operator must show that the key safety parameters of the new core are within their verified limits. For this purpose the fuel vendor performs the necessary static and dynamic calculations. Usually, HSK does not perform independent calculations. At special occasions, HSK may require an independent calculation. Often, such calculations are performed by the Paul Scherrer Institute (PSI), which acts as an HSK expert.

The description of the computer models used for the safety analyses and their validations must be submitted to HSK Modifications to these computer models have to be approved by HSK.

2.3 Inspection of nuclear fuel operation

During start-up a number of core parameters are measured and compared with the results of pre-calculations. Such parameters are the critical boron concentration (PWR), shutdown reactivity, moderator temperature coefficient and power distribution. The start-up test program must be approved by the HSK. The tests are performed mostly in presence of HSK personnel. The differences between measured and calculated parameter values must not exceed specified tolerances.

Inspections during the power operation are related to the performance of the core monitoring system and to the coolant and off-gas activity of nuclides which are sensitive to fuel defects.

2.4 Operating NPP with fuel defects

For each Swiss nuclear power plant a maximum allowable activity concentration of I-131 in the reactor coolant has been specified. For one plant an additional Cs- 137 limit is specified. Operation, with defective fuel is permitted below these limits. Depending on the plant type the operating strategy should be adjusted to moderate degradation of failed fuel rods.

Unless the above limits are exceeded, an intermediate shut-down must also be considered in cases where the increase of the Np-239 reactor coolant activity concentration indicates fuel failures with significant uranium washout. Based on a prediction of the Np-239 increase and the behaviour of fission products the amount of tramp uranium is estimated and compared with a maximum tolerable value. This value is not predetermined. It is evaluated by means of a multi-criteria optimisation method considering factors like release rates of radioactive effluents, collective doses to the personnel, long term radiological impact on the plant, cost and time of an intermediate outage to remove defective fuel elements etc.

Radiological limits which would require an intermediate shutdown for removal of defective fuel exist in terms of release limits. Here especially the I-131 limit; set for a weekly time period is restrictive.

2.5 Fuel Inspection after unloading the core

If there is evidence of fuel defects an in-core sipping is performed to find the defective elements. These elements are visually inspected to locate the failed rods. There is an HSK requirement to reveal the primary cause of the failure in order to take corrective actions for preventing future fuel rod failures due to this cause.

The HSK does usually not inspect the repair of defective fuel elements. However, HSK requests a safety evaluation for the reinsertion of these repaired or reconstituted elements.

Measurements of cladding oxide thickness, fuel rod growth, control rod guide tube growth etc. are performed on selected fuel elements, mainly in connection with high burnup verification programmes.

2.6 Fuel handling

Loading and unloading the core are not regularly inspected by the HSK. The correctness of the core loading is verified by IAEA inspectors.

Inspections of the storage of fresh fuel are performed on a case by case basis. Before the introduction of new fuel types HSK checks that the requirements regarding subcriticality are fulfilled.

Inspections of the wet storage are usually performed during the outages, mainly in connection with the fuel inspection program.

2.7 Policy of evaluations of inspection findings

Depending on the severity of findings the licensee is requested to take measures or design modifications in order to improve the situation. For instance, due to repeated fuel defects caused by debris fretting one licensee was requested to introduce debris filters in the fuel elements.

The events to be reported to the HSK are specified in the HSK Regulatory Guide HSK-R-15. For the operating period of a NPP they include e.g. violation of core operating or safety limits, occurrence of fuel defects, longer unavailability of a safety related core monitoring system. For the outage period of a NPP they include e.g. damage of fuel elements during handling operations, disturbances of decay heat removal from the core or the fuel storage pool, larger leakage from the fuel storage pool.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Approval of reloading plan

The reloading plan/core composition (Reload Licensing submittal) has to be approved by the HSK.

3.2 Change of reloading plan

In the case that the reloading plan must be changed during refuelling outage due to removal of defective fuel elements, the impact of these changes on the key safety parameters must be evaluated by the licensee. Usually this is done by a Supplement to the Reload Licensing Submittal.

3.2 What happens if the reloading plan must be changed during refuelling outage due to defective fuel elements foreseen for reloading?

Same as 2.2

Contribution from:

Tom Warren, HSE, United Kingdom

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of Core Design
Safety Analysis Report
Specifications of Safety Margins
Operation Limits

NII does not grant a licence for a given core design, it grants a licence for a particular type of nuclear installation on a given site. The operator who holds this licence for the installation, is required to produce a safety case (safety analysis report) for the installation which includes details on core design and specify safety margins and operating limits. NII must be satisfied by this safety case before NII will consent to commissioning of the reactor, or its operation. The operator of a reactor requires the formal consent from NII prior to the restart of the reactor following their periodic outage. (For a PWR, this means the refuelling outage. For a Gas Cooled Reactor, this means the periodic outage which occurs every two or three years.) If NII is not satisfied by the safety case, including any detailed safety aspects such as core design, then the plant will not be allowed to start commissioning or operate.

1.2 Licensing of fuel design
Specifications quality of material

There is no such thing as licensing of a given fuel design in the UK. The specifications and quality of materials in fuel and core components is a matter for the fuel vendors and operators to agree upon. These details are then incorporated in the safety case and NII assesses the adequacy of that safety case. Subsequent changes to fuel require the safety case to be modified and, depending on the degree of safety significance of the change, NII will re assess the modified safety case (but see answer to 1.3 beneath). The operator is not allowed to operate the reactor unless there is an adequate safety case justifying the safety of operation prior to the start of operation.

1.3 Modifications of core and fuel design requiring licensing
Licensing procedures for modification

As part of the requirement of the nuclear licence, all operators must have procedures for plant modifications. These procedures require NII's involvement for those modifications which are of safety significance. A modification is very broadly interpreted and includes changes to fuel, core and core design. The operator is required by the force of law to follow these formal modification procedures.

1.4 Quality Assurance of nuclear fuel
Licensee's QA Programme
Manufacturer's QA Programme
Regulatory Inspection on fuel fabrication

The operator is required by the licence to have QA arrangements which cover all safety aspects, including fuel. These arrangements call for a programme which covers the manufacture of fuel, no matter where it is manufactured. NII inspects these arrangements as part of its routine duties and may choose to carry out specific audits if this is considered to be necessary. Since the manufacture of nuclear fuel in the United Kingdom is a licensable activity, NII also inspects the fuel manufacturing plants. NII has on occasion, inspected the manufacturing process in detail in following up concerns arising from particular reactor fuel incidents.

2. REGULATORY INSPECTION PROGRAMME DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-Inspection of each delivery batch of new fuel

The operator's QA arrangements call for pre inspection by independent inspection agency or the operator. NII does not generally inspect new fuel, although it may do so as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors.

2.2 Composition of New Core After Fuel Exchange and Reloading
Safety related values and margins
Required calculations by the operator
Independent calculations by the inspector or the inspection authority
Use of computer codes

The procedures outlined in answers 1.1, 1.2 and 1.3 above cover the general approach to this question. As part of the operator's absolute responsibility for the safety of operation of his reactor, it is for the operator to specify and then justify the composition of the core against pre-set criteria including safety related values and margins using justified calculational procedures including computer codes. This justification is subject to peer review. The operator is required to follow the modifications procedure for any core changes or changes to calculational methods (see also answer to 1.3 above). NII inspects these activities as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors..

2.3 Inspection of Nuclear Fuel Operation
Fuel operation parameters
Verification of calculated core properties during start-up, required tests and measurements
Periodic tests
Inspection on these tests and measurements
Verification of results
Obtaining reference data

Part of the operator's safety case includes his arrangements which require that all fuel and core parameters must be verified by measurement and/or appropriate research. Core properties are confirmed following initial start-up by use of physics testing which (in the case of a commercial PWR) complies with ANSI 19.6.1. NII inspects both the extent of the requirements and the results of the licensees work as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors..

2.4 Operating NPP with Fuel Defects
Contamination limits for reactor coolant
Policy and requirements for continued operation or shutdown
Radiological limits

Part of the operator's safety case includes his arrangements which require that Technical Specifications (for PWR) or Station Operating Instructions (for Gas Cooled Reactors) together with Operating Rules covering these matters. These allow reactors to continue to operate with known fuel failures present within relatively tight constraints so as to avoid further significant degradation of the fuel and to avoid serious contamination of the coolant. Once pre-determined limits are reached the failed fuel is required to be discharged. Gas Cooled Reactors are allowed to return to power with known failed fuel present in the core provided that the release is within specified limits. NII inspects these activities as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors.

2.5 Fuel Inspection after Unloading the core
Visual inspection
Tests for fuel defects
Inspection of spacer grids
Measurements of oxide layer of zircaloy tubes
Requirements for storing defect fuel rods on-site
Inspection of repair of defective fuel elements

Gas Cooled Reactor fuel is inspected upon discharge with a suitable sample being inspected in the pond by means of the endoscopy technique. Some selected fuel is subjected to extensive in-cave Post Irradiation Examination (PIE) in line with an agreed programme. Any failed Gas Cooled Reactor fuel which is discharged is usually sent off-site for PIE.

PWR fuel is visually monitored during discharge so as to identify any significant fuel damage and deposits. If leakers are present they are identified using sipping equipment. At present there are no plans to do detailed measurements such as thickness of the clad oxide layer. Defect fuel rods will have to remain in the storage pond at site. There is no policy yet with regard to their long term storage/disposal. So far no commercial PWR fuel has been repaired in the United Kingdom and so no inspections of repairs have been required.

NII inspects these activities as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors.

2.6 Fuel Handling
Inspection of storage of new fuel
Loading and unloading of core
Wet storage
Inspection of spent fuel shipment

Handling and storage of spent fuel is also covered by the safety case. From the safety case appropriate conditions and limits are derived and implemented by the operators. UK Nuclear Site Licences have a specific condition requiring arrangements for the dispatch of nuclear materials from sites. These arrangements will dovetail with other relevant legislation covering packaging and transport of nuclear material. NII inspects these activities as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors. In addition, Inspectors from the United Kingdom's Department of Transport are closely involved in aspects relating to packaging and transport of nuclear material.

2.7 Policy of Evaluations of Inspection Findings Abnormal occurrences, reportable events Follow-up of corrective actions

Inspection findings are evaluated by the operator in accordance with their procedures. Findings of safety significance are treated as abnormal occurrences. In some cases, this may lead to the operator amending the safety case to justify continued or further operation of the reactor.

Operators are required under the licence to have arrangements for recording all abnormal occurrences, incidents and event and which also cover reporting, investigating and implementing corrective actions them. NII inspects these arrangements as part of its routine work by the site inspector. NII also follows up some abnormal occurrences, with if needed the assistance of specialist NII inspectors and may instigate its own investigation in more serious cases.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAMME

3.1 Is the reloading plan / core composition approved / endorsed by the inspection authority?

NII does not specifically approve or endorse the reloading plan or core composition. Such matters are covered by the procedures outlined in the answers to 1.1, 1.2 and 1.3 above.

3.2 What happens if the reload plan must be changed during refuelling outage due to defect fuel elements foreseen for reloading?

The operator has procedures to deal with such eventualities. Where the problem is of such significance as to be outside these procedures, then it is caught by the procedures outlined in the answers to 1.1, 1.2 and 1.3 above. NII inspects these activities as part of its routine work by the site inspector, with if needed the assistance of specialist NII inspectors.

Contribution from:

R. Gallo, US NRC, USA

1. LICENSING AND QUALITY ASSURANCE (QA) REQUIREMENTS FOR NUCLEAR FUEL

1.1 Licensing of core design

- NRC Standard Review Plan NUREG-0800
- Licensee's Safety Analysis Report
- NRC Safety Evaluation Report (SER)
- Specifications of Safety Margins - SER
- Operation Limits - SER/Tech Specs/Core Operating Limits Report (COLR)

1.2 Licensing of fuel - SER

Specifications - Vendor "Topical" report approved by regulator

1.3 Modifications of core and fuel design requiring licensing

Licensing procedures for modifications - Generally not reviewed unless major change involved

1.4 Quality assurance of nuclear fuel

Licensee's QA program - Documented in the FSAR

Manufacturer's QA program - usually documented in vendor's topical report approved by NRC. Not all vendor's have QA topicals.

Regulatory Inspection of fuel fabrication - inspections are issue driven and performance based.

2. REGULATORY INSPECTION PROGRAM DURING NPP OPERATION AND REFUELLING OUTAGES

2.1 Pre-Inspection of Each Delivery Batch of New Fuel - monitored by resident

2.2 Composition of new core after fuel exchange and reloading safety related values and margins - contained in regulator's SER

Required calculations by the operator - reviewed by the resident

Independent calculations by the inspector or the inspection authority - If submitted as a "topical" report. NRC uses National Lab as reviewer.

Use of computer codes - National laboratory analysis of new designs - FRAPCON Program

2.3 *Inspection of nuclear fuel operation*

The following activities are performed by the licensee and monitored by the resident inspector or regional staff.

- Verification of calculated core properties during start-up, required tests and measurements
- Periodic tests
- Inspection on these tests and measurements
- Verification of results
- Obtaining reference data

2.4 *Operating NPP with fuel defects*

- Contamination limits for reactor coolant - limits on coolant activity in technical specifications
- Policy and requirements for continued operation or shut-down - Technical specifications
- Radiological limits - technical specifications

2.5 *Fuel inspection after unloading the core*

- Visual Inspections - Licensee and/or Vendor
- PIE (Post Irradiation Exams) - Vendor/Owners Group
- Tests for fuel defects - limits on coolant activity in technical specifications
- Inspection of spacer grids - included in visual inspections, as needed
- Measurements of oxide layer of zircolay tubes - Fuel vendor supplies limit - generally 100 microns
- Requirements for storing defective fuel rods on-site - canister storage in spent fuel pool
- Inspection and repair of defective fuel elements:
  - Fuel sipping on site
  - Vendor Repair at site

2.6 *Fuel handling*

- Fuel Handling Tool Design - Evaluated During Inspections of Fuel Vendors
- Loading and unloading the core - FSAR/Design Basis

The following activities are monitored by the resident inspector or regional staff.

- Inspection of storage of new fuel
- Wet storage
- Inspection of spent fuel shipment

2.7 *Policy of evaluations of inspection findings - findings from inspections of licensees are factored into SALP ratings*

Abnormal occurrences, reportable events, follow-up of corrective actions - Impact on plant safety assessed through evaluations of licensee's core design and operation. Inspections are initiated by regions and supported by Headquarters staff. Inspections may lead to follow-up at fuel vendor. Results of licensee inspections may also be reported to the industry through generic communications.

3. PROCEDURES FOR INSPECTION PRACTICES AND INSPECTION PROGRAM

3.1 Is the reloading plan/core composition approved/endorsed by the inspection authority?

Yes. NRC has approved methods for vendors/licensee individual core reloads reviewed, SER issued by regulator.

3.2 What happens if the reloading plan must be changed during refuelling outage due to defective fuel elements foreseen for reloading?

Included in approved methods; may require SER revision.

3.3 Other procedures -

The NRC is developing a programmatic inspection procedure that will address core reload analyses and core performance data.