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Regulatory surveillance of safety related maintenance at nuclear power plants

Report of a Technical Committee meeting held in Vienna, 9–13 October 1995

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FOREWORD

Operational safety at nuclear power plants (NPPs) depends on, among other things, the quality of maintenance activities.

Inadequate maintenance sooner or later results in performance degradation or the occurrence of safety significant operational events. Ensuring effective maintenance is therefore a challenging management task in the operation of NPPs, as are the activities of the regulator in the monitoring of the maintenance tasks performed by the operators of NPPs. NPP operators are reconsidering their existing approaches to planning and evaluating maintenance activities to ensure effective and efficient maintenance.

Numerous analytical methods have been developed and are being implemented by the operators of NPPs. Under consideration are reliability centered maintenance (RCM) and risk focused maintenance (RFM), including the application of probabilistic safety assessment (PSA). These methods are all aimed at streamlining the maintenance activities by identifying those components that are the most critical for safe operation. Furthermore, these methods, through decision approaches, may assist in optimizing the preventive maintenance tasks.

All these developments require regulatory consideration and assurance that the requirements to maintain the safety of the NPP have been met.

CONTENTS

1. INTRODUCTION

The operational safety and reliability of a nuclear power plant as well as its availability for electricity generation depend on, among other things, its maintenance programme. Regulatory bodies therefore have considerable interest in maintenance activities.

There are several approaches to maintenance, i.e. reliability centered maintenance (RCM) or risk focused maintenance (RFM), aimed at optimizing maintenance by focusing on important components or systems. These approaches may result in significant changes to maintenance activities and therefore have to be considered for regulatory acceptance.

In order to review and discuss the status of maintenance regulation in participating countries, the IAEA convened a Technical Committee Meeting on Regulatory Oversight of Maintenance Activities at Nuclear Power Plants in Vienna from 9 to 13 October 1995. The meeting was attended by 16 experts from 11 countries.

In addition to the consideration of papers that were presented and which are reproduced here, extensive group and panel discussions took place during the meeting. These covered three main topics: general features and basic characteristics of maintenance regulation, regulatory acceptance of maintenance optimization and use of PSA for maintenance optimization. The discussions are summarized in Section 2.

Section 3 discusses the following three additional topics: regulatory involvement in the maintenance programme, modifications to the maintenance programme and personnel related aspects of maintenance.

The conclusions are presented in Section 4.

2. A BASIS FOR THE REGULATORY SURVEILLANCE OF MAINTENANCE

2.1. GENERAL FEATURES AND BASIC CHARACTERISTICS OF MAINTENANCE REGULATION

The following paragraphs are applicable to all maintenance activities in the nuclear power plant. It is expected that every country will have its own maintenance related regulations and requirements. It is up to the country to decide which requirements are appropriate or relevant, keeping in mind that safety is the responsibility of the licensee.

General statement

Maintenance is important to ensure safe nuclear power plant operation. It needs to be of a standard that is sufficient to ensure that the reliability and design requirements of the equipment are maintained. In this document, maintenance activities include remedial measures taken to prevent and to correct an equipment deficiency. This includes such activities as testing, inspection, preventive maintenance, corrective maintenance and other supporting activities.

Maintenance programme

The licensee needs to establish a maintenance programme using good practices and a quality assurance programme. Maintenance programmes normally identify the maintenance organization, interval/frequency, procedures, work plans, record keeping, training, etc.

The maintenance programme, especially the testing/inspection programme, needs to be based on information acceptable to the regulator. These data may be based on manufacturers recommendations, safety analysis, operating experience and engineering judgement. With proper justification of the criteria used, the classification of components and systems relevant to safety and the corresponding maintenance programme including intervals for preventive maintenance, testing and inspection, may also be based on or verified by probabilistic safety analysis.

If condition based maintenance is used, a condition monitoring system will be required to establish the necessary database.

The testing or inspection programme is important, for it verifies the condition of the equipment. Therefore, the regulator will normally approve the test or inspection programme for safety related equipment. In general, the maintenance programme for safety related equipment will be provided to the regulator for information and may require formal approval.

Changes to programme

Normally, any change or deviation to the maintenance programme affecting safety needs to be reported to the regulator. The reason and consequence associated with the change or deviation are clearly documented and made available to the regulator for review. The regulator may further request that the change or deviation be subject to formal approval. (See also Section 3.3 of this report.)

Maintenance organization

Maintenance programmes normally include a description of the maintenance organization, in accordance with a required quality assurance programme. All functions, roles and responsibilities of the organization are properly defined and delineated.

Post-maintenance testing and verification

When maintenance on a piece of equipment is completed, it is a good practice to thoroughly test it to show that it is capable of functioning in accordance with its design requirements. It may also be necessary to verify that the maintenance objectives are achieved or the original deficiency has been corrected.

In general, after maintenance, a formal process is established for returning the safety related equipment to service; this includes the post-maintenance testing of such equipment.

Contractors

It is expected that a licensee may use outside contractors for some maintenance activities. These contractors need to follow the same requirements as the licensee. However, the licensee has overall maintenance responsibility.

Maintenance criteria

The regulator might encourage the licensee to establish and make use of maintenance performance indicators covering the maintenance performed on the safety related equipment in order to judge the effectiveness of the maintenance programme related to the safety performance of the plant. These indicators may have to be reported to the regulator at agreed intervals.

Record keeping

Maintenance activities produce numerous records. Example of such records include test results, maintenance check sheet, etc. Normally, all maintenance records are kept in accordance with a quality assurance programme and when necessary they are made available to the regulator for inspection or audit.

Failure assessment

In general, the licensee assesses all internal and external operating experience including equipment failure and inspection findings to determine if it might be necessary to improve the maintenance programme and/or make design modification to equipment.

2.2. REGULATORY ACCEPTANCE OF MAINTENANCE OPTIMIZATION

From a regulatory point of view one can distinguish two important activity groups in a plant maintenance programme: first, periodic maintenance consisting of functional testing and in-service inspection as required by the technical specification and second, the remaining activities on safety systems, safety support systems and balance of plant (BOP) systems as planned under the responsibility of the licensee. The total programme needs to ensure design performance of the safety systems throughout the operational life of the plant and taking into consideration the challenging environmental conditions during accidents.

The first group has been introduced on the basis of the safety analysis and normally requires regulatory approval. Requests for changes to this group are reviewed in detail on the basis of operational experience. This review needs to be consistent with the safety analysis and applicable rules and regulations. The possibility of accepting requests for changes improves when accepted PSAs are available, as PSA may be used as part of the case to support proposed changes to maintenance frequencies.

The above mentioned second group seems more suitable for optimization at short notice due to the limited regulatory involvement but technical specification requirements etc., i.e. allowed outage times (AOTs), cannot be violated.

RCM is an approach to a performance based maintenance programme. The following main capabilities of RCM approaches can be recognized:

- to improve the maintenance programme,
- to find components and failure modes which were overlooked in the safety analysis,
- to identify improvements to plant safety by increased reliability and availability of systems and components,
- to optimize the collected man-dose,
- to optimize the use of available resources (e.g. manpower).

On the other hand, limitations in RCM applications can be expected from:

- the validity of any PSA or database that is used as part of the RCM process,
- the justification of RCM internal criteria,
- the common mode failure behavior when not adequately addressed in the PSA model or database,
- the fact that most optimization approaches take into consideration only the known failure modes.

Licensees are developing RCM methods in different ways. When the RCM approach is being considered for use in optimizing the maintenance programme, the licensees will normally:

- present a detailed description of the optimization approach,
- demonstrate the quality of the input data bases,
- demonstrate the adequacy of the methodology and the values of the internal criteria.

Changes resulting from the maintenance optimization process need to be validated or verified for impact against the specific NPP safety analyses and all appropriate operational experience.

Periodic review of the optimization process is advisable to incorporate operating experience including new failure modes and data.

In the optimization process due attention needs to be paid to maintain sufficient protection against unknown phenomena.

2.3. USE OF PSA FOR MAINTENANCE OPTIMIZATION

2.3.1. Analysis

In many countries, level 1 probabilistic safety assessments (PSAs) of NPPs have been completed in recent years, based both on generic data and on data specific to the plant.

Current maintenance programmes have been developed during the operating lives of the NPPs. They were originally based on the recommendations of the plant designers or manufacturers and have been developed following experience of operation of the plant and from the results of plant condition monitoring.

Future developments

Possible future developments in derivation of maintenance programmes include the following:

- Condition monitoring will have a greater influence and maintenance based on condition monitoring will replace time based maintenance for some specific plant items.

- PSA may be used as part of the case to support proposed changes to maintenance tasks and frequencies but specific studies may be necessary in areas such as in-service inspection of primary circuit components.

- If the PSA is fast enough, it may be used to provide information on how best to respond to changing situations, such as plant failures, which may require changes to planned maintenance activities.

- The RCM approach, which may make use of PSA, may be used to optimize maintenance requirements.

Uses of PSA

PSA can be used in maintenance optimization:

- to identify and rank key systems, components and failure modes (this is an important part of the RCM method);

- to recognize if more frequent maintenance is required in order to achieve risk targets;

- to assess the effects of changes to maintenance requirements on system availability and the overall plant risk for all operating and shutdown states;

- to assist with outage planning in particular to show that co-incident maintenance outages do not compromise the required level of safety;

- to justify existing maintenance requirements;

- as part of the case, to support reductions in maintenance frequencies.

Maintenance input to PSA

Maintenance findings can be used to support PSAs by providing plant specific data for the PSA and validation of PSA assumptions and models. Maintenance frequencies can affect component reliability data used in the PSA. Specific studies may be necessary to evaluate the effect on PSA input data of changes to maintenance frequencies and tasks.

Potential difficulties in the use of PSA for maintenance optimization

(1) Confidence in the results of the PSA:

  - validity of reliability data, use of generic data;
  - validity of the assumptions made and the model used;
  - possibility of unanticipated failure modes;
  - treatment of human error, particularly with regard to maintenance induced failures;
  - models and data for common cause failures.

(2) The need for commitment to the use of the PSA in terms of resources and keeping the PSA up to date. Effort required could be for example 1-2 man-years for each PSA.

(3) Determining acceptance criteria for changes in risk due to changes in maintenance in terms of integrated risk and instantaneous risk.

(4) Difficulty in assessing the effect on PSA input data of a change in maintenance frequency.

(5) PSAs based on conservative assumptions may not be as valid for use in maintenance optimization as a best estimate PSA.

6) PSAs may include simplifying assumptions, for example assessment of only representative parts of the plant, which could affect use of the PSA for maintenance optimization.

Precautions necessary in the use of PSA for maintenance optimization

(1) The PSA must be maintained as a living PSA, taking account of operating feedback and changes to plant and with an adequate commitment of resources.

(2) Feedback data must be collected and assessed to establish its implications on the PSA.

(3) The possibility of maintenance induced failures and common mode failures should be considered, including maintenance induced common mode failures, implying that the PSA should include consideration of human error.

(4) The PSA may have to be adapted or extended for use in maintenance optimization, for example by using best estimate rather than conservative assumptions or by assessing all trains of a system rather than representative trains.

(5) The overall risk criteria and/or technical specification requirements must still be achieved.

(6) Changes to reliability data assumed following changes to maintenance tasks or frequencies may be based on expert judgement but must be followed by validation including use of feedback from operating experience.

(7) Maintenance optimization may not be appropriate for inspection requirements for passive components — specific studies may be necessary for such components.

2.3.2. Conclusions

(1) PSA can be of great value in maintenance optimization but it must be used with care.

(2) Proposals arising from a PSA based approach to maintenance optimization can be considered on a case by case basis by the regulatory body without necessarily implying general approval of the methodology used.

(3) There may be other factors dictating maintenance frequencies, e.g. regulations on inspection of pressure circuit components (but it is possible that PSA based arguments might prompt reconsideration of the regulations, particularly if reductions in radiation doses would be achieved).

(4) PSA can be used to identify key systems, components and failure modes as part of the RCM process but caution is necessary in using PSA in other ways in maintenance optimization studies.

(5) Findings from PSA based RCM studies may be used as an aid to decision making on maintenance optimization.

3. DISCUSSION ON SPECIFIC TOPICS

3.1. GENERAL

This section of the report was added during a consultants meeting held in June 1996 in order to address additional aspects of regulatory surveillance of maintenance activities at NPPs, specifically:

- regulatory involvement in the maintenance programme,
- modifications to the maintenance programme, and
- personnel aspects of maintenance.

For the purposes of this section, the term maintenance programme refers to all periodic, routine, planned activities undertaken to ensure that components and systems fulfil their intended functions when they are required to do so. The maintenance programme consists of a schedule of maintenance activities listing tasks and frequencies and the procedures/instructions relating to those tasks. The tasks include testing and inspection as well as preventive and planned component replacement maintenance. Testing includes non-destructive testing as well as functional tests.

It is recognized that there are maintenance strategies that do not involve periodic activities, for example breakdown maintenance or maintenance based on continuous condition monitoring. These may be appropriate depending on the safety significance of the maintenance tasks and the components and systems and on the knowledge of their potential failure modes. Similarly, regulatory controls will be dependent on the safety significance of the task/component/system.

Of particular importance in ensuring the adequacy of maintenance are post-maintenance functional tests that are representative of the conditions that the component or system will experience in normal and anticipated abnormal use.

3.2. REGULATORY INVOLVEMENT IN THE MAINTENANCE PROGRAMME

The regulator's concerns are primarily with regard to maintenance of safety related systems. There are many maintenance activities in a maintenance programme for NPPs. The extent of involvement of the regulator is dependent on the practice in each country. The regulatory body may be involved in the following activities:

- To mandate rules and conditions to ensure an appropriate maintenance state of the systems related to safety, and a feedback system for operational experience (e.g. rules and guidelines for the contents of the maintenance programme for safety related systems, requirements for reviewing the maintenance programme based on new approaches);

- To approve the parts of the maintenance programme and all changes to these parts related to technical specifications, or, in general, related to safety;

- To monitor compliance with the maintenance programme and the related quality assurance programme (e.g. by requiring the licensee to report on the extent of his compliance with a maintenance programme, or by sample inspections of maintenance records and check sheets);

- To monitor and assess the results of the maintenance programme (e.g. functional test, non-destructive tests, preventive maintenance, inspections, surveillance of systems);

- Witnessing by representatives of the regulatory body of selected maintenance activities;

- Assessment of maintenance work instructions and checklists;

- Consideration of proposals for RCM, condition directed maintenance, etc.

3.3. MODIFICATIONS TO THE MAINTENANCE PROGRAMME

3.3.1. Reasons for modifications to the maintenance programme

Modifications to the maintenance programme can be requested either by the licensee or by the regulatory body. The potential effect of modifications to the maintenance programme on plant safety will be of primary interest to both parties.

The licensee may wish to modify the maintenance programme for the following reasons:

- To overcome deficiencies identified during experience of plant operation and performance;

- To increase plant availability, for example by transferring maintenance tasks from outages to on-line;

- To respond to changes in manufacturer's recommendations;

- To avoid maintenance that is inappropriate either because it is not effective or because the maintenance interval is not optimal;

- As a result of application of new maintenance planning techniques and/or strategies (e.g. replacement of time directed maintenance by condition directed maintenance or use of new methodologies for maintenance optimization).

The licensee might require temporary, short term changes to the maintenance programme and/or exemption from maintenance requirements for reasons of operational convenience, plant unavailability, or to take advantage of forced shutdowns.

The regulatory body may ask for modifications to the maintenance programme:

- to increase reliability and safety following identification of deficiencies in the programme;

- to achieve a required level of reliability (for example as identified in a PSA).

The regulatory body might also require use or encourage use of systematic maintenance planning techniques which may result in modifications to the maintenance programme.

3.3.2. Justification of proposals for modifications to the maintenance programme

When a licensee requests that a regulatory body approve a proposed modification or temporary change to a maintenance programme, it will normally present a justification for the proposal which may include:

- Use of operational experience feedback from routine collection and analysis of plant performance data and in reaction to plant failures both at the site and elsewhere;

- Use of specific indicators which address aspects of maintenance, such as trends in the requirement for corrective maintenance or unavailability of trains of safety systems;

- PSA results which demonstrate the adequacy of the proposed modification or change and the contribution of it to the level of safety (presuming that at least the current level of safety has to be demonstrated).

3.3.3. Consideration of proposals for modifications to the maintenance programme

In considering whether to accept a proposed modification to the maintenance programme, the regulatory body's assessment will address the following topics in order to avoid unanticipated results:

- Achievement of reliability targets;

- The balance between availability and reliability of safety related components and systems — if, in order to achieve the reliability target, availability falls to an unacceptable level, design changes may be necessary;

- Effects on the PSA in terms of the significance of the proposed modifications and the resulting decrease in risk;

- Use of expert judgement based on knowledge of the design of the systems and components and their behaviour during operation (from operational experience feedback);

- Recommendations from component manufacturers;

- Standards/rules/specifications.

During the assessment process particular attention needs to be given to proposals for large changes in maintenance frequencies, even when a justification has been made. It is preferable to make changes to maintenance frequencies in small (step by step) increments in order to build up experience to support the intended final frequency.

3.3.4. Developments in tools and techniques that may be used to support proposals for modifications to the maintenance programme

The following tools and techniques are in use or are being developed to assist with optimization of maintenance programmes:

(1) Condition monitoring systems, including vibration monitoring, fatigue damage monitoring, infrared cameras, etc.: condition monitoring can be used as an alternative or supplement to time directed maintenance to give advance warning of when corrective maintenance will be necessary. The use of such systems in maintenance optimization is dependent on several assumptions:

- that the monitored parameter is an appropriate indicator for the condition of the system or component,
- that acceptance criteria are available,
- that symptoms oriented procedures are available and corrective actions can be taken as required.

Implementation of condition monitoring systems, particularly for components of high safety significance, needs to be carefully monitored to ensure that all failure modes are addressed.

(2) Operational experience feedback: the operating performance of components and systems (both plant specific and generic if appropriate) can be used together with expert judgement to identify the need for changes to the maintenance programme and to assess the effects of proposed modifications to a maintenance programme.

(3) Risk monitoring: on-line risk monitoring may be used to assist with scheduling maintenance activities so that availability requirements and risk criteria are achieved, subject to acceptance by the regulatory body that the technique is appropriate for this application.

3.4. PERSONNEL ASPECTS OF MAINTENANCE

Maintenance is often a complex process and the results of maintenance depend considerably on human performance, above all on the performance of maintenance personnel. In order to achieve a high level of performance from its maintenance personnel, it is essential that the licensee develops a strategy for training of personnel as part of its quality assurance programme.

Training of personnel will ensure development of the competence of the staff by addressing the following topics:

- Theoretical knowledge of the components and systems with which the person is involved;

- Skills and attitudes in order to perform maintenance duties properly and with high quality — these should include self checking techniques, e.g. STAR (stop, think, act, review);

- Special skills and knowledge when required for specific tasks, e.g. welding for which a licence or other authorization may be required;

- Radiation protection and procedures for working in areas of high radiation so that the work environment has no impact on work performance;

- Transfer of operational and maintenance feedback experience, especially focused on good practices in maintenance and on maintenance induced failures;

- For complex maintenance tasks and/or work in high radiation areas, practice on full scale models to improve the efficiency and quality of the work.

The same requirements for training of maintenance personnel also apply to contractors working on maintenance tasks.

It is also necessary that the licensee pay appropriate attention to the training of other personnel involved in maintenance, including:

- maintenance planning,
- maintenance control,
- maintenance supervision,
- post-maintenance checking and testing.

Good administration can also contribute to achievement of the required quality in maintenance.

To achieve the goal of high quality maintenance, the licensee needs to establish a continuing process of maintenance staff training and will periodically require demonstration and verification of the knowledge and skills of maintenance personnel. It is necessary that the regulatory body monitor all aspects of training of maintenance personnel described above.

4. CONCLUSIONS

The nuclear industries in many countries are under pressure to improve safety and control costs, at the same time as the population of reactors is ageing. One of the key factors in reconciling these potentially conflicting trends is optimization and quality control of maintenance. This report has addressed some aspects of regulatory surveillance of maintenance activities at NPPs, in particular new techniques in maintenance optimization, modifications to maintenance programmes and personnel aspects of maintenance.

Regulatory bodies need to keep themselves informed of developments relating to maintenance so that they can respond to initiatives by the licensees and, in some circumstances, encourage or direct licensees to make use of new techniques. The participants in the Technical Committee and consultants meetings have appreciated the opportunities provided by the IAEA to discuss topics related to regulation of maintenance and hope that some of the ideas presented in this report may be of interest and use to readers who were not at the meetings.

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REGULATORY ISSUES IN THE MAINTENANCE OF ARGENTINE NUCLEAR POWER PLANTS

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Abstract

The influence of maintenance activities upon nuclear safety and their relevance as a means to detect and prevent aging make them play an outstanding role among the fields of interest of the Argentine nuclear regulatory body (ENREN).

Such interest is reinforced by the fact that the data obtained during maintenance are used —among other— as inputs in the Probabilistic Safety Analyses required for those nuclear power plants.

This paper provides a brief description of the original requirements by the regulatory body concerning maintenance, of the factors that led to review the criteria involved in such requirements and of the key items identified during the reviewing process. The latter shall be taken into account in the maintenance regulatory policy, for the consequent issue of new requirements from the utilities and for the eventual publication of a specific regulatory standard.

The Argentine nuclear power plants

Argentina has two nuclear power plants in operation: Atucha I, 350 MWe PHWR, and Embalse, 600 MWe CANDU. A third PHWR NPP —Atucha II— is presently under construction, without a definite date for a soon start of commercial operation.

Atucha I started commercial operation in 1974 and, except for Atucha II, is the only one of its type in the world. It is a KWU design and was supplied on the basis of a turnkey operation.

Embalse started commercial operation in 1983 and, as it is well-known, its design has been broadly tested and diffused.

Original regulatory requirements and utility activities concerning maintenance

Both plants are operated under licenses granted by the ENREN and, since the very start of their operation, such licenses establish, as a regulatory requirement, that ***"the degradation of the installations' components, equipment and systems shall be prevented by means of adequate preventive and predictive maintenance"***.

Control of compliance with this requirement has been traditionally performed through routine inspections, through special inspections during scheduled outages and by means of audits in the framework of the Quality Assurance Programme.

The utilities have applied maintenance practices focused on their organizational areas, such as mechanics, electricity and instrumentation and control. Although such practices are a basic and important part in a maintenance programme, they have not been assembled in a single document following modem, well-defined and accepted criteria.

In compliance with explicit requirements in the operating license, they have also implemented their in-service inspection programmes.

In the case of Atucha I, the initial in-service inspection programme included only a few practices and non-destructive tests. Since then, the programme has been developed, has evolved to cover the whole installation and is presently ruled by the plant's own standard based on Section 9 of ASME Code *"Boiler and pressure vessel code"*, 1986 issue.

Contrarily, since the start of its operation, the Embalse NPP has been applying an in-service inspection programme ruled by Canadian Standard CSA-CAN3-N 285.4-M 83. Considering the operational experience in this type of installations, both the maintenance and the in-service inspection programmes are better structured.

Both Atucha I and Embalse are supplementing their maintenance practices with their respective periodic tests programmes.

The Atucha II construction license has been enforced, requiring compliance with Standard AR 3.7.1. (*"Documentation to be submitted to the Regulatory Authority prior to the commercial operation of a nuclear power plant"*) that, in turn, requires the presentation of the installation's Maintenance Manual within one month prior to the request of an operating license for full-power operation.

Delays incurred in the execution of the Atucha II project have caused a large number of parts and components to be stored for long periods broadly exceeding those foreseen by their manufacturers. Consequently, there was a need to assess the effects of such storage upon such materials, the optimum conditions and features required for storage and the type of maintenance required for the various components.

This situation led the regulatory body to issue detailed requirements concerning the transport, storage and maintenance of safety-related components, materials, parts and spare parts. Compliance with such requirements was controlled by means of special inspections and audits, including temporary warehouses at some manufacturers' premises.

In addition to the above described requirements, no other maintenance-related requirements exist, nor are maintenance practices expected to contemplate specific techniques or to contain any distinct elements.

Operational incident at Atucha I - Review of regulatory requirements

The regulatory policy being applied in connection with nuclear power plant maintenance —in the form of license requirements and of applied control measures— was unchanged and appeared to be sufficient until an operational incident occurred at Atucha I in August 1988.

Summarizing, the incident involved the breakage of a coolant channel and of a fuel element contained therein, plus the partial detachment and breakage of a level-measuring probe in the moderator tank.

As a result of this event, the National Atomic Energy Commission —at that time, the utility— had to develop and operate the technological tools required for removing the pieces of the fuel element, of the coolant channel and of the thermal insulation plates in the moderator tank that had been previously detected by means of TV cameras.

The plant was shutdown until December 1990 and, considering the modifications introduced due to the incident and the need to monitor the evolution of the reactor internals and to prevent the recurrence of such failure or the occurrence of similar ones, the nuclear regulatory body added a series of new requirements to the license, submitted the re-start of the plant to the implementation of the necessary measures for their compliance and intensified controls related to maintenance after re-start.

Also, taking into account the time during which the plant had been in operation and the results of several evaluations, the performance of backfitting tasks was required, including:

- Installation of additional instrumentation in the reactor core.
- Building an additional heat sink.
- Installation of a fully-independent emergency power supply system.
- Implementation of a monitoring system for detecting loose parts within the moderator tank

Operational incidents at Canadian CANDU plants

In December 1994, a spurious opening of the liquid release valves occurred at the primary heat transport system of the Canadian nuclear power plant Pickering A, due to a breakage of their diaphragms. Similar incidents had previously occurred at the Wolsung and Bruce Plants.

The corresponding assessments indicated that the main reason for diaphragm failure was aging.

Following to this operational experience, our regulatory body demanded the utility in charge of the Embalse NPP –where the same failure had occurred– to analyze the problem as related to that installation and to include the necessary measures to prevent such failure among its maintenance activities, while reporting on how this would be performed.

Further on, the regulatory body emphasized its own control activities over compliance with such measures.

The need to review the regulatory policy

Both the experience gained at Atucha I and other external factors led to the decision of reviewing the previously issued maintenance-related regulatory requirements and of modifying them on the basis of modern criteria arisen from operational experience and from the application of specific techniques in the nuclear field and of practices being applied in other industries, such as aeronautics.

Among the above-mentioned external factors, the following are to be noted:

- The growing importance given to maintenance all over the world, considering its influence upon nuclear safety and its relevance as a tool for detecting and preventing aging.
- The experience developed by nuclear power plant operators abroad, although applying different basic criteria.
- The efforts applied and the resources dedicated by other regulatory agencies in the creation of specific standards in this issue.

Undoubtedly, the results of the review process shall be influenced by local factors, such as:

- The scarce number of nuclear plants in operation in our country.
- The difference in technology between both plants.
- The fact that one of the technologies is unique in the world and exclusively applied in our country.
- The impact to be exerted by the new requirements upon the utilities.

Current situation of the reviewing process

Although the reviewing process is yet unfinished and, therefore, the new requirements are still to be issued, the following needs have already been identified as a result of such process:

1. A plant's integral maintenance program, in the form of a single document, involving the following areas of interest:

- Organization, planning and management
- Maintenance technologies
- Assessment of the programme's efficiency, evaluation and monitoring
- Specific training of personnel

2. A maintenance programme involving the following attributes:
   - A defined maintenance policy established in writing.
   - A well-defined organization with a broad safety culture.
   - Clear and long-term objectives.
   - A clear definition of interfaces between maintenance and other activities, such as operation and engineering.
   - Definite and validated methods for assessing its effectiveness.
   - Collection of data on failures and the corresponding engineering evaluation and root cause analysis.
   - The establishment and follow up of high labor and quality standards.
   - Well-trained and qualified personnel.
   - Sufficient facilities and resources.

3. The use of performance indicators belonging to the following categories:

   * Processes
   * Equipment
   * Miscellaneous

4. Application of the reliability-centered maintenance (RCM) method, in agreement with the probabilistic safety criterion already adopted by the regulatory body, and requiring the plants to develop their own Probabilistic Safety Analyses.

5. A close relationship between the maintenance and quality assurance programmes

6. Promotion of the following practices, considered as beneficial for maintenance, by the utilities:

   * Self assessments
   * Visits by maintenance assistance review teams
   * Assistance on outage management
   * Human performance evaluation
   * Maintenance peer evaluation
   * Long-range performance evaluation
   * Training accreditation
   * Workshops

7. An efficient system for the identification, collection, filing and processing of maintenance data.

8. Application of maintenance data in backfitting implementation.

9. Emphasis on the importance of a special management of parts and spare parts, particularly in the case of the oldest plants.

10. Emphasis on the importance of managerial self assessment towards verifying compliance with the established goals.

Final remarks

The progress attained in the reviewing process concerning regulatory issues related to maintenance allows for assuming that, considering their relevance, the needs or criteria identified, as listed above, shall have an influence upon the regulatory policy in such field and shall be taken into account in future requirements to be issued for nuclear power plants and, eventually, in a specific regulatory standard.

Considering the above, it is reasonable to expect that:

- primarily, such policy will focus its demands on pro-active maintenance (as opposed to reactive maintenance) programmes and on long-term objectives;

- the regulatory body will exert a more strict control upon:

  - maintenance issues concerning safety and safety-related components and systems;

  - the validity of the data obtained from the maintenance programme and used as inputs for the Probabilistic Safety Analysis;

- the regulatory body, either by itself or through independent verifiers, will verify the effectiveness of the maintenance programmes, using —among other tools— carefully selected performance indicators.

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REGULATORY REQUIREMENTS RELATED TO MAINTENANCE AND COMPLIANCE MONITORING

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Canada

Abstract

The maintenance related regulatory requirements are identified in the regulatory documents and licence conditions. Licensee complies with these requirements by operating the nuclear power plant within the safe operating envelope as given in the operating policies and principles and do maintenance according to approved procedures and/or work plans. Safety systems are regularly tested. AECB project officers review and check to ensure that the licensee operates the nuclear power plant in accordance with the regulatory requirements and licence conditions.

1.0 Introduction

Atomic Energy Control Board (AECB) is the independent federal agency that controls all nuclear activities in Canada. Our mission is to ensure that the use of nuclear energy in Canada does not pose undue risk to health, safety, security and the environment. We assess every station performance against legal requirements, including the conditions in the operating licences we issue. To do this we review all aspects of a station' s operation and management and we inspect each station.

2.0 Regulations

The Atomic Energy Control Act gives the AECB the authority to make regulations. The Atomic Energy Control Regulations give the AECB the authority to issue a Power Reactor Operating Licence (PROL) to a licensee. The standard PROL contains conditions the licensee must observe including specific references to the licensee's own operating documents.

3.0 Regulatory Documents And Sample Maintenance Requirements

Table 1 is a list of sample regulatory documents and National Standard of Canada. These regulatory documents and the licence contain specific maintenance related requirements for the nuclear power plant and the special safety systems. Table 2 provides a sample of regulatory maintenance requirements for the shutdown system. Table 3 is a sample of maintenance related licence conditions that a licensee must comply with.

Table 1: AECB Regulatory Documents

AECB Regulatory Documents (Sample requirements for discussion only)		
R-7	-	Requirements for Containment Systems for CANDU Nuclear Power Plants.
R-8	-	Requirements for Shutdown Systems for CANDU Nuclear Power Plants
R-9	-	Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants
Power Reactor Operating Licence for Nuclear Generating Station.		
R-99	-	Reporting Requirements for Operating Nuclear Power Facilities
R-98	-	Reliability Requirements for Safety Related Systems of Nuclear Reactor Facilities (For Information Only)
CAN3-N290.1	-	Requirements for the Shutdown Systems of CANDU Nuclear Power Plants

Table 2: Regulatory Maintenance Requirements

Regulatory Maintenance Requirements (Sample requirements for discussion only)	
1.	If any component of a shutdown system is found to be inoperable, or impaired below its minimum allowable performance standards, that component and its associated equipment shall immediately be put in a safe condition. (R-8, 4.1.6)
2.	As far as practical, maintenance of a shutdown system component shall be carried out only when that component and its associated equipment have been put in a state which does not reduce the availability of the shutdown system. (R-8, 4.1.7)
3.	Maintenance of a shutdown system component shall be carried out only on one channel at a time and with the affected channel placed in a safe state. (R-8, 4.1.8)
4.	When maintenance on a channel is completed, it shall be thoroughly tested to demonstrate to the extent practical that the equipment associated with that channel is capable of functioning in accordance with its design requirements. This shall be done prior to returning the channel to its poised state. (R-8, 4.1.9)
5.	If redundant components require maintenance, each component shall be thoroughly tested following its maintenance, prior to the start of work on a subsequent component. (R-9, 4.1.5)

Table 3: Licence Conditions

Licence Conditions (Sample requirements for discussion only)	
A.A.11	Maintenance at the nuclear facility shall be of such a standard that, in the opinion of the Board, the reliability and effectiveness of all equipment and systems as claimed in the Safety Report and the documents listed in the application are assured.
A.A.13	Except as otherwise directed in writing by the Board, all systems shall be tested at a frequency sufficient in the opinion of the Board to substantiate the reliability claimed or implied in the Safety Report or in the documents listed in the application.
A.A.14	Except with the prior written approval of the Board, no change which would render inaccurate the descriptions and analyses in the Safety Report or in the documents listed in the application shall be made to the reactor shutdown system no. 1, shutdown system no. 2, the containment system, the emergency core cooling system or associated systems necessary for the proper operation of these systems.

The licence also contains the reporting requirements that a licensee must comply with. On Table 4 is a sample of an event reporting requirements.

Table 4: Reporting Requirements for Operating Nuclear Power Facilities

Reporting Requirements for Operating Nuclear Power Facilities (Sample requirements for discussion only)	
1 1	An event report shall be submitted for· - a violation of licence condition; (a) - a degradation of a special safety system or a relevant safety-related system that prevents a special safety system or a safety related system from meeting its defined specifications; (j) - a reduction of the effectiveness of the systems for reactor power control, for the primary heat transport system pressure and inventory control or for turbine protection, below the defined specifications (whether caused by failure, equipment inadequacy, improper procedures or inappropriate human action); (l) - a failure to perform a test that is required by a licence condition, including any routing test of a safety-related system that is required in the licensing documents, except in accordance with approved procedures. (s)

4.0 Compliance

To comply with the operating licence, a licensee must demonstrate that the nuclear facility has been operated within the frame work set out by the regulations and licence conditions. Table 5 is a sample of documents that contain maintenance requirements to which the licensee operate the nuclear power plant. Table 6 provides a sample of the maintenance related operating policies and principles which are referenced in the operating licence.

Table 5: Licensee Documents Containing Maintenance Requirements

Licensee Documents Related to Maintenance (sample only)
Operating Policies and Principles (OP&P) Requirements
Various Maintenance Procedures and Policies
Work Plans

Table 6: Operating Policies and Principles (OP&P)

Operating Policies and Principles (OP&P) (sample limits for discussion only)
00.2.2 Operation and Maintenance Standards
Operation and maintenance standards shall be such that the reliability and effectiveness of equipment (as claimed in the Safety Report) is assured.
0.02.3 Maintenance Authorization
The Shift Superintendent (or Shift Supervisor) shall be aware of all maintenance activities. The Shift Superintendent (or Shift Supervisor) shall directly authorize all maintenance on systems required to control reactor power, cool the fuel, and contain radioactivity during normal operation and following any postulated accident.
0.02.4 Maintenance of Special Safety System
Components in Special Safety Systems shall be placed in a safe state prior to performing maintenance unless Operation Manager approval is given for an alternative state. The method of performing maintenance on channelized systems, which shall be used unless Operations Manager approval is given for an alternative method, is to put in a safe state, repair, test, and return one channel to service prior to working on another channel.

5.0 Monitor For Compliance

AECB project officers at the station:

5.1. Do routine check of equipment/station performance and report the results.

We looked at the licensee daily shift supervisor report to its management. We looked at any failure, test or abnormal events. If necessary, we will do an inspection of the system and follow up with the licensee. Licensee also inform us of a unit outage schedule and the maintenance work to be done.

We report the results of our review of station performance regulary to our management and staff. Also, the annual assessment report on the station operation includes maintenance performance indicators. We have formed a Performance Indicators Team to better define the indicators. The team's task has not been completed yet. In the interim, given below are some of the indicators that we used to assess maintenance compliance:

5.1.1 Jumper

Licensee uses jumper to record and authorize temporary changes. The number of jumper increases when a unit is shut down, as jumper is used to record temporary changes which are required during maintenance. High number of jumper could indicate that there are still many maintenances/modifications to be completed.

5.1.2 Preventive maintenance, preventive maintenance to corrective maintenance ratio and calls up

Good preventive maintenance program is essential to the safe operation of the station. Proper preventive maintenance on plant equipment will minimise or eliminate equipment breakdown.

5.1.3 Net capacity factor

High net capacity factor indicates:

- Process systems are functioning well.

- Process systems are able to be tested and the availability of equipment can be verified under operating conditions.

- Maintenance is such that systems can be operated satisfactorily to meet requirements.

- Safety system testing can be performed to verify the system and equipment availability.

5.2. Review maintenance related requests that affect safety system performance

If a maintenance work affects safety system performance, the licensee is required to get AECB approval. Usually, before we approve such request, we review the licensee's submission to check that under various accident conditions there will be no fuel failures or potential for releases to the environment.

5.3. Review Maintenance Procedures and Work Plans

We review, but no approve, the maintenance procedures and work plans. We review to check if maintenance procedure follows the regulatory requirements or the operating policies and principles. For example, we check that test or maintenance is done one channel at a time, after putting the channel in a safe state.

5.4. Check special safety system test frequency and change to test frequency

We check that special safety system tests are done as scheduled. When test frequency is changed, licensee informs us of such change. We check to see if the availability requirement is still met.

5.5. Review Outage Work

We review the outage work with the licensee. We check to see if outage work includes those commitments that the licensee made to us.

6.0 Conclusions

The maintenance related regulatory requirements are specified in the regulatory requirements and licence conditions. Licensee complies with these requirements by operating the nuclear power plant within the safe operating envelope as given in the operating policies and principles and do maintenance according to approved procedures and/or work plans. AECB project officers review, check, inspect and audit the maintenance activities at the nuclear power plant to ensure that the licencee operate the plant in accordance to the regulatory requirements and licence conditions.

XA9745103

REGULATORY ISSUES IN NUCLEAR POWER PLANT MAINTENANCE IN CHINA

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Abstract

At present two nuclear power plants are operating in China. The safety of NPP is supervised by National Nuclear Safety Administration.

The current legislation on nuclear safety is specified as State Administrative Regulations and NNSA Department Regulations. For the safety of NPP 4 safety codes and 48 guides have been issued on sitting, design, operation and quality assurance, which have been developed in light of IAEA NUSS documents.

The safety requirements on maintenance for NPP are included in the safety code for NPP operation, and the safety guide "Maintenance of NPP".

Regulatory Issues in the NPP Maintenance in China

In China, the NPP construction was started in 1984. At present time there are 2 NPPs in operation. One is Qinshan NPP with 300 MW(e) PWR, and has been operating since December 1991. The other is Guangdong NPP with 2 units per 900 MW(e) and has been operating since August 1993. Both NPPs have completed their first fuel reloading and have had their own periodic maintenance respectively.

The safety of NPP construction and operation is strictly under surveillance and control of Chinese National Nuclear Safety Administration, which was established in 1984.

The current legislation on nuclear safety is specified as State Administration Regulations, these are:

- Regulation on Safety Supervision and Control for Civilian Nuclear Installations;
- Regulation on Nuclear Material Control;

- Regulation on Nuclear Emergency Control;

- Regulation on Radiation Protection of Radioactive Isotopes and Radiation Generating Facilities.

The nuclear safety regulations are specified as NNSA department implementation rules and Safety Codes and guides. These regulations have been developed in 6 areas: NPP, Research Reactors, Fuel Cycle, Nuclear Material, Emergency Management, and pressure retaining Component.

For the safety of NPP, 4 safety codes and 48 safety guides have been issued on sitting, design, operation and quality assurance. The codes are statutory documents defining nuclear safety objectives and requirements. Safety guides are non-mandatory documents providing a guidance to interpret the requirements of codes, or to recommend methods and procedures for meeting the safety requirements.

All these safety codes and guides have been developed in light of IAEA NUSS documents with some modifications were necessary for meeting national conditions. After Chernobyl accident, following the revision of IAEA NUSS codes, our national revised codes had been issued in 1991.

The safety requirements on maintenance for NPP are included in the Safety Code for NPP operation. A special safety guide was also issued to provide detailed guidance for the maintenance of NPP.

The basic requirements for maintenance include:

- A periodic maintenance (testing, examining, inspection) programme for the structures, systems, and components essential to safe operation shall be prepared by operating organization before operation, and shall be available to the regulatory body;

- The written maintenance instructions and procedures shall be prepared by operating organization in co-operation with designers, suppliers, QA and radiation protection personnel before maintenance;

- The programme shall be carried out by qualified persons, using appropriate equipments, and techniques.

- The standards and frequency of maintenance shall be determined by their relative importance and shall ensure that their level of reliability and effectiveness remains in accord with the design and satisfy the licensing conditions.

- The structure, systems and components shall be tested, examined or inspected after maintenance and before their normal operation. Records shall be maintained and available for the regulatory body.

In our practice the programme of periodic maintenance of structures, systems and components important to safety shall be reviewed by NNSA, and its implementation shall be under surveillance of inspectors of NNSA regional office.

XA9745104

USE OF RISK IMPORTANCE MEASURES IN MAINTENANCE PRIORITIZATION

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Abstract

A RCM method has been developped at EDF since 1990 to optimize maintenance through a prioritization of resources for equipments that are important in terms of safety, availability and maintenance costs.

In 1994, the Nuclear Power Plant Operations Division decided to apply this method to the most important systems of the french PWRs. About 50 systems are in the scope of the RCM. Those that have a role in safety were ranked depending on their contribution to the risk of core melt provided by PSAs. The RCM studies on the 20 most important to safety systems are performed by the Nuclear Power Plant Operations division, the other 30 systems are studied on sites.

The RCM study consists first in the research of equipments and failure modes significant to safety, availability or maintenance costs and the evaluation of the performance of those equipments. Those studies lead to the distinction of equipements and failure modes that are critical or non critical to safety, availability and costs. The last part of the study consists in optimizing maintenance on those equipments.

In this process, risk measures are used to help defining equipements and failure modes critical to safety. This is done by calculation of risk importance measures provided by PSAs. We explain in this paper which measures of risk have been defined, how PSAs allow calculation of those measures, and how we used those results in the RCM studies we processed. We give also extensions of the use of those measures in the process of defining optimized maintenance tasks.

After having defined a RCM method for the french PWRs, the Nuclear Power Plant Operations Division decided to start a generalized program of maintenance optimization for the most important systems. The three criteria on which the method relies are : safety, unit availability and maintenance costs. We present here the safety aspect of the method and more precisely the use of risk importance measures in the RCM process.

1. SAFETY SYSTEMS SELECTION AND RANKING

About 50 systems were selected to be in the scope of the RCM program. About 20 of these have a significant role in safety. The ranking of the systems for the safety critieria was done using the system contribution to the risk of core melt provided by PSAs. The safety systems examined are those for which the contribution to the risk of core melt represents at least 0.5% of the global risk calculated by PSAs.

The main safety systems studies that require an intensive use of PSAs remain in charge of the Nuclear Power Plant Operations Division. Other systems are studied on NPP sites.

2. IDENTIFICATION OF CRITICAL EQUIPEMENTS AND FAILURE MODES FOR THE SAFETY CRITERIA

Safety requirements are taken into account in the functional study of a system by means of a process intended to highlight :

- the failure modes whose effects result in a significant increase in core-melt risk or initiation of an emergency procedure,
- equipments whose unavailability is governed by French Technical Specifications.

This process (see Appendix 2) takes the form of a series of questions addressing the following points:

① Is the equipment modelled in the PSA? If so, what are the core-melt risk importance measures of its failure modes ?
The definition of these contributions and the thresholds adopted are discussed hereafter.
If one of the values exceeds the threshold, the failure mode is declared to be critical. A failure mode declared to be critical is mandatorily given special attention through enhanced monitoring or appropriate preventive maintenance.

② Can an equipment failure constitute an initiating event requiring implementation of an incident or emergency procedure? If so, the failure is subject to Operating Feedback examination in order to determine the appropriate technical choices.

③ Is the unavailability of the equipment governed by French Operating Technical Specifications? If so, the failure modes inducing its unavailability are identified and strictly examined, particularly through operating feedback, to deduce the most appropriate preventive maintenance policy.

④ The last step consists in taking into account the regulatory definition of important to safety equipments, in order to ensure the exhaustivity of this search for critical failure modes.

3. USE OF PSAS RISK MEASURES TO DETERMINE CRITICAL FAILURE MODES

3.1 Method for selecting critical PSA fault modes

In conjunction with the other criteria defined above, PSAs are used to identify critical safety-related fault modes.

The selection process involves two risk indicators (one for measuring the risk contribution, and one for measuring the "risk achievement") which can be used to assess the importance of equipment failure modes with regard to the risk of core melt.

Care is taken to use both measurements of the importance of risk, for they do not have exactly the same meaning.

A threshold has been defined for each of these indicators: beyond it the failure mode is said to be "critical".

3.1.1 Measurement of contribution

The contribution a failure mode for a set of equipment makes to the risk of core melt is the proportion of risk induced by that mode. It is therefore the difference between the risk calculated with the failure and the risk calculated without the failure.

It is measured with the Risk Reduction Worth (RRW) which determines the relative proportion of risk induced by the failure.

It is calculated for each failure mode for sets of equipment. A set of equipment is a group of identical equipment having the same function for which it is not envisaged to have different maintenance programmes.

When the measured contribution of a mode is higher than the threshold, the mode is said to be critical for the set studied, and each equipment item of the set is critical for the mode.

3.1.2 Risk achievement worth

A second calculation determines the Risk Achievement Worth (RAW) resulting from the failure of the equipment. The RAW gives a relative measurement of the core melt frequency global increase if the component becomes unavailable (or more precisely, when the failure mode is certain, i.e. with a probability of occurrence of 1).

The procedure involves measuring the increase in risk due to the failure of equipment items taken individually, for it is assumed that the equipment failures are independent of each other.

When the RAW for an equipment item is greater than the threshold, the equipment is said to be "critical for safety".

3.1.3 Choice of thresholds

Contribution threshold

A threshold of 0.1% has been adopted. This corresponds to a 1% increase in risk when the failure rate of a set of equipment is multiplied by a coefficient of 10.

This threshold matches the criteria for definition of the safety-sensitive equipment, equipment for which data will be updated every three years.

Risk achievement threshold

A threshold has been adopted, which is coherent with the criterion of the Operating Technical Specifications (OTS) corresponding to the definition of "group 1" equipment: the calculation of OTS criteria is based on a maximum increase in the core-melt risk of 10^{-7}. Group 1 equipment is that for which the allowed unavailability time with the unit operating is less than 15 days. The corresponding value for the risk achievement threshold is 5%.

3.2 Results obtained

The equipment items or sets of equipment, and particularly equipment for which at least one failure mode has been selected after assessment of the risk reduction worth or risk achievement worth, are taken as critical for safety, following the PSA criteria.

The procedure recalled above therefore makes it possible to obtain a list of safety-critical equipment, as defined for PSA, and of risk indicators concerning the failure modes of individual equipment items or sets of equipment.

Besides those quantitative results, these studies lead to a qualitative interpretation. The list of safety-critical equipements is compared to the list of equipment that are subject to the existing preventive maintenance program, the differences are analyzed and justified.

This procedure has already been used for ten or so thermohydraulic systems of 900 or 1300 MW nuclear power plants where the systems have an important role with respect to safety. The resulting list of safety-critical equipment is often very similar to that already subject to a preventive maintenance programme. However, some differences can be observed: for example, on the AFWS of 900 MW units, the resulting list revealed the importance of a manually operated valve common to most of the configurations used for refilling the AFWS tank, and of the sensors necessary for operating the system under emergency conditions. On the contrary, because of their redundancy, the steam inlet valves of the AFWS turbine are not critical according to PSA criteria.

The main value of this approach is to lead to a better traceability of the selection of safety-critical equipment by taking account of the actual level of performance of the equipment and its exact role in safety functions.

Critical components that will be subject to preventive maintenance are generally better identified. The method allows optimization of maintenance actions for greater efficiency of the preventive maintenance program. This should result in enhanced equipements reliability, and therefore greater safety.

3.3 Specific difficulties

Limits of the PSA model : example of the hidden missions of a system

One of the major difficulties is to find out which equipement failure mode can be hidden in the model. For examples, if the mission of a system is initiated by an operator action, the equipment failure modes are often negligible because of the higher rate of human error. In this case, the equipment failure modes are not explicitly modelled in the PSA, so that an automatic sensitivity study would not take into account the failure of the mission due to an unavailability of the system. Another example is the hidden contribution of a system to an initiating event in the accident sequences. Those difficulties are common to each type of PSA tool and require a specific study for each system contribution evaluation.

Datas and operating feedback

This use of PSA requires high-quality data, and therefore makes extensive use of operating feedback. But feedback introduces a problem of bias: equipment which is not particularly critical because it is reliable with the current maintenance programme may cease to be so reliable if its maintenance is reduced, and may then become critical. Importance factors must consequently be used with caution: no decision can be made to upgrade or reduce maintenance, and even less so to eliminate it, on the simple basis of an importance factor. These factors must be used in conjunction with other information obtained from feedback or from expert judgement on equipment. Experts can indeed judge the predictable evolution of the reliability of equipment in accordance with the envisaged maintenance programme, whereas safety experts can, with the help of PSA, judge whether this evolution is acceptable or not. Moreover EDF decided to follow the evolution of the reliability of equipment and if necessary to fit the maintenance programme according to this evolution in the framework of a « living RCM programme ».

RCM studies (and particularly the selection of failure modes for critical equipment) therefore call for different skills to be brought together.

A new maintenance policy is likely to result in an evolution in the reliability and availability of the equipments. As far as this evolution can be appraised, the impact of the new policy can be evaluated with PSAs in order to achieve full optimization.

3.4 Perspectives

It was decided to extend this procedure for selecting safety-critical equipment to all the 900 and 1300 MW unit systems with an important role in safety (i.e. a little over 10 systems for each unit).

A U.S. maintenance rule type approach

This procedure is to be compared to the U.S. maintenance rule. The PSA studies in the french RCM process result in a list of critical equipments. But they produce also risk measures concerning the failure modes of these equipments. Those measures could be used to define performance goals, and to monitor the equipment performances. It may be envisaged to define reliability or availability goals for the equipment or functions of the greatest importance with respect to safety and to measure the efficacy of the preventive maintenance programme by comparing the actual reliability or availability of the equipment as determined from operating feedback with the established goals.

Help for defining maintenance task

Similarly, it may be envisaged to use these criticities as decision support in defining maintenance tasks.

Used in conjunction with the notions of equipment reliability and maintenance task costs and efficiency, they can also be used to determine trends with respect to upgrading or downgrading of maintenance (RRW) and upgrading or downgrading of check and inspection tasks (RAW).

A technico-economical tradeoff can be made, involving sustaining or upgrading the overall level of safety while reducing maintenance costs.

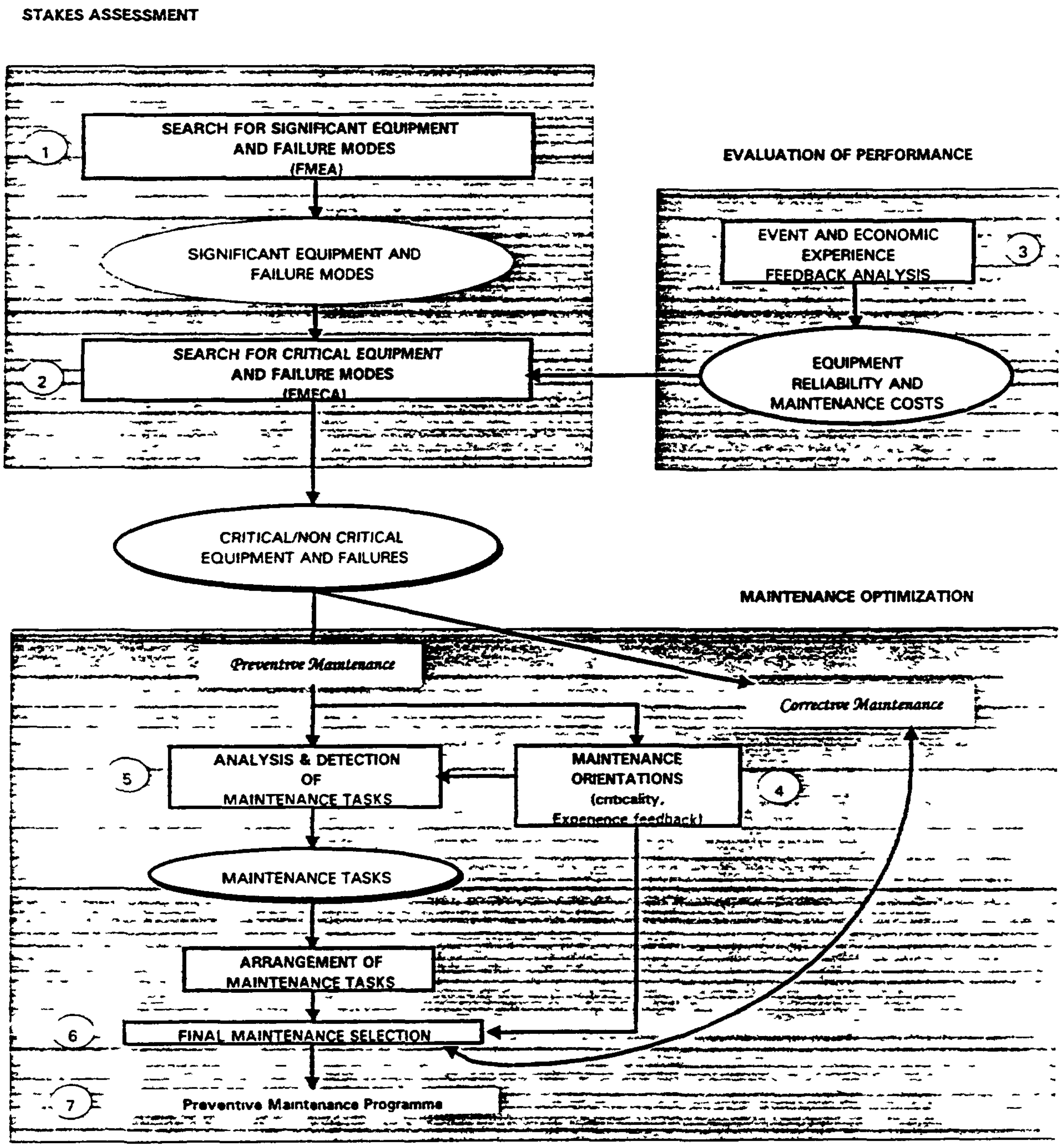
The equipment with a high RRW is that for which a variation in the failure rate has an appreciable effect on the risk of core melt. It is therefore the equipment for which an improvement in the level of reliability as a result of tailored preventive maintenance can give rise to an appreciable improvement in safety.

On the contrary, for equipment with a low RRW, any impairment to its reliability does not engender any appreciable loss in the level of unit safety.

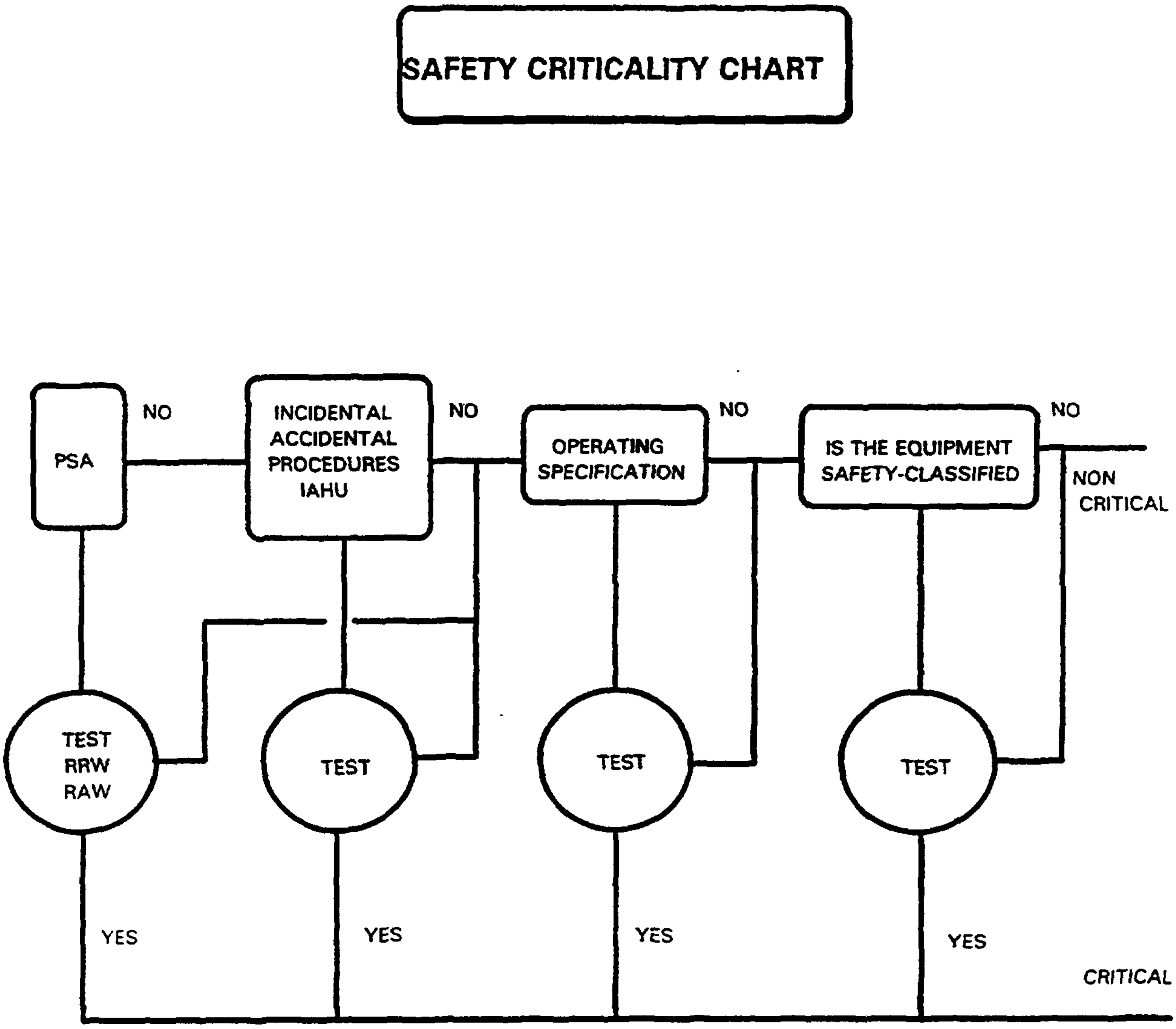
The equipment with a high RAW is that for which a failure engenders a substantial extra risk. It is therefore that for which the actual level of reliability must be that called for in the design Equipment with a high RAW is therefore that for which checking of the level of reliability or availability is important.

4. CONCLUSION

A distinctive feature of the french RCM process, compared to the US one, seems to be the definition and use of quantitative performance indicators. We make an intensive use of our PSA models in this context, taking special care about the limits of the models. But the use of these performance indicators appears to be a promising aspect of the process.



Appendix 1 : Phases of research



Appendix II : Maintenance policy

REGULATORY OVERSIGHT OF MAINTENANCE ACTIVITIES AT NUCLEAR POWER PLANTS IN FRANCE

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Abstract

In France the nuclear safety authority sets out the main safety objectives but the operator remains the first responsible for the NPP safety. During the operation, operators have to demonstrate that the safety level remains the same as defined in the design studies. Maintenance contributes to meet this objective.

The french regulation insists on the quality of the safety related components maintenance, especially in the 1984 order. All gap between results and requirements have to be analyzed by operator who provide feedback measures to avoid similar failure to occur. This gap have to be mentioned to regulators.

The use of probabilistic safety analysis (PSA) and reliability centered maintenance (RCM) methods is not well developed in France to optimize maintenance. For the french regulator, the major difficulties in the use of PSA are :

- the impossibility to detect unanticipated failure mode;
- the validity of the input data;
- the validity of model use, based on "engineering judgement".

For the specific case of passive components inspection, such as the vessel of the primary circuit, the french regulator has already indicated to the operator that the optimization of maintenance by use of PSA cannot be used, for the following reasons:

- the safety analysis does not take into account the failure of the vessel;
- unanticipated failure modes have already damaged part of the primary circuit;
- the use of defense in depth concept requires a systematic detection of any defect on the vessel.

1 French nuclear power plant regulatory system

In France, the nuclear safety authority (DSIN) sets out the main safety objectives. This objectives are detailed in the french regulation, in orders, decrees, and letters to operator.

The operator is the first responsible for NPP safety. He proposes terms and conditions for achieving these objectives and justifies them.

The nuclear safety authority checks that terms and conditions suggested by operator will allow the safety objectives compliance.

The operator put into practices the terms and conditions initially approved by the DSIN and the DSIN checks that correct measures have been taken. This checking is carried out through inspections.

2. Regulatory documents for maintenance

2.1 The decree of 11th December 1963

This decree defines basic nuclear installations (BNIs), subjects them to a licensing procedure, lays down the guidelines for technical regulations, organizes inspections of BNIs.

The main safety objectives are defined in this decree. During the design phases, the operator has to prove analytically that no inadmissible risk is able to occur. During the operating phases, he has to demonstrate that the safety level remains the same as defined in the design studies. The maintenance contributes to meet this objective.

2.2 Construction license decree

All the nuclear power plants are subjected to a construction license decree, delivered by the Prime minister. This decree defines the perimeter of the installation and the requirements which must be met by the licensee. This decree contains general prescriptions for maintenance of the installation : the operator has to be sure that the quality level of the safety related components is sufficient and in accordance with the regulation requirements.

2.3 Quality order of 10th August 1984

This order explains that all safety related activities are subjected to a quality insurance program. This requirement includes all the maintenance activities on safety related components. It recalls that operator is responsible for safety and must check the contractors intervention on safety components. The operators have to establish written procedures to ensure that all activities on safety related components are carried out in proper conditions and to organize internal control of their respect. These procedures are available to the DSIN. Maintenance results have to be recorded so that the operator could have feed-back data on operating installation. This records are also available to the DSIN. All gap between maintenance results and requirements have to be mentioned to the DSIN. This gap must be analyzed by the operator who then provides feedback measures to avoid failure mode to occur. The DSIN checks of the requirement compliance.

2.4 26th february 1974 order concerning the primary circuit

This order is applying pressure vessel regulations to the nuclear steam supply systems of water-cooled reactors.

It describes all the requirements concerning the checking of the primary circuit quality. It stresses on systematic and periodic tests, like pressure vessel inspection. This global test, in addition to the maintenance program, contributes to detect unanticipated mode of failure. For example, it has contributed to detect the cracks on the vessel head penetration in 1991. The utility have to provide means to monitor any damage on this circuit.

2.5 Basic safety rule II.3.8 concerning the secondary circuit

This rule describes the requirements concerning the design, the building and the monitoring of the secondary circuit. The utility has to be sure that the secondary circuit never operates with more severe conditions than the design limits. This is obtained by a permanent monitoring, periodic inspections, and maintenance.

2.6 Other Safety Authority requirements

DSIN has formulated to operators a lot of specific requirements (more than 300 are still in application) concerning the outages and in particular :

- the organization of maintenance;
- the outage organization (tests, suppliers supervision, gap ...);
- maintenance on specific safety related components;
- fire protection ...

3 French operator procedure about regulatory maintenance requirements

3.1 French codes and standards

French operator EDF is establishing rules for in service monitoring of the mechanical equipment, "Règles de surveillance en exploitation des matériels mécaniques des îlots nucléaires" (RSEM). These rules are created in the same way as design and construction rules codes, RCC-M (materials), RCC-P (process) ...

Discussion with french nuclear safety authorities already started, concerning this rules.

At the present time, DSIN has approved one part of this rules : chapter A500 (Methods concerning the analysis of cracks). It gives the necessary conditions to consider a default as acceptable on a component.

3.2 Maintenance programs

Moreover, in accordance with the requirements of the creation authorization, the french operator EdF has written a lot of maintenance programs for the safety related equipment, during the operating lives of the NPPs. They were originally based on the recommendations of the plant designers or manufacturers and have been developed following plant operating experience and monitoring results. They are periodically reviewed to take into account the data of the feedback. The maintenance programs are sent to Safety Authority, who systematically review the most important ones, such as those concerning the primary circuit.

4 Outage supervision by Safety Authority

The DSIN checks the safety related activities performed by the operator during outages. Thi action is devoted to the specialized Nuclear Divisions (DIN), included in the Regional Directorates for industry, research and the environnement (DRIRE). It consists in:

- approval of outage program, before the outage. The inspection and maintenance programs are analyzed, in accordance with the technical maintenance rules defined for each system (extent and frequency of the planned works). Preparation of safety relevant modifications and pressure vessel tests are also examined in view of the approval;

- supervision of the quality during the outage, especially in the field of pressure vessels test : the DRIREs are legally responsible for monitoring the application of pressure vessel regulations to all installations, including nuclear installations,

- preparation of the authorization for operation; this phase includes a meeting with the operator at the end of the outage to check maintenance results and examine how anomalies were treated.

Plant restart is submitted to the approval of DSIN. The approbation is given on the basis of the DRIRE report at the end of the outage.

5 Trends in maintenance

Since 1994, EDF has developed the RCM method in the aim to optimize the maintenance thanks to the data on the reliability of the safety related components. This method consists first to detect equipment and failure modes significant to safety, availability or maintenance costs and then in evaluation of the performance of those equipment. Those studies lead to the distinction of equipment and failure modes that are critical or non critical to safety, availability and costs. The first part of the studies consists in optimizing maintenance on those equipment.

French regulatory position :

DSIN wrote a letter to EDF, in september 1994, concerning the specific case of the optimization on the primary circuit maintenance. In this letter, DSIN explains its position which could be summarized as follows : to define the maintenance program, the operator has to take into account the possibility of un-anticipated failure mode. For example, the cracks on the vessel cover penetration was detected by a systematic and periodic inspection, without taking into account any consideration of optimization. The vessel is a component for which the failure is not taken into account in the safety analysis. That's why, DSIN refuses to try any maintenance optimization on it. Moreover, the defense in depth concept requires a systematic detection of any default.

This defense in depth requirement can be extend to all safety related components. For example, a lot of leaks on safety related circuits was not detected by maintenance program. This kind of failure appears after 10 years of operating without any way to anticipate it.

The RCM method is well adapted to detect component which is critical for safety and which was not taken into account by the design studies. The use of RCM method could lead to increase the amount of maintenance on it. If the operator wants to decrease the amount of maintenance on a component, by using RCM method, the justification of the input DATA and of the model have to be available to the DSIN.

NUCLEAR POWER PLANT MAINTENANCE IN GERMANY: STRATEGY AND SUPERVISION BY THE AUTHORITY

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Abstract

The construction, operation and possession of nuclear installations require a license and are subject to continuous supervision. According to the Federal Atomic Energy Act the supreme authorities of the Länder acting on behalf of the Federation are responsible for granting such licenses and for exercising supervisory and control functions.

The Safety Critera for Nuclear Power Plants contain basic principles for the design of NPP's in particular the necessary precautions against damage according to the status of science and technology. Among other items these principles cover the maintainability of systems and components, the quality assurance program and the conduct of testing and inspection in due intervals.

The inspection programmes carried out by the Länder cover all activities of the licensee related to the safety of the plant. Within this scope the preventive maintenance, inspection and testing of equipment is an important area. For the maintenance outage a detailled inspection program will be set up to cover repairs, modifications, reactor core refuelling, and recurrant testings of systems and components.

1. Regulatory Agency

As indicated by its name, the Federal Republic of Germany is a federal State. The Federal Constitution therefore contains detailed provisions on the legislative and administrative competences of the Federation (Bund) and the individual States (Länder). Persuant to the *Federal Act of 1959 on the Peaceful Uses of Atomic Energy and Protection Against its Hazards* (Atomic Energy Act), the supreme authorities of the Länder, designated by their governments, are competent for the granting, withdrawal and revocation of licences for nuclear installations.

The Atomic Energy Act empowers the Federation (Bund) to issue ordinances and general administrative regulations which are largely implemented by the Länder as Agents of the Bund. The federal control and supervision relate to the legality and expediency of the implementation of the Atomic Energy Act by the Länder. The Authorities of the Länder are subject to the directives of the competent supreme federal authority, in this case the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Under the Atomic Energy Act, any person who constructs and operates or who substantially modifies a nuclear plant or its operation must obtain a license. The licensing prerequisites are laid down in this act:
1. Reliability and qualification of the responsible personnel
2. Necessary knowledge of the operating personnel with respect to safe operation, possible hazards and safety measures
3. Necessary precautions in the light of the status of science and technology to prevent damage resulting from construction and operation of the plant
4. Necessary financial security to cover all legal liability to pay for compensation for damage
5. Necessary protection against disturbances or other 3rd party acts
6. Compatibility with overriding public interests, in particular to protect the environmental media water, air and soil

As to maintenance activities the above prerequsites no. 1 - 3 are the most important.

The construction, operation and possession of nuclear installations are subject to continuous supervision. The supreme authorities of the Länder are responsible for exercising supervisory and control functions, which they may delegate to subordinate agencies, in individual cases. In general, the Technical Inspection Agencies (TÜV) are involved as experts.

2. Codes and Standards

The general clauses and requirements chosen by the legislator keep the Atomic Energy Act free from the burden of detailed features and make it possible to compile technological requirements in technological codes in accordance with prevailing knowledge and experience.

For maintenace activities the technological codes are, in the order of decreasing importance and increasing detailed contents:

- Safety criteria for Nuclear Power Plants
- RSK-Guidelines for Pressurized Water Reactors
- Checklist table of content of a Standard Safety Analysis Report
- KTA-Safety Standard
- Industrial Technical Standards

Safety Criteria for Nuclear Power plants

The Safety Criteria, published 1977 by the Federal Ministery of the Interior, contain basic principals for the design of nuclear power plants. In particular the necessary precautions against damage according to the status of science and technology are laid down. With respect to maintenace the applicable safety criteria are:

Criterium 1.1
Among other items:
- the maintainability of systems and components must be given with due respect to the radiation commitment of the personel
- quality assurance within fabrication, construction and operation
- conduct of testing and inspection in due intervals

Criterium 2.1:
Comprehensive requirements for Quality Assurance Program, testings during fabrication, construction and commissioning, documentation

Criterium 2.2:
Access to testing of all safety relevant equipment

Standard Safety Analysis Report

According to the ordinance (AtVfV) regulating the licensing procedure for nuclear installations, a major document to be submitted for application of a construction license is the Safety Analysis Report. The content of this document is described in detail. Within this SAR a program for recurrant testings and inspections has to be given for all safety relevant equipment, systems, components and structures. The Safety Analysis Report will be presented to the public for information and as a basis for a public hearing with those persons who have filed objections.

KTA-Safety Standard

The KTA-Safety Standards contain detailed requirements for fabrication, construction, commissioning and operation of components and systems as well as operation of the entire nuclear power plant. Many of these standards also contain requirements for quality assurance and recurrant testings and in-service-inspections.

3. Inspection Programmes

The inspection programmes cover all activities of the licensee related to the legal requirements and to the provisions of the Construction and Operational License of the plant.

During the construction of a nuclear installation or during implementation of modifications so-called accompanying controls are carried out, which are designed to ensure that the manufactoring, construction and testing of all safety systems and components comply with the requirements of the permit. After start of operation, inspections are carried out at regular intervals.

The supervisory program during the plant's service life includes:

- monitoring adherence to legal regulations and licensing notifications, adherence to safety regulations and guidelines,
- adherence to physical security regulations

- inspection for safety deficits
- safety reviews, assesment of Periodical Safety Reviews (PSR)
- normal operation, recurrant inspections and in-service-inspections and testings
- evaluation of abnormal occurrences
- approval of minor modifications (major modifications require a license)
- control of radioactive discharges
- operating the KFÜ-System (automatic transfer and recording system of important NPP-status and operation data)
- radiation protection monitoring of personal and environment, independent control of radioactive immissions
- control of professional skills of the operation personal and training programmes

Onsite visits at the plant take place on the average of about once a week. Contacts are made at different levels (plant manager, shift supervisor, RP manager, section heads). There are no resident inspectors at the site.

The supervisory authority may order the discontinuance of any situation which is contrary to legal provisions or conditions of the licence or which causes danger to life, health or property through the effects of ionizing radiation. It may, in particular, order that (specific) safety measures be taken, that radioactive substances be stored or kept in custody and that the construction or operation of a nuclear installation be suspended temporarily or permanently.

On behalf of the Federal Government, the BMU ensures, that the instruments available to the Länder Authorities are used uniformly and effectively with regard to the matters of law and expediency. In particular, the BMU

- requests regular reports on operation experience
- involves advice of the Reactor Safety Commission (RSK) and of the Commission on Radiological Protection (SSK)
- involves a central registration office for abnormal events at BfS and in-depth evaluation at GRS
- evaluates accumulated operational experience nationwide and international

4. Shutdown Activities

The operation organisation (licensee) is required to provide plans for the outage period in advance. These plans shall define all refuelling, maintenance and testing programmes, the implementation of planned modifications taking into account the operational conditions (availability) of the safety systems, e.g. residual heat removal systems, as laid down in the Technical Specifications (Operation Manual). A detailled inspection program will be set up to cover repairs, modifications, reactor core refuelling, and recurrant testings of systems, components, valves, etc. The calculation of the reactor core composition is to be validated by independent experts (TÜV). Individual working plans expected to consume more than 50 mSv collective dose are to be described in detail and are checked for ALARA provisions.

The plant startup usually requires approval by the regulatory body after the formal notification, that all required testings have been completed succesfully.

5. Abnormal Occurrences

Abnormal events have to be reported to the supervisory authority of the Länder according to the reporting criteria laid down in an ordinance. The criteria are categorised in S (immediately), E (within 24 hours), N (within 5 working days) events. These categories refer to possible administrative actions to be taken by the authority. The INES-scale is used to refer to the safety significance of such events.

The supervisory authority evaluates the events, in general by involving the TÜV's or other independent expert organisations, to ask for corrective actions, if necessary. All reported events from all nuclear installations in the Federal Republic of Germany are documented and evaluated by the Incident Reporting Office at the Federal Office for Radiation Protection (BfS). Summary reports of abnormal events are forwarded to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the parliament.

A systematic in-depth screening of all events is performed by the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS). Events identified by this process to be of significance relevant to other nuclear installations are investigated in depth. GRS provides these evaluations to all licensing and supervisory authorities of the Länder, to the TÜV's and to the operators of nuclear installations. In return, the supervisory bodies of the Länder require the operators to check these informations for relevance and necessary corrective actions in order to avoid similar events.

Evaluations of events from nuclear installations in other countries are also carried out by GRS and made available to the supervisory authorities and the utilities.

6. Inspectorate Personnel

Within the regulatory body of a state (Land) approx. 5-10 man-years per NPP-unit and year are spent for inspection and supervision. Typically one or two inspectors are in charge of inspection regarding nuclear safety of one NPP unit. Inspection regarding e.g. radiation protection, often is delegated to subordinate governmental agencies. In addition, supervision for industrial safety and environmental matters as legally required for all types of industrial activities is carried out by other competent agencies.

In general, for all supervisory and inspection programmes independent experts are assigned by the Länder authorities for examination of reports, reported events, calculations, technical specifications, safety assessments for modifications and for conducting or assessing in-service-inspections. In most cases, the

Technische Überwachungsvereine (TÜV's) are assigned as expert organisations. Including non-nuclear inspection programmes (e.g. for cranes, fire protection, pressure vessels, etc.), which are also carried out by TÜV-personnel, a total manpower of approx. 30-40 man-years per NPP-unit and year is spent for inspection by experts. This does not, however, include safety assessments and expertises for major modifications, for which a license is required. For the assignment of experts the regulatory body gets reimbursement by the licensee.

The inspectors of the regulatory body are in possession of university degree (e.g. engineering, physics, chemical engineering) and have several years of practical experience in industry, research centres, with technical expert organisations or in licensing bodies. Personnel of technical expert organizations who are contracted as authorized experts hold university degrees in technical fields or technical engineering degrees. The inspectors are trained in professional courses, symposia, workshops, simulator training courses and, as guests, during actual operation of nuclear facilities, and by exchange of experience.

The inspectors authorised by the supervisory authorities, as well as experts consulted by them, have access to the nuclear installations, and may carry out necessary examinations and request pertinent information.

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MAINTENANCE STRATEGY IN GERMANY: SUPERVISION BY THE AUTHORITY

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Abstract

This paper is a follow-up to the previous paper which contains the "pertinent standards and regulations".

First, the difference is explained between the regular verifications of the functionability of the safety functions that are necessary to ensure overall safety and maintaining sufficient component quality by preventive maintenance, also taking into account the resulting differences in supervision and licensing procedures.

Following that, the influence of the international discussion relating to performance-based maintenance on German practice is discussed; in this context the conclusion is that at present no formal transition to a performance-based maintenance strategy is planned even though the principle methods are being applied in practice. Finally, maintenance practices are explained on some examples.

1 Main Issues of Strategy

Basic Points

As has been explained in Part 1 of the paper, the Atomic Energy Act ("Atomgesetz", AtG) provides the basis for the peaceful use of nuclear energy in Germany. To make its implementation in licensing practices better understandable, some relevant requirements with regard to maintenance strategy will be briefly introduced in the following.

- The applicant and his responsible personnel have to provide proof of the requisite reliability and technical qualification (Sec. 7 AtG (2) No.1).

- It must be verified that the design and construction of the plant provide the necessary prevention against damage according to the state of the art (Sec. 7 AtG (2) No.3).

- State supervision has to ensure adherence to the Atomic Energy Act; experts may be commissioned for this purpose (Sec. 19 AtG, Sec. 20 AtG).

This results in the following principles:

- it is the utility's responsibility to prevent any inadmissible risks that may be posed by the plant

- the state supervises the utility and may involve experts to do so.

The sharing of the tasks between utilities and the state applies to the construction, operation, and eventually to the decommissioning phase of a plant. The following will concentrate on the construction and operation phases.

Construction Phase of the Plant

During construction, the utility has to provide analytical proof that the plant will pose no inadmissible risk. The analyses in question are accident analyses with deterministic assumptions of the failure behaviour as well as probabilistic assessments of parts of the safety system. Complete probabilistic safety analyses (PSA) have only been performed for some years; they were initiated for all operating plants and have so far been finished for 5 of them, the rest still awaiting completion.

The main foundations for the results of the analyses are:

- the design of the plant

- the reliability of components

A quality assurance system is to ensure that basic prerequisites on which the analysis is based are not altered during the plant's lifetime. The quality assurance system comprises the planning of the plant, the qualification of delivery and manufacturing companies, and the construction and operation of the plant.

During the construction of the plant, the supervisory authority examines i.a. the accident analyses submitted by the applicant and the planned regular verifications of the system functions that are important to safety. These examinations are carried out on the basis of deterministic principles defined by rules and guidelines (RSK-guidelines, KTA-rules). These deterministic examinations are supplemented by reliability analyses of selected systems and components. Here, the main points of examination are:

- the assumed spectrum of accidents
- assumptions of the failure behaviour of the safety systems (n+2 design)
- assumptions and boundary conditions of the analyses
- whether the safety-related system functions can be tested, during which plant states they can be tested, and how far the tests are adequate with regard to the challenge cases
- the control of common-mode failures,
  resulting in requirements for system configuration and inspection strategy
- the required reliability of components,
  from which the requirements for the qualification of components and the evaluation of operating experience are derived

Among other things, the following will have been defined for the plants at the latest by the time the operating license has been granted:

- which systems of the plant belong to the safety system and therefore have to undergo regular in-service inspections
- detailed definition of the in-service inspections
- intervals between the in-service inspections
- admissible periods of unavailability of partial systems
- safety-relevant limit values of the plant
- detailed instruction how to operate the systems
- operational organisation, e.g. work routines to rectify disturbances

These definitions are laid down in the plant's operating manual and may only be changed in agreement with or with the approval of the state regulatory authority.

Operation of the Plant

During the operation phase, too, the utility is in principle responsible for the safety of its plant. There are, however, certain activities by the utility that fall under state supervision.

In principle, the utility regularly has to evaluate the operating experience with regard to safety and to feed back the gained knowledge into the operation of the plant (Safety Criteria for Nuclear Power Plants; Criterion 1.1). Apart from cases of special operational parameters, like released doses of activity etc., this procedure is followed in line with the quality assurance system within the utility's own responsibility. The state regulatory authority has the right to examin the evaluations of the notifiable operational paremeters.

The evaluation of operating experience, which the utility performs on its own authority, is supplemented by a verification of the operational performance of the plant to be submitted to the state regulatory authority. This obligation to provide such verification has only existed for a relatively short time in Germany. Consequently, the contents of the verification have not been finally laid down. The transparences 'Regular utilization's of operational performance' illustrates the most relevant contents.

As regards state supervision, the following distinction is important:

1. regular verification of the ability to function of the system functions that are necessary for the safety of the plant

2. ensuring sufficient component quality by preventive maintenance measures

Verification of the safety-relevant system functions is subject to state supervision. As mentioned earlier, these verifications are defined in the "test list" of the plant's operating manual. Any alterations are also subject to state supervision. (Transparency Test List)

Preventive maintenance measures, on the other hand, are taken by the utilities in their own authority and are not subject to direct state supervision. This means that in this area the utility decides on the kind of maintenance strategy (time-dependent, condition-dependent, or 'operation until damage') itself. (Transparency 'Preventive Maintenance) Here, the freedom of decision is limited by the prescriptions for the operation of the plant laid down in the operating manual (e.g. admissible unavailability periods of partial trains). Special care must be taken that the methods selected by the utilities do not infringe the status of the reliable personnel (according to Sec. 7 AtG) and thereby the main prerequisite for the operating license.

In practice, however, the distinction between 'regular function tests' and 'preventive maintenance measures' can't be applied to all components; in the case of the pressure retaining boundary, for example, no further preventive maintenance measures are performed by the utilities in their own authority other than the destruction-free material tests prescribed by the "test list".

For the inspection and maintenance strategy the obligation to evaluate the operating experience on a regular basis means that the procedures as well as the intervals of in-service inspections or preventive maintenance measures have to be constantly checked and possibly adapted with reference to the operating experience. The operator informs the state regulatory authority of his activities in the area of maintenance (more extensive measures, conspicuous damage causes, etc.) at regular intervals (e.g. annually).

2 Performance Aspects of Maintenance Activities

In Germany, there exists no formal transition to a 'performance-based maintenance strategy' as yet. However, the aspects of such a procedure do exist in various kinds in practice or are being discussed.

If one briefly characterises the performance-based strategy by the following issues

- determination of the safety functions
- identification of the components whose failure represents a considerable contribution to the plant's damage state
- maintenance measures in line with the relevance of the components
- regular evaluation of operating experience with special consideration of the identified systems and components
- optimisation of the maintenance measures in accordance with operating experience

one can see that these aspects largely correspond to the methods that have so far been applied in Germany. Both the regular inspections according to the 'test list', which are subject to state supervision, and the preventive maintenance strategies implemented by the utility are laid down on the basis of the above-mentioned aspects.

Apart from formal aspects, the most important difference between current practice and the 'performance-based maintenance strategy' that is presently being discussed is that the defined issues are mainly based on eingineering judgement underpined by experience, and that reliability observations or PSAs only play a subordinate role. If one looks at the developments of the last few years, however, the contribution of probabilistic influence on the determination of maintenance strategies has risen sharply with the performance of plant-specific PSAs.

Examples

The procedure will now be illustrated on a few examples.

- The first example shows that in-service inspections according to the 'test list' and preventive mainenance measures by the utility supplement each other in practice. The residualheat removal (RHR) pumps in a BWR are inspected monthly by the utility in line with the 'test list' and annually together with the authorised expert within the framework of the function test of the RHR chain. In this context, the pumps are subjected to a visual inspection on location, with special attention being paid to unusual sounds, oscillations and leakages. During the annual inspection, the pump curves are additionally inspected.
  In line with its own maintenance strategy, the utility performs an additional inspection of the interior of the RHR pumps every 4 years. This inspection includes checks of the coupling, seals, bearings and hydraulic components with regard to their wear and to possible damage.
- In the case of the 10-kV electric motors of the safety system, many utilities have changed from a time-dependent to a time-independent preventive maintenance strategy. Before, the ball and roller bearings used to be replaced every 4 to 8 years in principle, which implied dissembling the motors. Now that the strategy has been changed, a shock impulse measurement is performed every year, with a decision being taken afterwards whether or not the bearings will be replaced.
  This meant a considerable reduction of the inspections of the motors' interiors, saving the utility some financial resources and reducing the possibility of assembly

faults, which in practice contribute a great deal to the failure behaviour.
A prerequisite for the introduction of a condition-dependent maintenance strategy is the exact knowledge of the failure behaviour and the examination by measurements of the parameters that are characteristic of the condition of the components. This prerequisite can be seen as fulfilled for the electric motors due to the long-standing operating experience.

- The next example is to illustrate how a systematic PSA may possibly influence the kind and frequency of in-service inspections. The plant concerned here is an older-type 2-loop PWR whose steam generator water level measurements are needed i.a. to control a steam generator tube leak. Before the PSA, the measurements were examined annually, following common practice, in line with the 'test list' (i.a. transducer curve, differential-pressure lines). It was found in the course of the PSA that during long operating periods with constant water levels the inspection interval of one year was too long with regard to the phenomenon of 'undetected freezing of the transducers'. The remedial measure now implemented looks as follows: during the monthly turbine inspections the steam generator water level is now also lowered monthly, and the water level measurement device is inspected.

- Finally, there is the example of the main coolant pumps, for which the 'test list' provides no function tests. The main coolant pumps are not part of the plant's safety system. In addition to the locally fixed noise monitoring system, the utility has provided the following time-dependent inspection measures for the main coolant pumps:

    - general overhaul of all parts lying in the main flow every 8 years
    - annual inspection of the seal cartridges
    - inspection of the axial and radial bearings every 4 years
    - inspection of the oils supply system every 2 years.

  This example shows clearly the effort that is deemed necessary to protect the invested capital and which is made without the regulatory authority being involved.

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OVERVIEW OF MAINTENANCE PRINCIPLES AND REGULATORY SUPERVISION OF MAINTENANCE ACTIVITIES AT NUCLEAR POWER PLANTS IN SLOVAKIA

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Abstract

The maintenance represents one of the most important tools to ensure safe and reliable operation of nuclear power plants.

The emphasis of Nuclear Regulatory Authority of the Slovak Republic to the maintenance issue is expressed by requirements in the regulations.

The current practice of maintenance management in operated nuclear power plants in Slovak Republic is presented. Main aspects of maintenance, as maintenance programme, organization of maintenance, responsibilities for maintenance are described. Activities of nuclear regulatory authority in maintenance process are presented too.

REGULATORY CONTROL OF MAINTENANCE AT BOHUNICE NPP

1. Introduction

Safe operation of nuclear power plants requires to ensure the prescribed technical condition of all structures, systems and components to fulfill their functions.

The maintenance of nuclear power plants is a subject of interest of the Nuclear Regulatory Authority of the Slovak Republic (NRA SR) and the regulation of the maintenance is done by the following legislation instructions.

LAW No. 28/1984 which regulates the state supervision on nuclear safety of nuclear installations, declares the following requests concerning the maintenance:

- the operators should ask the regulatory body for decision to "perform changes and modifications with impact on nuclear safety of nuclear installations"
- the operators should ask the regulatory body for approving of quality assurance programmes and the way of ensurance of nuclear safety of nuclear installation
- the operators should inform the regulatory authority about events with impact on nuclear safety of nuclear installations.

NOTICE No. 436/1990 about the quality assurance of nuclear installations from the point of view of classified equipments. The requirements resulting from this notice and which concern the maintenance are as follows:

- the operators should have the appropriate knowledge about the technical condition of the operating equipment to demonstrate that the quality of components prescribed by the documentation has been met and maintained
- the repairs of flaws and faults of components, the modifications and replacements should be implemented according to approved maintenance procedures and other conditions prescribed by the quality assurance programme
- the quality of performed repairs and replacements should be checked by using appropriate tests and the new status should be recorded into the equipment documentation.

At present time, no regulatory guides related to the maintenance have been issued, but three safety guides are prepared for issuing focused on welding of equipment in nuclear installations:
- requirements for welding of equipment
- requirements for filling material for welding
- requirements for weld quality testing.

It is expected that they will be issued soon and the use of these guides will be recommended to the operators and industry.

2. Present status of NPP maintenance in the Slovak Republic

This paragraph deals with the maintenance practices in the Bohunice Nuclear Power Plant (2 units of WWER 440/230, 2 units of WWER 440/213 and

1 unit of A-1 NPP under decommissioning), as Mochovce NPP is under construction.

2.1. Maintenance programme

The basis for the maintenance programme before commissioning has been submitted by the manufacturers or/and contractors in the "Instruction for operation" for particular equipment, as a part of the individual quality assurance programme.

These instructions prescribe the limits and conditions for safe operation, requirements for pre-service and in-service inspection and main principles of maintenance - as the basis for the development of maintenance procedures.

The preparation of the preventive and remedial maintenance programme is based on the "Technological Database" which contains all data on the particular equipment:

- name and code number of equipment
- location area
- access to equipment
- technical parameters
- material specification
- sequence of maintenance
- history of maintenance and repairs
- number of maintenance procedure.

The maintenance planning and the preparation of maintenance programme is performed using computer network and the computer code SOZAR has been developed for this system. The use of this system is described in the plant internal instruction No. 16/93 and it prescribes:
- working position of personnel with the right of access to the system
- procedure for development of failure cards
- procedures for equipment preparation
- system of maintenance orders
- responsibilities of operational and maintenance personnel.

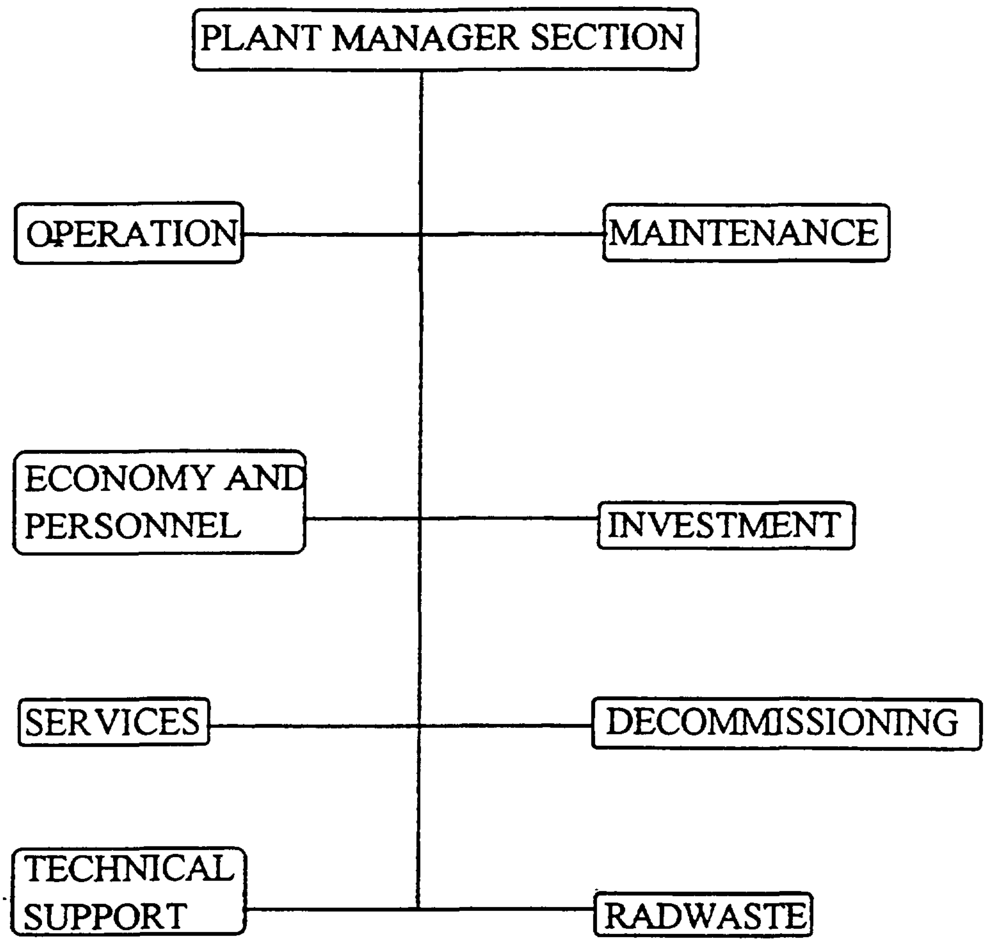
In principle, two types of maintenance programmes are developed

- one-month preventive maintenance programme, from which one-week programmes are derived
- maintenance programmes for planned refuelling outages (or for extraordinary outage).

The most important works, e.g. repairs, replacements and/or modifications, are planned to be fulfilled during refuelling outages.

2.2. Organization and responsibilities for maintenance

The present organizational structure of the Bohunice NPP is as follows - see the organizational sheet.



Bohunice NPP organizational sheet

The maintenance section has the following departments:
- technical support
- in-service inspection
- pressure component maintenance
- rotating component maintenance
- workshop facility and civil structure maintenance
- electrical and lifting equipment maintenance.

The main responsibilities of the maintenance section are as follows:
- implement the maintenance, repair and replacements
- develop maintenance procedures
- develop new technologies for maintenance and repairs
- perform personnel training.

The responsibility for up-dating the technological database has the owner components.

The responsibility for maintenance programme development, co-ordination of maintenance (both preventive maintenance) and co-ordination of all works during refuelling outages is on the "maintenance preparation branch" which is included in the operation section. The reason is that mainly the maintenance during the refuelling outages and the possibilities to keep the critical path depend on the operational conditions required (e.g., for fuel cooling).

The responsibility for the development of maintenance work procedures is on the maintenance technical support. Periodical review of maintenance working procedures is regularly performed in three-years interval.

The exceptions from these responsibilities are the I&C equipment and partially the electrical equipment and systems. The responsibility for the maintenance are on the electrical and I&C departments in the operational section.

2.3. Administrative controls

The administrative controls cover all activities which concern the maintenance and they are as follows:
- maintenance planning

- maintenance co-ordination
- maintenance work procedure development and revision
- in-service inspection
- work order authorization
- equipment isolation permit
- radiation protection
- industrial safety control
- fire hazard control
- spare part and material control
- housekeeping and cleaning control
- maintenance and in-service inspection record generation
- modification and replacement control
- shut-down planning
- personnel training.

For all of these activities, internal instructions are established which prescribe:
- subject of instructions
- procedures
- responsibilities.

2.4. Maintenance facilities

To ensure that maintenance will be carried out effectively, nuclear power plant is equipped with appropriate maintenance workshop facilities and laboratories, namely:
- mechanical shops (inside and outside the control area)
- electrical shops
- laboratories for I&C equipment

and other equipment and facilities for:
- lifting and transport
- decontamination
- radiation protection
- shielding
- communication.

3. Nuclear Regulatory Authority Activities in maintenance

In line with the regulations described in chapter 1, the NRA SR focuses its regulatory activities in NPP maintenance process to ensure that the technical status of all equipment is such that it enables to fulfill all requested functions and safe operation.

The main activities are as follows:

- approval of the documentation of safety related components, equipment and systems for:
  * repairs
  * replacements
  * modifications
- approval of individual quality assurance programmes of new, repaired or modified components, equipment and system
- supervision of important maintenance works, repairs, replacements and modifications
- inspection of maintenance system performance
- supervision of tests demonstrating the quality of repair.

As follows from the regulatory decisions No. 5/91 and 110/94 for the V-1 NPP reconstruction, inspections are regularly performed by teams of inspectors before the restart of the V-1 NPP units after refuelling outages. Inspections were focused mainly on:

- results and completeness of the in-service inspection programme performed during the outage
- results and completeness of planned maintenance works, including repairs, replacements and modifications
- quality of documentation and records from ISI and maintenance
- operational procedure modification after equipment modification
- operational personnel training performance
- evaluation of reactor pressure vessel brittle fracture temperature.

The permit for further operation, in case of positive inspection results, is given for one operational cycle only.

At the V-2 NPP, similar in-depth inspections are performed each four years, when the in-service inspection cycle is completed. However, inspections focused on maintenance are performed more frequently, too.

A special team inspection focused on the maintenance system in the Bohunice NPP was performed in March 1995. The results of the inspection were quite positive, administrative shortcomings were identified, specifically:

- internal maintenance instructions did not reflect last organizational changes in the Bohunice NPP
- shortcomings were identified in using invalid national technical standards in maintenance working procedures.

Nowadays, the quality assurance programme for the Bohunice NPP is under development. One of the important part of this programme deals with maintenance.

4. CONCLUSIONS

1. The maintenance management applied in operated nuclear power plants in Slovak Republic meets the main aim of maintenance, i. e. to ensure required technical condition of NPPs components and systems.

2. A further upgrading of maintenance management, namely in administrative controls area, is expected by the Quality Assurance Programme introduction which at present time is under development.

3. It can be stated that the operating experience are implemented (and approved by regulatory body) into the maintenance programme anualy; a systematic performance based approach is under consideration.

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FUTURE TRENDS IN MAINTENANCE REGULATIONS IN SPANISH NUCLEAR POWER PLANTS

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Abstract

Experience in Nuclear Industry confirms the essential role of effective maintenance improviding safe operation.

Effective maintenance in safety SSC's and other than safety SSC's is essential to assure that number of transients, challenges of safety systems and failures which become in initiators are minimized.

Additionally, there is a close relationship between availability and reliability of certain SSC's and safe operation.

Spanish Rules follow basically American Standards, country origin of NSSS suppliers. Until now, no specific regulations have had in Spanish NPP's related to maintenance except regulations and utilities commitments as reliability targets in response to SBO Rule 10CFR50.63, surveillance test and inspections performed in accordance with Section XI of the ASME, containment leakage test performed in accordance with Appendix J of 10CFR50, component surveillance or testing required by plant technical specifications, fire protection test and maintenance requirements set in Appendix R of 10CFR50, etc. Additionally, the resident inspectors cover operational safety areas including maintenance. There are other programmed inspections, approximately one/power plant/year involving operational areas as maintenance including environmental qualification.
In EEUU the Nuclear Regulatory Commission approved the 10CFR50.49 Maintenance Rule, to take effect on July 10, 1996.

The NRC developed the Regulatory Guide 1.160 which endorsed NUMARC 93-01 as an acceptable method to implement the Maintenance Rule.

The Nuclear Safety Council, Regulatory Organization in Spain, is going to require the implementation of 10CFR50.49.

This Rule is "results oriented" which means that let NPP's freedom to make its own maintenance, requiring only that they had a method to review its effectiveness and take corrective actions when appropriate.

In a similar way than was done in EEUU with NUMARC 93-01 Spanish NPP's formed a Working Group to provide guidance for the development of a Guide and a Verification & Validation plan for two NPP's one PWR (Vandellos II) and one BWR (Cofrentes).

The main objectives of the Working Group are to discus with CSN the proposed Guide which is very similar to NUMARC.93-01 in order to obtain its approval of the regulatory body as a way to meet 10CFR50.49 and learn how to apply it making use of the thecnical resources and organizations of Spanish NPP's.

In November the 1988, NRC proposed new regulations to ensure the effectiveness of nuclear power plants maintenance programs and to correct perceived variations across the industry in the implementation of maintenance programs. Inspections of some facilities had indicated perceived weaknesses in areas of engineering support,root cause analysis, trending, predictive maintenance, and recordkeeping.

On July 10, 1991, after assessing industry progress in the maintenance area and considering public and industry comment on the proposing rulemaking, NRC issued a final rule promulgating a revised 10CFR50.49.

The NRC developed the Regulatory Guide 1.160 which endorsed NUMARC 93-01 as an acceptable method to implement the maintenance rule.

Spanish Rules follow basically American Standards, country origin of NSSS suppliers.

Until now, no specific regulations have had in Spanish NPP's related to maintenance except regulations and utilities commitments as reliability targets in response to SBO rule 10CFR50, surveillance test and inspections performed in accordance to section XI of ASME code, containment leakage test performed in accordance with appendix J of 10CFR50, component surveillance or testing required by plant technical specifications, fire protection test and maintenance requirements set in Appendix R of 10CFR, etc.

Additionally, resident inspectors cover operational safety areas including maintenance. There are other programmed inspections, approximately one/power plant/year involving operational areas as maintenance including environmental qualification.

It is the intention of Spanish CSN, to require the implementation of CFR50.49.

In Spain there are seven sites and nine NPP's, seven PWR: José Cabrera (Westh. One Loop), Almaraz I and II (Westh. Three Loops), Ascó I and II (Westh. Three Loops), Vandellós II (Westh. Tree Loops), Trillo (KWU. Three Loops) and two BWR: Garoña (GE. Mark I) and Cofrentes (GE. Mark III).

Spanish Utilities have formed a Working Group in order to develop activities leading to implement the maintenance regulation.

The program schedule for the Owners Group Maintenance Rule Program Plan is comprise by the proposal of a detailed methodology; data gathering (level I); plant screening; data specification; data acquisition; risk significant guide; determination of risk significant systems; remaining guides (which will cover establishing system and plant level performance criteria, establishing system/train or component level goal, establishing methods for monitoring, cause determination, root cause analysis and for determining MPFF's, establishing on a periodic basis the effectiveness of the specific plant programs by programmatic review and documentation and establishing methods for assessing the impact on safety of equipment out of service and establishing safe plant configurations); test/application process; implementation and final documents.

At the present time meetings between the Working Group and the regulatory body are being held in order to approve the detailed methodology proposed.

It is the general criteria of the regulatory body not to approve significant deviations of NUMARC 93-01 if they are not completely justified as set bellow.

Relating to scope, the MR. set SSC's safety related and not safety related that are relied upon to mitigate accidents or transients or are used in plant EOP's, whose failure could prevent safety related SSC's from fulfilling their safety related function and those whose failure could cause reactor scram or actuation of safety related systems.

Could cause implicates the use of all analysis and tools available by the plant: "Plant Familiarisation Document" used for PRA, use of Dacne Data Bank etc.

The Plant familiarisation document involves the use of NUREG/CR-3862, Plant scrams at 25% power and above, FSAR(Chapter XV) and Failures Modes and Effects Analysis.

The Dacne Data Bank comprises the Operational Events Data Bank and the Equipment Failures data Bank.

With regard to non safety related SSC's used in EOP's there is not yet a specific criteria about to add significant value to the mitigation function of an EOP by providing the total or a significant fraction of the total functional ability required to mitigate core damage or radioactive release.

Among SSC's included in the scope of the Maintenance Rule are identified those risk significant using at least risk significant measures set up in NUMARC 93-01: Risk Reduction Worth, Core Damage Frequency Contribution and Risk Achievement Worth. It should be used PRA, IPE, critical safety functions or another methods documented.

An Expert Panel should be used to analize this information and determine risk significant SSC's.

This expert panel will be composed by plant experienced people in risk analysis, reliability, operation, engineering and maintenance.

In Spain, specific PRA's were required to all and each one the NPP's. First PRA, level I and without external events considerations, was required to Garoña NPP in 1983. Requirements to another NPP's has been made adding additional aspects to the scopes, so, Almaraz, level I including fire risk and containment system reliability analysis; Ascó level I including internal flooding risk; Cofrentes level I including external flooding risk;

Jose Cabrera level II; Vandellos II level II including risk analysis from earthquake and consideration of risk from all modes of reactor operation; Trillo level II including risk analysis from all external events and consideration of risk from all modes of reactor operation. Later 1994, Garoña's PRA was revised. According to the PRA programme all the NPP's should revise their PRA's to reach the Trillo and Garoña scope.

This scope is level I and II for initial events at full power, low power and outage including external events.

Paragraph a (1) of the maintenance rule requires that goal setting and monitoring be established for all SSC's within the scope of the rule except for those SSC's whose performance or condition is adequately controlled through the performance of appropriate preventive maintenance as described in paragraph a (2) of the rule. The evaluation and control of the performance of SSC's is fulfilled by means of the establishment of performance criteria. For risk significant systems and for stand-by systems these performance criterias must by specific to the systems and where a redundant risk-significant system exists the performance criterias must be to the train level, usually performance criterias consists in reliability, availability condition and number of MPFF-For non-risk significant systems performance criterias consists in plant level criterias: Unplanned automatic reactor scrams per 7000 hours critical, Unplanned capability loss factor and unplanned safety systems actuations. Besides for non-risk significant systems repetitive MPFF must be analysed. Cause Determination in an appropriate depth (root cause) must be made for all functional failures in risk significant and non-risk significant systems.

The term maintenance preventable functional failure as defined in appendix B of NUMARC 93-01, is the failure of an SSC within the scope of the maintenance rule to perform its intended function where the cause of the failure of the SSC is attributable to a maintenance related activity.

When establishing goals it must be taken account risk significance and industrywide operating experience. Industrywide operating experience includes information from NRC (applicable in Spain), industry and vendor sources. Dacne data bank is an available tool for this application.

Section 9.4.4 of Numarc 93-01 provides guidance on determining when dispositioning SSC's from paragraph a (2) to paragraph a (1) is required. This is generally required when a performance criteria is not met. Then goals must be defined and monitoring of the achievement of this goal established.

NPP's have a great flexibility to choose performance criterias and goals, these may be performance oriented (reliability, availability) and condition oriented (flow, vibration, current etc).

For SSC's inherently reliable and run to failure, this SSC's would be inside the scope of the maintenance rule but woldn't be necessary to establish performance criterias or goals. Inherently reliable is a SSC that without preventive maintenance has inherent reliability and availability (e.g. raceways); "Run to failure" SSC is a SSC that provide little or no contribution to system safety function and could be allowed to run to failure.

Regulation requires that an assessment of total equipment out of service be performed in a ongoing bases. There is not a specific regulation about the way to do it and it could be since deterministic judgments assessing the cumulative impact on the performance of safety functions to the use of an on line living PRA used to ensure that the plant is not placed in a risk configuration.

Paragraph a (3) of the maintenance rule requires to perform periodic assesment each refueling outage cycle not exceeding 24 month and giving NUMARC 93-01 a three month period after completion of the refueling outage for data gathering and analysis. Activities to evaluate consist in revision of adjustments to the goals and redisposition from a (1) to a (2), assessment of performance criterias in order to ensure their effectiveness, effectiveness of corrective actions and balancing unavailability and reliability in order to insure that the objective of preventing failures of SSC's through maintenance is appropriately balanced against the objective of minimizing unavailability of SSC's due to monitoring or preventive maintenance activities.

XA9745110

SOME PROBLEMS OF MAINTENANCE REGULATION AT UKRAINIAN NUCLEAR POWER PLANTS

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Abstract

Among all the possible problems arising in a connection with provision of NPP power units safe operation, the maintenance and repair at the Ukrainian NPPs possess an important place.

System of maintenance and repair at the Ukrainian NPPs is presently still traditional one, based on the former USSR' document "Rules of the NPPs Equipment Maintenance and Repair Arrangement" (РД.53.025.002-088).

For to provide technical systems reliability and safety in an accordance with "General Provisions on NPP Safety" (ОПБ-82) (presently ОПБ-95 is in underway in Ukraine) nuclear operators are implementing their maintenance and repair. These procedures are obligatory conditions for NPP operation during all the life term.

To implement an equipment maintenance and repair there are appropriate divisions in NPP structure envisaged such as departments, laboratories, sections, shops, etc. composing an NPP maintenance and repair service. There are also another specific enterprises engaged in such activities.

1. Maintenance at the Ukrainian NPPs

A maintenance is in conduct of some operations implementing which do not require equipment to be moved in a routine repair while being carried out during a periodic review of technical state, cleaning, adjustment, grease replacement, etc. as envisaged by manufacturer specifications and rules of technical operation.

Presently there are 14 power units in operation in Ukraine. A brief information is presented in Table 1.

A maintenance and repair arrangement and management are not the same at all the Ukrainian NPPs.

A typical, traditional structure is adopted at the Rivne and Khmelnitsky NPPs, where the responsible person is a deputy Chief Engineer for maintenance (Drawing 1).

Nuclear Power Plant in Ukraine

Table 1.

NPP UNIT	REACTOR TYPE	POWER (Mwe)	DATE COMMISSIONED	OPERATIONA L LIFE*	PRODUCED IN 1994 (million kWh)	IAEA MISSIONS Type-R
RIV 1	VVER-440/V-213	402	12/31/80	14,5 years	2848	
RIV 2	VVER-440/V-213	416	12/30/81	13,5 years	2952	1993
RIV 3	VVER-1000/V-320	1000	12/24/86	8,5 years	5983	November
RIV 4	VVER-1000/V-320	1000	under construction			
****ZAP 1	VVER-1000/V-320	1000	10/10/84	10,5 years	4035	
ZAP 2	VVER-1000/V-320	1000	7/2/85	10 years	4396	1994
ZAP 3	VVER-1000/V-320	1000	12/10/86	8,5 years	4601	June
ZAP 4	VVER-1000/V-320	1000	12/24/87	7,5 years	6248	
ZAP 5	VVER-1000/V-320	1000	8/31/89	6 years	5180	
ZAP 6	VVER-1000/V-320	1000	under commission			
****KHM 1	VVER-1000/V-320	1000	12/31/87	7,5 years	6689	
KHM 2	VVER-1000/V-320	1000	under construction			1993
KHM 3	VVER-1000/V-320	1000	under construction			March
KHM 4	VVER-1000/V-320	1000	under construction			
****SUK 1	VVER-1000/V-302	1000	12/22/82	12,5 years	5377,8	
SUK 2	VVER-1000/V-338	1000	1/6/85	10 years	4224,8	1995
SUK 3	VVER-1000/V-320	1000	9/20/89	5,5 years	5898,5	January
SUK 4	VVER-1000/V-320	1000	under construction			
CHO 1	RBMK-1000	1000	9/26/77	17,5 years	4763	
CHO 2	RBMK-1000	1000	12/21/78	**		1994
****CHO 3	RBMK-1000	1000	11/10/81	13,5 years	5693	May
CHO 4	RBMK-1000	1000	12/1/83	***		

* - Operational life as of 6/1/95

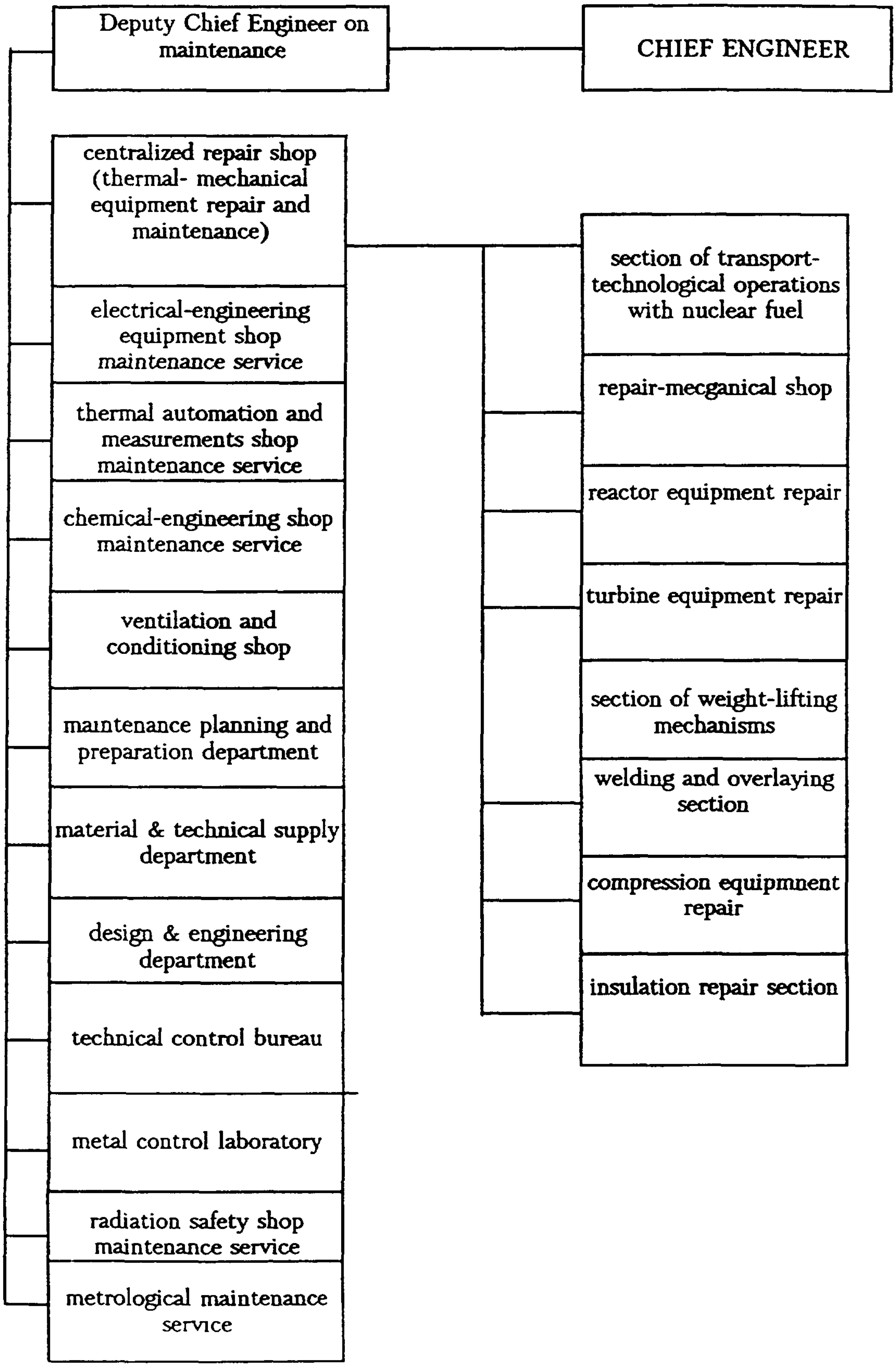
** - Unit 2 was shut down after the fire on October 11th, 1991

*** - Unit 4 was destroyer during the accident on April 26th, 1986

**** - Routine maintenance repair as of 6/1/95

Draw.1

KHMELNITSKY NPP MAINTENANCE SERVICE STRUCTURE



At the South-Ukraine NPP the 1st deputy Chief Engineer is responsible for maintenance and repair arrangement, while deputy Chief Engineer - for documentation.

At the Zaporozhye NPP the responsibility for repair and maintenance is distributed between four persons as follows:

- deputy General Director on electrical and C&I systems operation and repair;
- deputy General Director on whole-station systems (water, oxygen, nitrogen supply, water treatment, compression station, etc.);
- deputy General Director on power units repair and maintenance (technical systems of reactor and turbine shops):
- deputy Chief Engineer on repair is responsible for preparation of documents

After NPPs obtained an "operational organization" status the maintenance and repair system and its structures underwent small changes as follows.

NPP is developing and upgrading by its own, with its structure taking into account, documentation on maintenance and quality assurance.

While issuing of licenses on NPP operation, reviewing or amending of operational documentation, making of technical decisions and undertaking of appropriate measures intended in safety improvement, analysing of reports on NPP operation malfunctions and annual reports on NPP safety current level the Regulatory Body of Ukraine is facing with problems of NPP equipment and staff reliability determination.

There exists a computerized data base in a STC where presently an information is maintained on more than 500 operational events occurred at the Ukrainian NPPs since 1992 up to now.

This information is transferred to the Regulatory Body by NPPs in an accordance with "Provision on NPP operation malfunctions investigation and account procedure" (ПНАЭ-Г-005-12-91).

Some of the reports on malfunctions are analysed by ASSET methodology with composing of events tree, determination of direct and root causes and implementing of corrective measures.

STC is already for 4 years dealing with an investigation of incidents occurring at the Ukrainian NPPs. The results were annual reports on incidents analysis.

While 14 units were in operation, the total number of malfunctions reportable to the Regulatory Body in 1994 was 135 cases (in 1993 they were 167, i.e. by 19 % more than in 1994).

In 9 cases of the total number the limits and conditions of the safe operation were violated (compare with 6 ones in 1993). There were deviations from the allowed mode of operation in all the 9 cases (level 1 by INES).

At the Diagram 1 the distribution of events at all the NPPs during 1994 year is presented.

At the Diagram 2 the distribution of events at all the NPPs during 3 years is presented.

Into an integral flow of malfunctions are included both those accounted as reportable to the Regulatory Body and recorded at the shop level. It revealed while collecting of statistical data that safety-significant systems malfunctions after maintenance, repairing and testing were recorded as shop level ones.

Presently the problem of clear distinguishing between malfunctions types is of considerable topicality, and here is a room for the Regulatory Body to assist nuclear operators.

The necessity appeared to create more expanded data base including complete information on malfunctions after maintenance and repair which would help to obtain representative data for to calculate reliability indices. These results can be used while PSA development.

At Diagram 3 some results on malfunctions connected with errors during equipment repair and maintenance are shown.

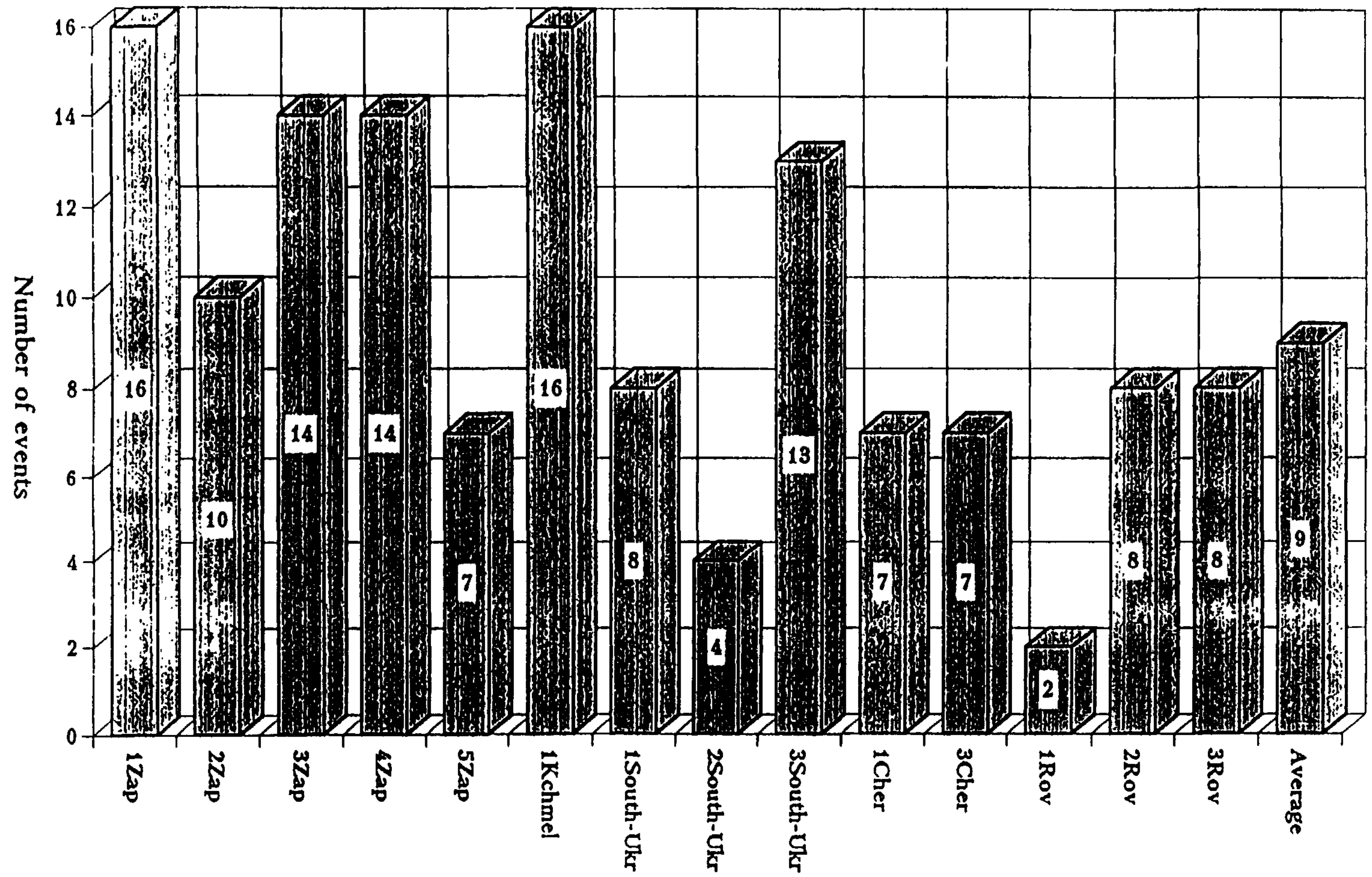
At Diagram 4 some results on malfunctions connected with errors during inspections, testing and maintenance are shown.

2. Maintenance quality indexes

NPP submit an information on its activity as to maintenance and repair as well as malfunctions of safety-significant systems after maintenance in "Annual report on power units operational safety current state assessment".

Deficiencies in power unit safety-significant systems equipment operation while maintenance and repair are estimated by maintenance and repair quality index. This is a parameter of equipment malfunctions stipulated by unqualified maintenance and repair flow averaged by the period under review.

Diagram №1. Event distribution over Ukrainian NPPs in 1994



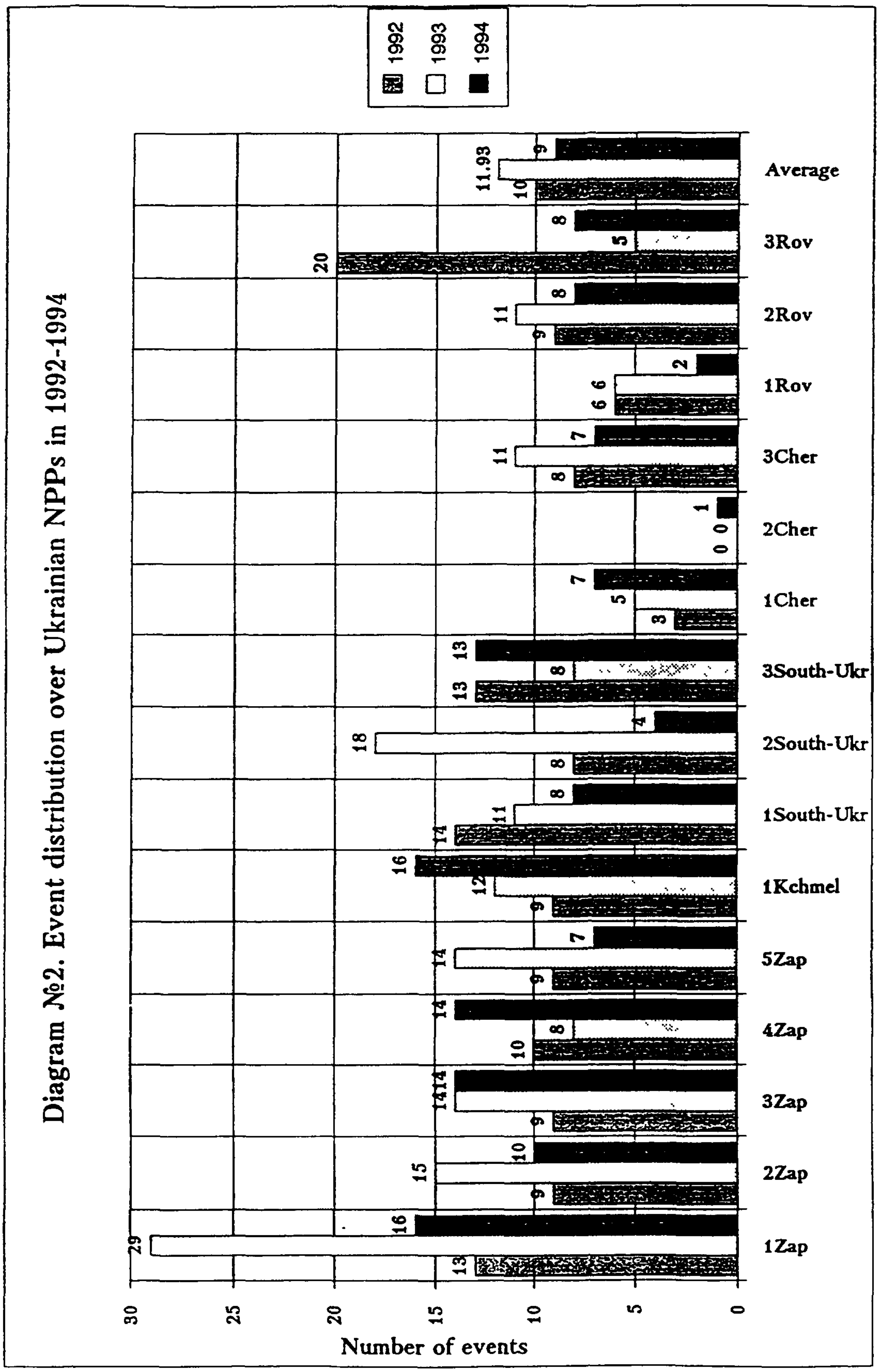
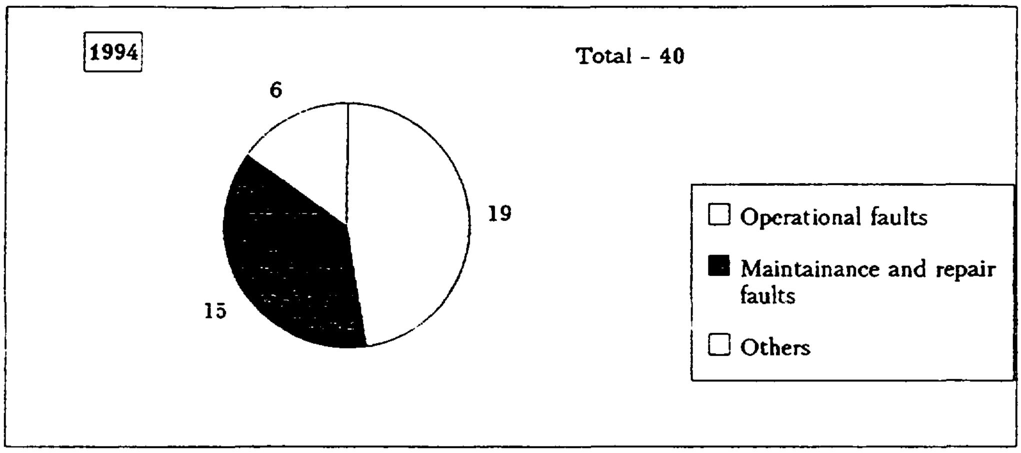
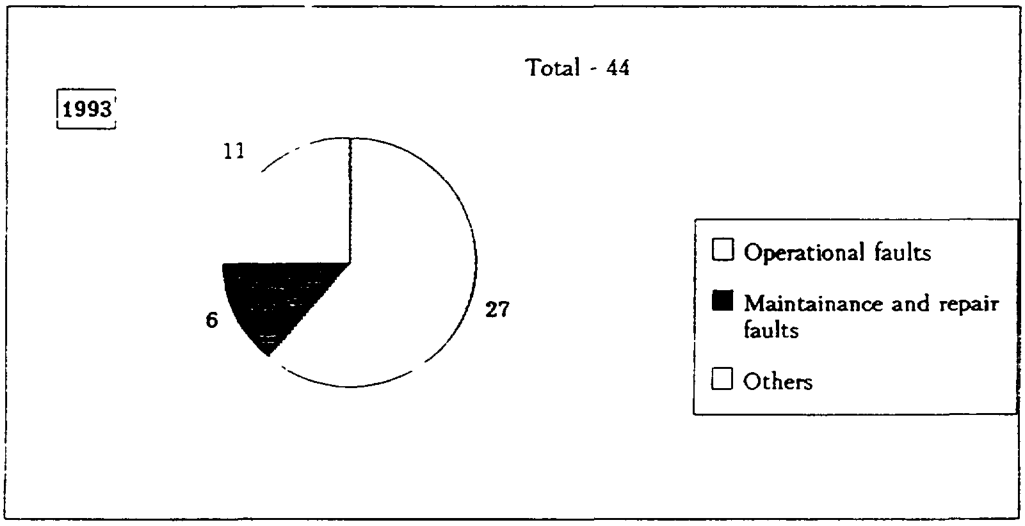


Diagram №2. Event distribution over Ukrainian NPPs in 1992-1994
1992
1993
1994
Number of events
0
5
10
15
20
25
30
1Zap
2Zap
3Zap
4Zap
5Zap
1Kchmel
1South-Ukr
2South-Ukr
3South-Ukr
1Cher
2Cher
3Cher
1Rov
2Rov
3Rov
Average

Diagram №3. Event distribution connected with maintainance and repair faults.





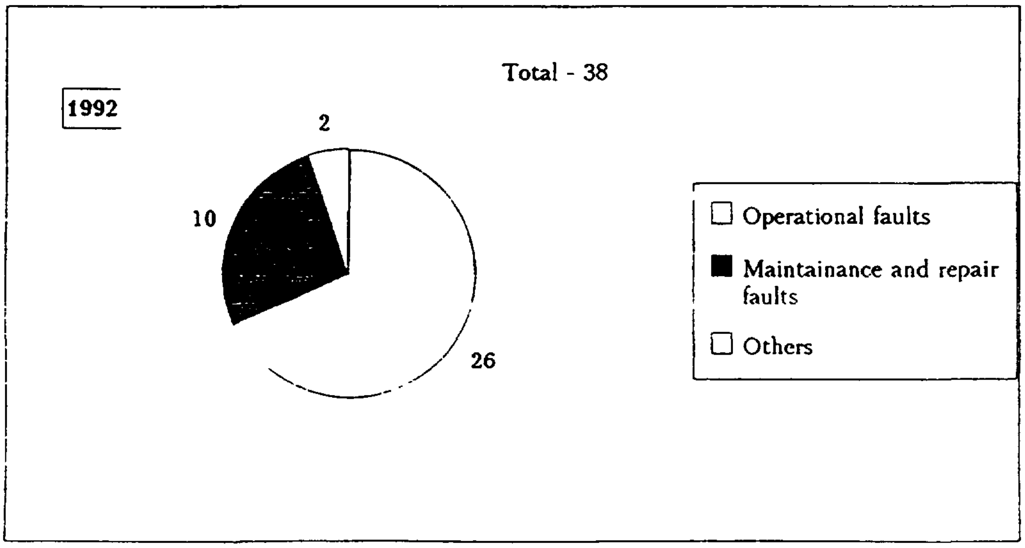
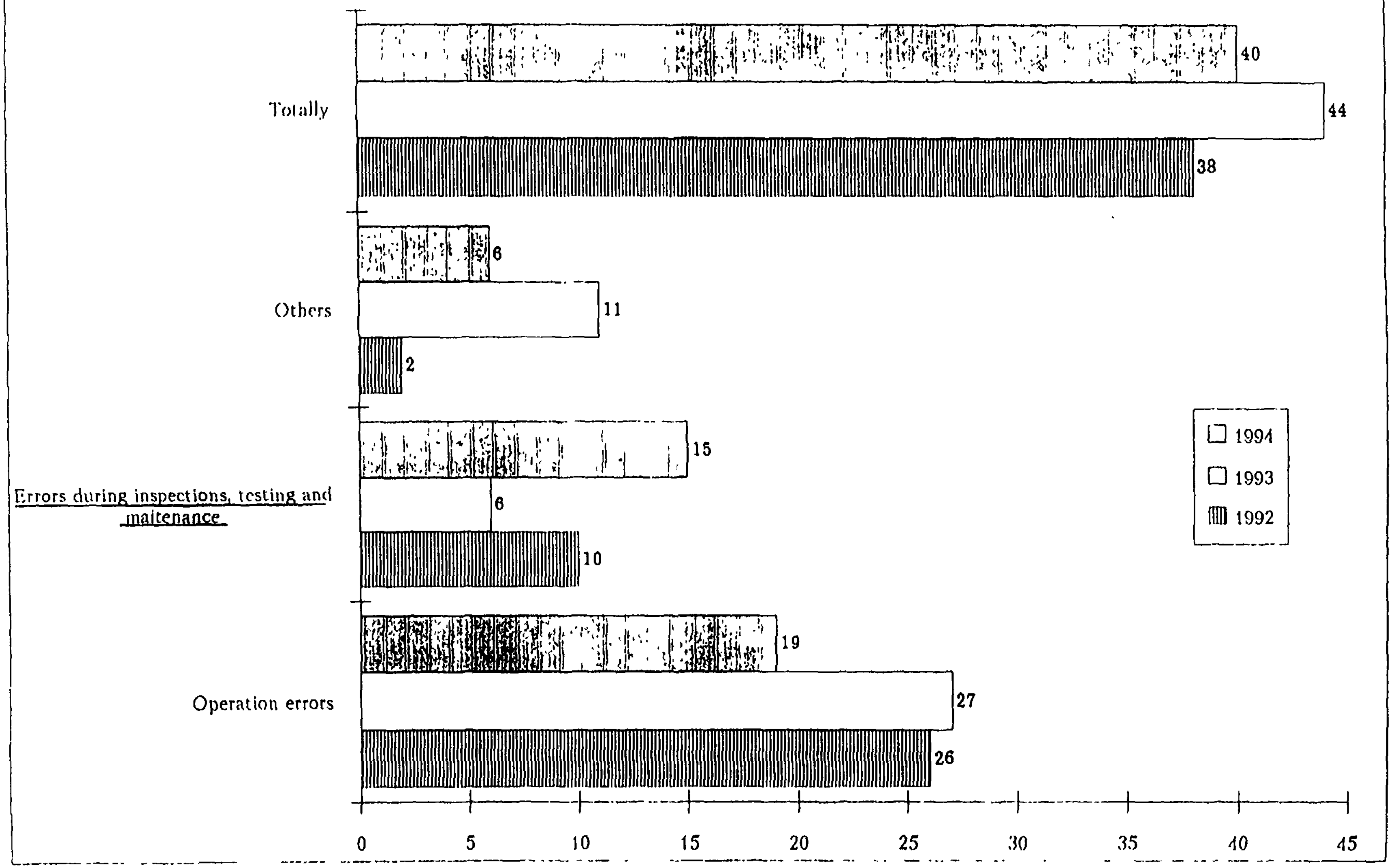


Diagram №4. HE led to initiating or propageting of operation events.



It is calculated by the formula as follows:

$$K = \frac{F}{To} \cdot 1000 \text{ , where}$$

F - safety-significant systems equipment malfunctions number
To - duration of unit operation on-power

They usually include into reports a graph of maintenance quality index quarterly distribution and assessment of its value acceptability. In Table 2 Ukrainian NPPs maintenance quality index distribution is shown.

Maintenance quality indices for 1992-94. Table 2

Unit,	Year		
Plant	1992	1993	1994
1KHM	**0.162**	**0.692**	**0.443**
3RIV	**0.685**	**0.230**	**0.49**
1SUK	0.163	1.239	0.176
2SUK	0.455	1.675	0.155
3SUK	0.301	0.453	0.321
SUK(average)	**0.3**	**1.12**	**0.22**
1ZAP	0.30		0.39
2ZAP	0.14		0.34
3ZAP	0.19		0.49
4ZAP	0.29		0.45
5ZAP	0		0.15
ZAP(average)	**0.18**		**0.36**
Average Ukr. NPP	0.33	0.86	0.38

3. Conclusions

It is necessary to solve the following tasks of the most topicality:

(1) To create the national normative-technical base in a field of maintenance and repair with the use of an international experience;
(2) To develop the QA programmes in a field of maintenance and repair;
(3) To create the unified data base on equipment malfunctions while operation;
(4) To adjust a feedback by operational experience.

It is possible to make conclusions as follows:

- during the last three years a flow of malfunctions connected with safety-significant systems inoperability trends to increase;

- despite of positive trends in safety-significant systems malfunctions account improvement, in-depth analysis is evident of real number of malfunctions sufficiently exceeds their number accountable by existing provisions.

Such a situation is stipulated the causes as follows:

- insufficient controlling by the Regulatory Body;
- lack of clearly formulated criteria of safety-significant system channel malfunction and its boundaries in operational documentation;
- requirements to reports on safety-significant systems malfunctions and those connected with transient processes at NPP are the same;
- insufficiency of malfunctions at NPP accounting system.

Generalization of experience and feedback arrangement require in-depth analysis of those malfunctions, mostly influencing upon safety. In this connection the methods utilizing probabilistic models of operational events and accident sequences are of great interest.

Taking into account the gained experience and considerable PWR integral work duration in Ukraine (more than 100 reactor-years for VVER) VVER operational experience generalization is also of great interest.

XA9745111

REGULATORY OVERSIGHT OF MAINTENANCE ACTIVITIES AT NUCLEAR POWER PLANTS

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Abstract

Regulation of nuclear safety in the UK is based on monitoring of compliance with license conditions. This paper discusses legislation aspects, license conditions, license requirements for maintenance and maintenance activities in the UK. It also addresses the regulator utility interaction, the regulatory inspection of maintenance and the trends in maintenance.

LEGISLATION

UK nuclear safety is regulated under the Health and Safety at Work Act and the Nuclear Installations Act The latter act provides for licensing and licence conditions, inspection, liability, etc. Offences under the acts can lead to prosecution or enforcement notices
Regulatory powers include being able to require

- a utility to shut down, test or inspect its plant,
- that a utility should not start-up plant without the regulator's consent,
- that a plant's Maintenance Schedule (MS) be approved, and
- that extensions to intervals specified in the MS be agreed

LICENCE CONDITIONS

Licence conditions include requirements relating to

Incidents	Training of staff	Control and supervision
Quality assurance	Modifications	Records
Safety mechanisms	Radioactive waste	Decommissioning
Emergency arrangements	Safety documentation	Periodic reviews
Radiological protection	Operating rules and instructions	
Maintenance	Periodic shutdowns	Etc

LICENCE REQUIREMENTS FOR MAINTENANCE

Licence requirements relating to maintenance include

- the need for arrangements for inspection, maintenance, etc
- preparation of a Maintenance Schedule for plant which may affect safety,
    - the MS must relate to the safety case
    - the MS will be a sub-set of the site maintenance plan
    - the MS must provide the start of an auditable trail
- the facility for approval of the arrangements / MS,
- the needs for competence, instructions, compliance with the MS, supervision,
- the facility for agreement to extensions to intervals specified in the MS,
- that defects are reported and investigated, and
- that reports on maintenance are kept

MAINTENANCE ACTIVITIES

Maintenance activities include

- inspection, eg of reactor core and pressure circuit for channel straightness, oxidation, cracks,
- testing and examination, eg of cooling water systems, safety relief valves, safety circuits and alarms,
- testing and maintenance, eg of control rods and actuators, gas circulator motors and lubrication systems, boiler feedwater systems, essential electrical supply systems, and
- calibration, eg of radiation monitors, safety circuit sensors.

(Note that "maintenance" is a lot more than replacement, refurbishment and lubrication)

REGULATOR / UTILITY INTERACTION

The utility

- prepares the MS,
- undertakes the specified maintenance,
- monitors compliance with the MS,
- applies for agreement to extensions if necessary,
- reports abnormal findings, and
- revises safety cases if necessary

The regulator

- assesses and approves the MS (but in the UK we are moving to approval of procedures for control of the MS),
- monitors compliance with the MS,
- agrees to extensions if satisfied with the case made by the utility, and
- undertakes specialist assessment of and agrees to revised safety cases.

REGULATORY INSPECTION OF MAINTENANCE

Regulatory inspection of maintenance activities includes checking on

- compliance with the MS,
- quality assurance arrangements,
- control and supervision of activities,
- compliance with access and isolation arrangements,
- control of contractors,
- training,
- recording and investigation of findings, and
- records.

TRENDS IN MAINTENANCE

The following trends relating to maintenance have already been noted or are anticipated:

- reducing the administrative burden (for the utility and the regulator), by approving procedures rather than the full MS,
- reducing the amount of maintenance, by more focused maintenance and less routine maintenance,
- reducing loss of output due to maintenance, by working rapidly, avoiding delays and overcoming unexpected problems,
- maintenance optimisation by use of reliability centred maintenance (RCM) etc.
- reductions in utilities' staffing, and
- greater use of contractors.

SUMMARY

(1) Regulation of nuclear safety in the UK regulation is based on monitoring of compliance with licence conditions.

(2) The licence conditions require that the utility has adequate arrangements, including arrangements for self-monitoring (self-regulation)

(3) The regulator inspects the utility's arrangements

(4) The regulator must be able to react to developments in maintenance such as RCM.

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