IAEA-EBP-LTO-07

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EXTRABUDGETARY PROGRAMME
ON
SAFETY ASPECTS
OF LONG TERM OPERATION
OF WATER MODERATED REACTORS

MINUTES OF THE PROGRAMME'S
WORKING GROUP 4 FIRST MEETING

3-5 March 2004

IAEA, Vienna, Austria

INTERNATIONAL ATOMIC ENERGY AGENCY

1. INTRODUCTION

The number of Member States giving high priority to extending the operation of nuclear power plants beyond their initial license is increasing. Decisions on long-term operation (LTO) involve the consideration of a number of factors. While many of these decisions concern economic viability, all are grounded in the premise of maintaining plant safety. The IAEA recognized this new industry initiative; therefore, in the 1990's, it developed comprehensive generic guidance on how to manage the safety aspects of physical ageing. It was recognized, however, that internationally agreed-upon, comprehensive guidance was needed to assist regulators and operators in dealing with the unique challenges associated with the LTO issue.

In response, the IAEA initiated this Extrabudgetary Programme (Programme) on 'Safety aspects of long term operation of water moderated reactors' (original title was 'Safety aspects of long term operation of pressurized water reactors'). The Programme's objective is to establish recommendations on the scope and content of activities to ensure safe long term operation of water moderated reactors. The Programme should assist regulators and operators of water moderated reactors, and, in particular WWERs, in ensuring that the required safety level of their plants is maintained during long term operation, should provide generic tools to support the identification of safety criteria and practices at the national level applicable to LTO, and should provide a forum in which MS can freely exchange information.

The Programme activities are guided by the Programme Steering Committee (SC), follow the overall SC Programme Workplan and SC Terms of Reference, [1], and are implemented in 4 Working Groups (WG). The WGs focus on:

– general LTO framework (WG 1);
– mechanical components and materials (WG 2);
– electrical components and I&C (WG 3);
– structures and structural components (WG 4).

Further detailed information on the Programme could be found at: http://www-ns.iaea.org/nusafe/s_projects/salto_int.htm .

The 1st meeting of WG 4 was held at IAEA in Vienna, 3-5 March, 2004. The purpose of the 1st meeting of WG 4 was to review and finalize the respective parts of the draft Workplan [2], and the draft Standard review process [3] and to initiate the WG 4 activities.

The Agenda for the Meeting is provided in Appendix I. The list of participants is provided in Appendix II.

2. MEETING SUMMARY

The meeting was opened by Radim Havel, the Programme Scientific Secretary, and Paolo Contri, Scientific Secretary for WG 4, who outlined the objectives and history of the IAEA Extrabudgetary Programme "Safety Aspects of Long Term Operation of Pressurized Water Reactors". As Mr. Katona, the WG-4 Chairman, could not attend the meeting due to personal matters, Mihail Batishchev, the WG 4 Co-Chairman, outlined the objectives of the first working group meeting, reviewed the meeting agenda and intiated discussion of national approaches to long-term operation.

2.1. IAEA and national presentations

P. Contri presented some background information on the IAEA documents, the glossary, the experience in some MS in LTO/PSR/AMP programmes and some proposals for the development of a global framework for the LTO programmes. An analysis of the safety implications of the programmes for long-term operation of NPPs, with reference to the available IAEA documents and experience in the review of national programmes was included in the presentation.
In particular, it was noted that in the last years many Member States started a programme to assess the possibility for a Long Term Operation (LTO) of their older nuclear power plants (NPPs). These programmes follow different approaches, being intrinsically dependent on the national regulatory framework and technical tradition. The analysis of the practice in countries operating NPPs suggests that despite of the differences related to the regulatory process, the main components of the programmes and their basic technical tasks are shared among most of the countries.
The presentation presented a short overview of the national approaches to LTO aiming at the identification of the technical aspects more directly affecting the decision for a long-term safe operation of a nuclear facility, independently from their licensing framework.
Other tasks, typically related to the LTO programmes, but more focused to the assessment of the current safety level of the plants were labeled as "pre-conditions for LTO" and discussed in details.

The meeting continued with the presentation of the national approaches to long-term operation. The summaries of the national presentations are provided next, the complete presentation handouts are provided in Appendix III.

Bulgaria (M. Milanov)

1. Define of scope.

Process used in developing the SCS Scope was presented. This process is based on:

- Safety Analysis Reports.
- PSA.
- Systems Interaction.
- Classification and Seismic Categorization of Civil Structures (CS) and Hydro Technical Structures (HTS).
- Defining of Safe Shutdown Equipment List /SSEL/.

Three Categories of Structural Components and Structures was defined:

1)All safety-related SSC /f(safety functions…)/

2)All non-safety related SCS whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined in point 1.

3)Other areas dedicated to a specific functional purpose that may be essential to the safe plant operation.

2. Regulatory documents.

No specific nationals Requirements and Standards for LTO of NPP are issued.
Nevertheless -International Codes and Standards are applicable. Law for safety using of nuclear energy (LSUNE) and -National Regulation on power plants and networks technical operation, as well as a set of Local Plant Instructions and Procedures for some specific activities are in use.

Guide for Seismic Reevaluation and Design of Nuclear Facilities in Bulgaria,
Methodology for Seismic Qualification of KNPP is developed and regularly updated;

Guidelines for Regulatory Review of Ageing Management Programmes and their Implementation is in progress (Developing for Regulatory body by British Energy - NNC).

3. Ageing Management Activities and Programmes

Current practice in Ageing Management was presented in the next basic points:

•Civil Structures and HTS Monitoring;
•Analyses and Investigations;
•Reconstruction and Modernization;
•Maintenance and Repairs
•Organization and Management of activities and responsibility.

The structures are run by the operating departments (workshops, sectors etc.), correspondingly EP-1 for Units 1-4 and EP-2 for Units 5 & 6.

Specialized monitoring and services are performed by:

•specialized Department (Dept. of HTS and CS);
•assigning separate tasks to external organizations.

The main objective of the conducted control is to assess the impact of the existing defects on civil structure safety and to specify measures for their treatment. The existing defects are divided into ***three categories*** according to their impact on the structure:

- A. Directly dangerous for the civil structure.
- B. Potentially dangerous for the civil structure
- C. Not dangerous for the civil structure.

Different methods and systems are established and used for inspection, measurement and observation of the important parameters for the structures.

Plant Specific Topics:

- Control of Containments Stress-strain State /CSSS/;
- Seismic Monitoring of Civil Structures;
- Cracks measurements and Mapping;
- Concrete investigation;
- Displacements Monitoring
- GIS for HTS;
- Passportization of Items (Buildings and Structures) e.t.c.;
- RLT Programme – for Units 3,4;
- Modernization Programmes – for Units 3,4; Units 5,6.

4. Reconstructions and Modernizations:
   - Seismic Upgrading of Civil Structures;
   - Construction of additional and substitute structures;
   - Units 5 and 6 Containment Pre-stressing System (CPSS)

5. Maintenance and Repairs.:
6. Applicable Ageing Effects.

KNPP structures ageing consists of occurrence and progress of different defects and processes related to the civil structures.

- -Ageing of Reinforced Concrete Structures, Cracking;
- -Defects and processes in CPSS of Units 5 & 6;
- -Leakages, due to Imperfect Roof Waterproof ;
- -Steel Elements and Joints Corrosion Progress;
- -Partial Damages of Buildings and Structures;
- HTS Deformation Gaps.

7. Plant Specific Safety Analyses and Data.
The list of available Analyses and Data was presented.

Czech Republic (J. Maly)

The Czech Republic presented its national experience and approach to LTO for structures and structural components. General information was presented on the Temelin and Dukovany NPPs (managed by the Czech Power Company). The Operator of both NPPs is making plans for the extension of their operating lives beyond their 30 year design life. All activities connected to the safety aspects of LTO are closely related to aging and maintenance of the plant and detailed programmes were established within a frame of the quality assurance system implemented for the plant. Applicable national laws and regulations are represented by Atomic Act No. 18/1997, that gives general rules and requirements for plant licensing and license renewal. More detailed safety requirements are included in regulations and guides issued by the regulatory body.

The Czech Power Company established special working groups for SALTO/PLEX programme to support the preparation and management of activities for plant license extension. A list of basic documents prepared by the operator has also been developed. Basic internal regulations and documents of the Nuclear Division are:

PP 043 – Procedures for PLEX/LTO management
PP 053 – Ageing Management
ME 085 – Technical – Economic feasibility study for PLEX/LTO
ME 086 – Data Collection and Record Keeping for PLEX/LTO (under development)

PP began a research programme on containment ageing mechanisms and studies on the mitigation of ageing in cooperation with the Technical University of Brno.

Hungary (S. Ratkai)

Safety aspects of long-term operation related to building structures and structural components are recognized as very important at the Paks NPP. The building structures and structural components as long-lived passive items have been subject to lifetime management since startup of the plant. Consequently, condition monitoring, based on safety, seismic, and fire safety classifications is going on at the plant. The identification of the scope of lifetime management and licence renewal has been carried out on the basis of new, state of the art regulation. The ageing processes have been identified and effective control methods selected. The plant programme includes: control of settlement and building movements, control of corrosion of carbon steel structures, control of cracks in concrete, monitoring of reinforced concrete behaviour in different environments, and monitoring of the corrosion of buried pipes and structural components, such as supports. Regular observation and evaluation of collected data are used to identify corrective measures, repairs, and reconstructions. As a result of systematic monitoring and corrective actions, as well as the modifications implemented in the framework of the safety upgrading programme, the condition of the building structures and structural components at Paks NPP is good. The building structures and structural components have not aged significantly.

The Licence Renewal Project concentrates on the safety aspects of long-term operation of building structures and structural components. Besides the continuation of the ongoing ageing management programme, the most important tasks are:

- Identification of the non-pressurized components within the scope of license renewal
- Analysis of the necessity of the soil stabilization by injection of the main building of Paks Unit 4;
- Analyses of liners corrosion at hidden surfaces,
- Introduction of an inspection plan for non-pressure retaining components (e.g. pipeline supports);
- Surveying of the reinforced concrete structures (environmental temperature is above 70 °C);
- Status survey of the penetrations;
- Analysis of embedments of mechanical equipment, taking into account the result of the survey reports (issues: high temperature, settlement of (main building complex (MBC), leaked coolants and lubricants);
- Development of upgrading and reconstruction plans.

Russian Federation (E. Zakharov)

The national approach to the management of NPP structural component life is based on approaches applied to life extension for WWER reactors.

The regulatory body of Russia (Gosatomenergonadzor, GAN) developed a document that sets forth the requirements for NPP life extension (HN-017-2000, "Life Extension Justification"). The operator (Rosenergoatom) developed a set of documents that specify the requirements for NPP life extension, including requirements for technical condition evaluation techniques, including techniques used to evaluate the condition of reinforced concrete structures relevant for NPP safety. These documents also provide categorization of structures used for construction of different types of WWER units.

The activities aimed at evaluation of condition and residual life are conducted in accordance with a specific flow chart (algorithm) for the assessment of concrete structures' life, and a stand-alone algorithm for containment structures. The presentation also includes approaches to identify the condition of the containment during operation. The decision to grant a license for further containment operation takes into account the data acquired from the instrumentation and control equipment installed in the containment and on the tendons. The condition of the pre-stressed containment is monitored through maintenance as well as through leak-tightness tests.

The presentation also mentioned the requirements for newly developed regulatory documents such as "Monitoring of NPP Structures" which address life extension and life management of buildings and structures.

Slovak Republic (SR) (M. Prandorfy)

All the VVER type NPPs have been designed in accordance with Soviet (Russian) standards valid at the time of plant design and components manufacture. Requirements imposed upon the assurance of general safety and design lifetime have been summarised in „Regulations for Design and Safe Operation of NPP Components, Testing and Research Reactors and NPPs (1973)".

Slovak Regulatory Bodies:

- National Labour Inspectorate of SR – NIP (former SUBP)
- Nuclear Regulatory Authority of SR (former CSKAE)

Legislation in SR

An overview of the Slovak legislation was provided.

AM Characteristic and AMP

Recently (approximately from 2001) Operators and Suppliers in the Slovak Republic began to prepare for establishment and application of Ageing Management Programmes (AMP) aimed at a long-term operation of NPPs with PWRs.

At present, Ageing Management Programmes are under preparation and that is why IAEA initiatives and its extra-budgetary programme on safety aspects of long term operation of pressurised water reactors are appreciated. It is expected that collection of WWER-specific information by all participants will contribute to increased quality and unification of national programmes.

Several Ageing Management Programmes focusing on ageing of structures and structural components (SSCs) are under preparation in the Slovak Republic; the most developed being the programmes related to Concrete Containment Building (CCB). These programmes have been prepared based on recommendation IAEA-TECDOC-1025.

In parallel with the development of these programmes, background materials for the Slovak Nuclear Regulatory Authority (UJD SR) will be used to clarify national regulations for the management of ageing and the evaluation of safe long-term operation (LTO).

Scope of SSCs that are subject to the LTO Review

Development of Ageing Management Programmes and monitoring of residual lifetimes depends on classification of individual building structures and selected rooms into one of three classes.

To classify a civil structure or its part, criteria related to nuclear safety, operating safety and extension of NPP lifetime have been taken into account.

Classes 1 and 2 include civil structures and their parts (SSCs) ranked within the "List of Classified Equipment" in safety classes 2 and 3 (BK 2,3) defined by the Slovak NRA (UJD SR) upon which extraordinary requirements are imposed in accordance with Decree 317/2002. For these selected SSCs, seismic resistance 1 against design seismic event is required.

Examples of Class 1 and 2 items were provided.

Collection of information on SSCs

For most important civil structures (Classes 1 and 2) summary information sheets are being prepared in Slovakia. The content of the information sheets for each SSC was presented.

AMP development

To develop an effective AMP, it is necessary to have rational methodical procedures based on widely accepted and long term verified experience. Taking into account recently issued IAEA aging evaluation guidelines for nuclear energy facilities, background material for elaboration of such methodical procedures were developed.

To develop AMPs for individual SSCs, procedures have been elaborated in Slovakia that are being developed in more detail at present (AMP – by VUJE, AMP for Concrete Containment Building - by VUEZ /L2/).

Prepared programmes for assessment and elimination of ageing effects

Fuel Pool liner leak-tightness verification

Fuel pools in general are provided with a liner. A boric acid solution penetrates through the leaks in the liner and is absorbed by hermetic zone concrete.

In VÚEZ, a procedure for leak detection of the fuel pool liner is under development and will be tested during work at the Dukovany and J. Bohunice NPP.

Programme of monitoring and identification of humidity sources in hermetic zone concrete

This programme is based on measurements of excess humidity created in selected locations in hermetic zone concrete by means of sampling points in the hermetic liner. Regular measurement of the amounts of accumulated solutions and their chemical composition will allow for the analysis of the primary source.

Programme of hermetic liner evaluation

Sampling and laboratory analyses will enable the evaluation of the status of the hermetic liner and estimation its lifetime.

Verification of lifetime by calculations

It is obvious that a proper lifetime prediction is an exceptionally difficult task. To address this the task, a number of factors shall be considered. Taking into account a high number of influencing factors and phenomena, it is advisable to consider the use of probabilistic methods to deterministic ones.

Sweden (J. Gustavsson)

There are many research and development activities underway related to the containment as well as in other fields. The Swedish Nuclear Inspectorate has performed investigation of the containments in Sweden, and has published its findings in report SKI 02:58. The report concludes that additional research and development on containments must be done.

The CONMOD-project, financed partly by the European Union, has been going on for two years. The project combines structural analysis with non-destructive testing (NDT) to determine the status and predict the lifetime of the containment structures. The project includes the development of a procedure for lifetime management of containment structures.

In connection with the CONMOD-project, destructive testing is used to investigate material properties such as compressive strength, E-modulus, humidity profile, etc.

The International Standard Problem (ISP) 48 on containment capacity is a project where structural models are tested against measured values in the Sandia project.

We also have a project on long time properties of containments with prestressed concrete. The research has so far been concentrated on the distribution of forces along curved ungrouted tendons.

The FSAR specifies the regulatory basis for the civil structures of the plant. Swedish building codes have been used as much as possible for the civil structures, but United States codes were used for the containments. Requirements for the leak tightness testing and the tendon inspections are specified in the technical specifications.

The pressure and leak tightness tests are carried out according to Option A of Appendix J to Title 10 of the Code of Federal Regulation Part 50 (10 CFR Part 50). All test results have been acceptable. Activities are going on to forward an application to the authorities to use option B in the future.

Visual inspections of all civil structures are being done every four years.

The tendon inspections are done every ten years, mainly following the procedures in Regulatory Guide 1.35. The results have been acceptable.

Experience has shown that damage to the containment liner occurs due to voids beneath the liner. Liner corrosion results if the voids fill with water and air.

Ukraine (O. Mayboroda)

The Ukrainian approach to LTO of NPP buildings and structures was presented. The Regulatory Authority has three levels of documents which contain requirements for the design and safe operation of NPP buildings and structures. Most of these documents can be used as justification for LTO of structures within the Periodic Safety Review framework. The first-level documents (called norms and rules for nuclear and radiation safety (PNAE-5.6, PNAE G-10-021-90, and PNAE G-1-001-85, etc.)) were issued in the former Soviet Union. The Ukrainian regulatory body developed the general document "Requirements to the Safety Analysis Report contents of WWER-Type Ukrainian NPPs" that includes requirements for safety limit analysis for structures and structural components, taking into account the effects of aging.

The second-level documents are norms and rules which are obligatory for all industrial buildings and structures. This set of documents includes two types of regulations: building norms and rules (SniP) issued in the former Soviet Union, and state building norms (DBN) issued in the Ukraine. These documents establish requirements for the design of industrial and civil buildings. The first-level documents reference the second-level documents and include additional requirements for NPP structures. The third level of documents issued by the Ukraine is for assessment of existing industrial structures' technical state and certification to demonstrate their reliability and safety exploitation. Currently the general regulatory document on license extension and the utility document on LTO are under development. These documents are required to implement the AMP.

NAEK "Energoatom" developed the list of building structures and their components that are planned to operate beyond the design life. For all NPP units, the working inspection programmes are implemented and include periodic inspection and maintenance during outages, special inspections, and settlement and slope monitoring. NAEK "Energoatom" has started to develop a general programme on technical state assessment and lifetime assignment for 8 types of building structures and structural components, such as the reactor cavity, walls and floors of the reactor hall, structures associated with the cooling pond, etc.

USA (W. Burton)

The presentation outlined the NRC mission and provided background on the development and status of the license renewal programme in the United States. To date, 23 NPPs at 12 sites have received renewed licenses to allow operation for 20 years beyond the original licensed operating period. 19 additional NPPs at 11 sites are currently under review for a renewed license. The United States began preparations for license extension of NPPs in the mid-1980's with the development of the Nuclear Plant Aging Research (NPAR) programme. This programme produced over 100 technical reports on aging for a variety of mechanical, electrical, and structural systems and components. This information was used to develop the initial license renewal programme in the early 1990's.

The license renewal rule is provided in Part 54 of Title 10 of the *Code of Federal Regulations* (the Rule). In 1995, the Rule was revised to change the focus from age-related degradation to aging effects. Associated with the Rule are several guidance documents which aid both regulators and operators to monitor, identify, assess, and correct aging in structures, systems, and components (SSCs) that are within the scope of the Rule. This guidance includes:

RG 1.188 – a regulatory guide, which provides guidance regarding the format and content of a license renewal application.

NEI 95-10 – guidance provided by the Nuclear Energy Institute, which provides guidance to operators as they develop their license renewal applications.

NUREG-1800 – the standard review plan which provides guidance to the regulator on the performance of its safety review of an application to renew an operating license.

NUREG-1801 – The Generic Aging Lessons Learned (GALL) Report, which documents the staff's review and conclusions regarding acceptable aging management practices and programmes which can be used by multiple operators.

The license renewal programme in the United States is based on 2 key principals: (1) the current regulatory process has been found to be adequate to ensure plant safety (with the possible exception of several age-related issues), and (2) that the current plant-specific licensing basis shall be maintained in the same manner and to the same extent in the renewal term as it was in the initial operating term.

Underlying these principals is significant experience in the monitoring, identification, assessment of NPPs, as well as the sharing of information on industry-wide operating experience among NPPs.

A detailed explanation of the license renewal review process was provided, including an explanation of the scoping and screening process, the aging management review process, the key attributes of aging management programmes, and time-limited aging analyses.

Several key issues were discussed related to structures and structural components, including aging management of inaccessible areas of structures and components, challenges posed by the erosion of concrete subfoundations, and experience with loss of prestress of containment tendons.

Information on the license renewal programme is readily available and can be found on the U.S. Nuclear Regulatory Commission website (www.nrc.gov).

*European Commission (*C. Rieg)

A presentation was made on the EC contribution to Nuclear Safety and Nuclear Power. General figures for the Institute for Energy were given, as well as an introduction to its activities in the areas of material science and component assessment. SAFELIFE is the current integrated approach to research and development (R&D) activities on critical components of ageing NPPs, but there is no ongoing R&D activity related to structural components. SAFELIFE integrates networking (AMES, ENIQ, NESC, NET, AMALIA & SENUF), contributions to R&D actions, particular support towards the acceding countries, and maintenance and development of the Joint Research Centre (JRC) research capabilities & R&D tools. Additional support is provided to the CEECs within the TACIS/ PHARE Nuclear Safety Programmes. In this frame, JRC provides for technical project management assistance and performs specific projects (e.g., dissemination / RPV embrittlement).

Examples of ongoing share cost actions on the development of structural analysis methods and non-destructive testing devices for concrete structures (MAECENAS & CONMOD) were given. There might be an opportunity in the future to share the experimental data on physical and mechanical properties of aged concrete, as well as the results of global tests of real structures and mock-ups. This would provide for a consistent database for calibrating advanced software for stress, crack initiation and propagation, and leak rate assessment. Mr Gustavson, the Swedish representative to WG 4, stated that there is an intention to propose a Network of Excellence on this subject.

Examples of past successful TACIS Nuclear projects dedicated to the containment/confinement improvement of the VVERs were presented. But, in recent years there have been no requests from Russia or Ukraine for support of concrete structure assessments. The Russian & Ukrainian utilities were encouraged to consider the possibility for the development of an updated assessment methodology.

2.2 Discussion outcomes

2.2.1 Generic comments on LTO-2 and WG-4 Workplan

The working group members discussed the work plan. Changes to the work plan were recorded in the document as the working group members reached a consensus on each issue. The latest revision of the work plan is documented in IAEA-EBP-LTO-02 [2]. The major changes to document are provided below.

1. Under the Section 3.0– Scope, item 3 on.

WG-4 members agreed to develop a more detailed text, also as a follow up of the suggestions from WG-2. The new text is a proposal that should be finally endorsed by WG-1, 2, 3 participants and SC. The criteria applied here to solve some of the conflicts of competences have been the following:

1. Items traditionally covered by design standards for civil structures have been put into WG-4 scope
2. Items in the same scope of supply together with the civil structures (embedded part of the penetrations) have been put into WG-4 scope
3. Items which are part of the containment pressure boundary (doors, small hatches) and which are not going to be operated on a regular basis (large equipment hatches) have been put into WG-4 scope

4. Structural items which are difficult to be replaced (large hatches) have been put into WG-4 scope
5. Structural items whose safety function is primarily to contain and support have been put into WG-4 scope

The potential interfaces with other WGs have been also made explicit in the text itself.

In conclusion, WG4 members agreed on the following new text:

3. There may also be certain other areas dedicated to a specific functional purpose that may be essential to safe operation of the plant, such as:

- *fire protection,*
- *environmental qualification,*
- *design basis and severe accident management.*

The activities of Working Group 4 will be primarily focused on PWR structures and structural components that:

- *are needed through LTO*
- *that are difficult or impossible to replace*
- *whose integrity is essential to ensure safe LTO.*

These structures and structural components may include, but are not limited to:

1. *Containment/confinement/pressure boundary structure*
2. *Structures inside the pressure boundary (compartment box, reactor box, etc.)*
3. *Other safety classified buildings*
4. *Radwaste building*
5. *Spent fuel pool*
6. *Water intake structures*
7. *Foundation systems (turbine, others), embedment, soil-structure interaction*
8. *Stack*
9. *Cooling towers*
10. *Buried pipelines*
11. *Cranes (only the supporting structures)*
12. *Pipe whip restraints*
13. *Anchorages, penetrations, hatches, etc.*
14. *Painting, coating, fire proof coating, etc.*

In addition to these structures, the following structural items are included in the scope of WG-4:

1. *Interfaces/anchoring of HVAC ducts (embedded in concrete or not). The ducts themselves are in the WG-2 scope*
2. *Concrete embedded part of the electrical and mechanical penetrations (the penetration and the welding to the embedded part is in the WG-2 scope)*
3. *Equipment hatches and hermetic doors, small hatches and other doors (including fire protection doors)*
4. *Buried pipelines (with direct interface with the soil), support (channels) and protection structures for the underground pipelines. Other pipelines supported by a structure (channel, building, etc.) are in the WG-2 scope.*

In general, it is suggested that any conflicts of competences that should arise among different working groups are solved through the application of special criteria. Therefore WG-4 scope may include the following items:

1. *Items traditionally covered by design standards for civil structures*
2. *Items in the same scope of supply together with the civil structures (embedded part of the penetrations)*
3. *Items which are part of the containment pressure boundary (doors, hatches) and which are not going to be operated on a regular basis (large equipment hatches)*
4. *Structural items which are difficult to be replaced with important structural function (hatches)*
5. *Structural items whose safety function is primarily to contain and support*

The Working Group 4 will co-ordinate its activity with Working Group 2 in relation to

– *material aspects of ageing of steel containments, and structural steel;*
– *support structures of mechanical components*
– *refueling machine, cranes and lifts*
– *the interfaces with the items identified above*

The Working Group 4 will co-ordinate its activity with Working Group 1 in relation to

– *design basis reconstruction issues (when present)*

The Working Group 4 will co-ordinate its activity with both Working Group 2 and 3 in relation to

– *procedures for environmental data acquisition*

<u>2. Under the Section 4.0– Tasks. Task 1</u>

WG-4 members proposed that an effort should be made by the SC to enlarge the participation to the EBP-SALTO project. A special recommendation has been issued to involve the experience of countries operating

- boiling water reactors
- heavy water reactors
- fast breeder reactors
- RBMK reactors (in Russia they are involved in LTO projects, in Ukraine they need some years for the decommissioning and therefore their LTO from the structure standpoint is of interest for the WG-4)
- AGR, HTGR reactors

The main reasons for that is that there is a large amount of technical literature available on these reactors. Moreover, the structural components are not very much affected by the differences in layout and plant technology and therefore the experience on the degradation models can be of real interest for the WG-4 members. However, the WG-4 members expressed their worry that the enlargement of the data base for the project could jeopardize the timely implementation of the tasks of EBP-SALTO and therefore they suggested the following:

The scope of the EBP-SALTO project, in terms of plant types to be addressed, should not change. However, additional data from the mentioned reactor types should be collected as a complement to the already agreed data base. For these reactors the collection task should not be fully implemented.

In this process of enlargement of the experience data base, emphasis should be given to the boiling water reactors and RBMKs, where many data are readily available in the WG-4 member countries (Sweden and Ukraine).

WG4 members also agreed to add the following new text:

A special effort should be carried out to get data from Finland, UK and Canada. However, the SC will take care that the processing of this information will not jeopardize the schedule of the WG-4.

3. Under the Section 4.0– Tasks. Task 2

WG-4 members agreed to add the following new text:

It is suggested to consider a "transversal" working method "category by category" which looks more suitable for the application to the structural items.

4. Under the Section 5.0– Milestone and deliverables. Task 1

WG-4 members agreed to modify the text as in the following:

Deliverables

1. *Report outlining the Standard Review Process developed for Working Group 4 (it is the minutes of the meeting of the Kick-off meeting)*
2. *Report to the SC on the collection of information (National Summary Reports for task 1)*

5. The schedule for WG4 tasks has been completely revised, as in Appendix II of LTO-2 [2]

WG-4 members agreed on the following key principles at the basis of the schedule review:

- Task 1 deserves more time than foreseen in the first draft of LTO-2. The end of September 2004 for the delivery of the first draft of the National Report for Task 1 is the earliest possible deadline compatible with a reliable and complete data collection task.
- In order to make the data review easier, it was decided to split the preparation of the national report for task 1 in two steps: the first step to be completed by end of May 2004 dealing with chapters 1,2,4,5 above. The second step to be completed by end of September 2004 dealing with chapters 3,6,7,8,9 above.
- The preliminary internal review of the reports submitted by the MS will be conducted by the Co-Chairman, the Secretary, the IAEA EC-JRC representative, and the Scientific Secretary for WG4. The objective is to review both the consistency of the national report with the format proposed above and the quality of the information provided (quantitative, suitable for the comparison to be carried out in Task 2,3). Comments will be submitted back to the MS by the end of June and October respectively for final endorsement by the end of November 2004.
- The next meeting for Task 1 can be held not earlier than beginning December 2004.

2.2.2 Generic comments on LTO-3 - SRP

The working group members discussed the SRP. Changes were recorded in the document as the working group members reached a consensus on each issue. The latest revision is documented in IAEA-EBP-LTO-03 [3]. The major changes to document are provided below.

1. Under the Section 3.0 – Scope of review

WG-4 members observed that the

1. PSR is not practice in many countries with LTO programmes in place,
2. PSR has different objectives than LTO programmes in many countries

Therefore WG-4 members agreed to delete the text *"(tool for LTO)"*

2. Under the Section 4.4 – Structures and structural components – WG4

WG-4 members discussed the table of content of the National Summary Report to be issued for task 1. Such a report should be consistent with the general mandate to WG-4 described at chapter 5.4 of [3].

The WG-4 agreed to modify the text as follows:

Working Group 4 will collect and process information in relation to the following areas:

1. *Regulatory position*
    - *Collect regulatory docs: only those relevant to structures*
2. *Scope of the LTO program*
    - *Table with the items included in the LTO program*
    - *Criteria for selection of items in the scope of this report. Suggested items are:*
        a. *Containment/confinement/pressure boundary structure*
        b. *Structures inside the pressure boundary (compartment box, reactor box)*
        c. *Other safety classified buildings*
        d. *Radwaste bldg.*
        e. *Spent fuel pool*
        f. *Water intake structures*
        g. *Foundation systems (turbine, others), embedment, soil-structure interaction issues*
        h. *Stack*
        i. *Cooling towers*
        j. *Buried pipelines*
        k. *Anchorages, penetrations, hatches, etc.*
        l. *Painting, coating, fire proof coating, etc.*
        m. *Other structures where significant degradation has been recorded*
3. *Baseline/Preconditions*
    - *Current practice in design, design safety requirements, any other design requirement (if any), design basis (loads, combinations, sketches, key design features, safety classification, safety margin available, design life time), assessment techniques for existing structures (in case they are not available, the procedures to reconstruct design basis are discussed in WG1)*
4. *Reference degradation mechanisms. The following mechanisms should be described:*
    - *Only those mechanisms which are life limiting*
    - *Mechanisms considered in general in the operating experience of your country*
    - *Mechanisms from R&D*
    - *Mechanisms particularly important for the LTO of your plants: their most significant effects, their location, how they affect the LTO of the plant*
5. *Monitoring, Surveillance, and Inspection (MS&I)*
    - *ISI, monitoring and surveillance practice*
    - *Periodical test practices (integrity, leak tightness, etc.) (both current practice and R&D)*
6. *Trend analysis and evaluation of the safety margin*
    - *Analytical and numerical methods (both current practice and R&D)*
7. *Maintenance practice, mitigation measures and repair technology*

8. *AMP characteristics*
    - *Organizational, management issues and interfaces with other plant processes*
9. *References*

It was also recommended that the information to be provided following the proposed format should be of quantitative nature in order to make the comparison (Task 2 and 3) feasible and meaningful.

3. In appendix I

WG-4 members expressed their doubts that this table is going to support the project development, for the main reason that the connection between PSR and LTO projects is still not completely clarified in many countries. However, the table has been completed (only the last column relevant to WG-4).

4. In appendix II

The WG-4 noted that the WG-2 inserted the Configuration Management topic in its scope. The WG-4 Members stressed the fact that such a program is not explicitly in place in many plants. The same safety objectives are met in many WWER plants with safety related projects with different names; it is recommended to clarify the issue to avoid further misunderstandings in the communication between WG-2 and WG-4.

The section 5 of the Information Report Outline has been modified according to the text in “task 3” of chapter 4 of [2], as follows:

1.0 WORKING GROUP 4

1.1 Regulatory position on LTO of structural components
1.2 Criteria for scope definition of the LTO programs
1.3 Design basis for structural items - Preliminary safety assessment of the current safety level
1.4 Reference degradation mechanisms
1.5 Monitoring, surveillance and inspection practices
1.6 Procedures for trend analysis and evaluation of the safety margin in the long term
1.7 Maintenance practice, mitigation measures and repair technologies
1.8 AMP organizational characteristics
1.9 Compilation of a list of reference documents from which the above information was collected.

2.2.3 Method of work and next meeting

The working group members discussed the method of work to be followed for Task 1.

1. Method of work

The WG-4 agreed the following:

- 5 days is the standard time that should be allowed for document review when the standard e-mail communication is used among Members
- The communication with NAEK (Ukraine) should always use the e-mail as the FTP/web page access is still not available

2. Next meeting

It was agreed that the next WG-4 meeting should be organized at the end of Task 1, with the following objectives:

1. Review of the national reports for Task 1
2. Planning Task 2 activities

3. Report to the Steering Committee
4. Other tasks assigned by the Steering Committee

The location will be selected later, according to the work development: either places where particularly interesting data/degradation mechanisms are available/visible and worth for sharing among MS, or places where the logistic arrangement is convenient for most of the Members.

2.2.4 Other comments/recommendations to the Steering Committee

<u>1. On EBP-SALTO Web Site (chapter 6 of WG-1 of [2])</u>

The WG-4 agreed to report to the SC the following comments.

The main objectives of the EBP-SALTO web site should be:

1. To make official project documents available
   - For review by project members
   - For retrieval
2. To make technical literature available, particularly
   - National and international standards relevant to LTO (for documents with limited distributions, not publicly available in Internet)
   - Useful internet links (for documents publicly available)
   - Operating experience in MS
   - Technical literature
3. To host a discussion forum on selected topics relevant to LTO, led by the project officer, with limited time for discussions and synthesis of the results

Further recommendations on web-site management

1. Documents should be placed only by the web page administrator (the EBP-SALTO project officer)
2. The web page should be developed as soon as possible, to support the complex task 1 on document collection when huge amount of data are expected to be transferred and shared among MS
3. A password should allow only MS to access the web page, in order to protect the limited distribution documents mentioned at item 1) above
4. A temporary tool should be made official through the project FTP site (no password), at least for document exchange: ftp://ftp.iaea.org/pub/NSNI/Havel/WG4/

3. ACTION ITEMS

The following actions items resulted from the meeting.

1. Messrs. Burton and Contri agreed to develop and distribute a draft of the meeting by March 8, 2004. The draft will be reviewed by the WG-4 Member by March 12. No reply by that date means agreement.
2. Mr. Burton and Mr. Contri agreed to review comments on the Workplan and Standard Review Plan for WG 4 (IAEA-EBP-LTO-02 and –03, respectively) and make appropriate revisions by March 8, 2004.
3. The Presentations provided by the MS will be available on the project FTP site (ftp://ftp.iaea.org/pub/NSNI/Havel/WG4/) since March 15, for two months.
4. Actions according to the revised workplan for WG-4 (Appendix to LTO-2): data collection, interim review, final data collection, second review.
5. The date of the next meeting of the WG-4 (December 2004?) will be fixed after the SC meeting. A proposal will be circulated by the Chairman of the WG-4 by March 22.

4. REFERENCES

[1] Minutes of the Programme's 1st Steering Committee Meeting, IAEA-EBP-LTO-01, Vienna, 2003 (internal EBP report).

[2] Minutes of the Programme's Planning Meeting, IAEA-EBP-LTO-02, Vienna, 2004 (internal EBP report).

[3] Minutes of the Programme's Planning Meeting, IAEA-EBP-LTO-03 Vienna, 2004 (internal EBP report).

APPENDIX I.
MEETING AGENDA

2.1. Wednesday, 3 March, 2004		
08:00	Pre meeting, only for Chairman, Secretary and IAEA TOs	P. Contri, M Batishchev, W. Burton
09:00	Opening, Meeting Objectives	P. Contri
09:15	EBP WG-4 Workplan, SRP	M Batishchev, W. Burton
10:30	Coffee Break	
	National Presentations	
11:00	Bulgaria	M Batishchev, M. Milanov
11:45	Czech Republic	M. Maly
12:30	Lunch Break	
14:00	Hungary	S. Ratkai
14:45	Russian Federation	E. Zakharov
15:30	Coffee Break	
16:00	Ukraine	O. Mayboroda, M. Sememnyuk
16:45	Sweden	J. Gustavsson
17:30	Adjourn	
19:00	“Wine and cheese” party at the VIC	
Thursday, 4 March, 2004		
09:00	USA	W. Burton
09:45	Slovakia	M. Prandorfy
10:30	Coffee Break	
11:00	The EC	C. Rieg
11:45	Discussion of National Approaches: scope of LTO, mechanisms, investigations, assessment methods, repairing actions	Chaired by Burton, Batishchev
12:30	Lunch Break	
14:00	Data collection issues: quality, quantity, data support, sources and scope	Chaired by Burton, Batishchev
15:00	Method of work, merging data, reporting, deadlines, next meeting	Chaired by Batishchev, Burton
17:30	Adjourn	
Friday, 5 March, 2004		
09:00	Updating the WG 4 Workplan, WG 4 Standard Review Process (LTO02-03)	Chaired by Batishchev, Burton
12:30	Lunch Break	
14:00	Final Discussion, preparation of the minutes, report to the SC (deadline and responsibilities)	Chaired by Batishchev, Burton
17:30	Adjourn	

APPENDIX II.
LIST OF PARTICIPANTS

BULGARIA

Mr. Mihail Batishchev *Co-chairman*
ATOMTOPLOPROECT
Nikoly Liliev Str. 20
1421 Sofia
Bulgaria
Tel.: +359 2 963 32 01/8687223
Cell: +359 889 317 492
Fax: +359 296 33185
E-mail: atp@cit.bg

Mr. Milan Milanov
Kozloduy NPP,
3321 Kozloduy
Bulgaria
Cell:+359 888 98 99 52
Tel.: +359 973 7 2445
Fax: +359 973 7 2445
E-mail: m_milanov@npp.cit.bg

CZECH REPUBLIC

Mr. Jan Maly
NRI-Rez
Energoprojekt
Vyskocilova 3
P.O. BOX 158
140 21 Prague 4
Czech Republic
Tel.: +420 241 006 420
Cell: +420 602 743 188
Fax: +420 241 006 409
E-mail: maly@egp.cz

HUNGARY

Mr. Sandor Ratkai
Paks Nuclear Power Plant Co., Ltd.
P.O. Box 71
H-7031 Paks
Hungary
Tel.: +36 75 508576
Cell: +36 20 9522241
Fax: +36 75 507036
E-mail: ratkai@npp.hu

LITHUANIA

Mr. Jevgenij Kozlov **(Interpreter)**
Visaginas 4761
Lithuania
Tel: +37038624335
E-mail: kozlove@mail.iae.lt; kidd@tts.lt

RUSSIAN FEDERATION

Mr. Eduard Zakharov
Atomenergoproect
Russian Federation
Tel.: +7 095 2638380
Cell:
Fax: +7 095 2650974
E-mail: gtb@aep.ru

SLOVAKIA

Mr. Milan Prandorfy
VUEZ, a. s.,
Hviezdoslavova 35,
P.o.Box 153
93480 Levice
Slovak Republic
Tel: + 421 36 638 3160/ 903 454605
Fax: + 421 36 6341617
Mail: prandorfy@vuez.sk

Mr. Daniel Benacka
Mochovce NPP
93539 Mochovce
Slovak Republic
Tel: + 421 36 63 63027
Fax: + 421 36 6391120
Mail: Benacka.daniel@emo.seas.sk

SWEDEN

Mr. Jan Gustavsson
RTTP
Ringhals AB
SE-430 22 Väröbacka
Sweden
Tel.: +463 40667950
Cell: + 467 06767950
Fax: + 463 40668389
E-mail: jan.gustavsson@ringhals.se

UKRAINE

Ms. Olena Mayboroda
SSTC
Scientific Center for Nuclear and Radiation Safety
Ukraine
Tel.: +380 44 452 6203
Fax: +380 44 452 8990
E-mail: ee_mayboroda@sstc.kiev.ua

Mr. Mikhayl Semenyuk
NAEK Energoatom
Vetrova,3
Kyiv-01032
Ukraine
Tel.: +380 44 201 09 13/20
+380 44 294 48 75
Fax: +380 44 294 48 53
E-mail:v.starostenko@direcky.atom.gov.ua;
dmstp@atom.gov.au

USA

Mr. William Burton ***Secretary***
USNRC
Division of Regulatory Improvement Programs
Mail Stop 0 - 11F1,
Washington, D.C. 20555-0001,
USA
Tel.: +1 301 415 2853
Fax: +1 301 415 2002
E-mail: WFB@nrc.gov

EUROPEAN COMMISSION

Mr. Claude Rieg
EC, Directorate General JRC
Westerduinweg 3
P.O. Box 2
1755 ZG Petten
The Netherlands
Tel.: +31 224 565153
Cell: +31 622 312661
Fax: +31 224 565 637
E-mail: claude-ives.rieg@jrc.nl

IAEA

Mr. Paolo Contri, NSNI-ESS (Scientific Secretary)
Mr. Radim Havel, NSNI-ESS

APPENDIX III.
PRESENTATIONS HANDOUTS

IAEA EBP
SAFETY ASPECTS OF LONG TERM OPERATION OF PRESSURIZED WATER REACTORS(SALTO)
WG-4 Structures and structural components
Kick-off Meeting
IAEA, Vienna, March 3-5, 2004

Introductory notes

Paolo Contri (NS/NSNI/ESS/DU)
P.Contri@IAEA.org

EBP-SALTO OBJECTIVES

Defined by the Steering Committee (IAEA-EBP-LTO-01)

- Develop an internationally agreed framework to support Regulators and Operators in the management of long term operation programs, through:
  - Collection of available experience in regulation and implementation of LTO programs
  - Development of guidelines for new LTO program management
  - Suggestion of practical implementation approaches

2

Method of work

- Four WGs **(IAEA-EBP-LTO-02)** :
  1. General LTO framework,
  2. Mechanical components and materials,
  3. Electrical components and I&C,
  4. Structures and structural components

- Tasks in every WGs:
  1. Compile/collect info (national summary reports)
  2. Review and compare info
  3. Reconcile info
  4. Formulate final reports

- A Standard Review Process (SRP) aims at guaranteeing uniformity and compatibility among the WGs **(IAEA-EBP-LTO-03)**

3

The WG4

- **Objectives**

Develop guidelines to support the development of LTO programs for structures and structural components

- **Scope**
  - Safety classified structures (containment, aux building, intake, spent fuel pool, underground piping, supports)
  - Irreplaceable structures

- **Interfaces**
  - With WG1 on the general approach, scoping, etc.
  - With WG2 on mechanical components (supports, interfaces, interactions)

4

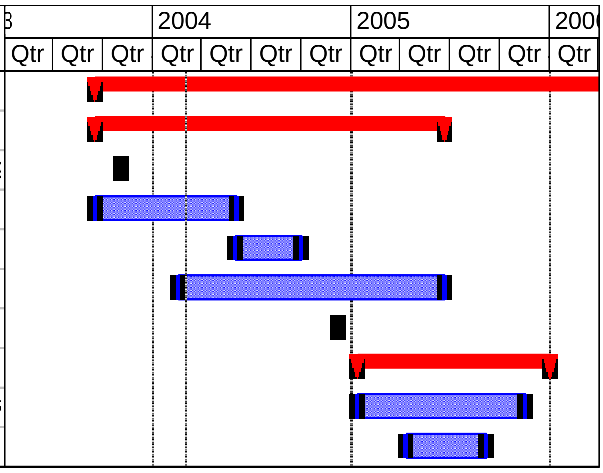
National summary report for Task 1

1. Collect regulatory docs: only those relevant to structures!!
2. Scope of the LTO program: table with the items included in the LTO program. Criteria for selection of items in the scope of this report
3. Baseline/Preconditions: current practice in design, design requirements, design basis (loads, combinations, sketches, safety classification, safety margin available, design life time), assessment techniques for existing structures (in case they are not available, the procedures to reconstruct design basis are discussed in WG1)
4. Reference degradation mechanisms (both from operating experience and from R&D): only those life limiting. Degradation mechanisms, their location and effects identified at your plants. Identify the LTO relevant mechanisms
5. ISI, monitoring, surveillance, periodical test practices (integrity, leak tightness, etc.) (both current practice and R&D)
6. Trend analysis and evaluation of the safety margin: analytical and numerical methods (both current practice and R&D)
7. Maintenance practice and repair technology
8. AMP characteristics: organisational, management and interfaces with other plant processes
9. References

5

Schedule

ID	Task Name
73	**WG 4 Structures**
74	**Task 1**
75	Kick-off&D.coll.Mtg
76	Draft St.Rev.Proc.
77	Final St.Rev.Proc.
78	Collect info
79	Info collection Mtg
80	**Task 2**
81	Init.anal.of info/mis
82	Draft Rpt.-Req.



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Kick-off meeting agenda

1. Agree on objective, scope, deliverable
2. Define format, content, quantity, quality, support of the data to be provided
3. Define data collection flow, roles and responsibilities, schedule
4. Next subtasks for completion of task 1, next meeting
5. General comments on LTO2, LTO3
6. Update the project schedule
7. Prepare the minutes of the meeting (LTO-6)
8. Report to the SC

7

Other issues

- The folder
- The logistics
- The admin
- The reception
- Update the participant list
- Leave a copy of your presentation
- Ask for IAEA docs

8

IAEA EBP
on
SAFETY ASPECTS OF LONG TERM OPERATION OF PRESSURIZED WATER REACTORS

1st Meeting of Working Group 4

IAEA, Vienna, 3-5 March 2004
Radim Havel

EBP BACKGROUND

- Scoping meeting – March 2003 (RF, SWE, USA)
- 1st SC meeting – May 2003 (BUL, CR, FI, H, RF, SR, SP, SWE, UKR, USA, EC) + (F, UK); IAEA-EBP-LTO-01; EBP overall Workplan incl. Objective, exp. outcome, and approach (SC+4WGs)
- Planning meeting – August 2003 (WG chairs + secs + SC chair); IAEA-EBP-LTO-02; WG 1-4 draft Workplans, initiated SRP development
- EBP: May 2003 – November 2006; RB 2007 onwards

EBP OBJECTIVE

- SC: IAEA-EBP-LTO-01
- Assist PWR operators and regulators:
  - to ensure the required safety level is maintained during long term operation
  - to provide generic tools to support the identification of safety criteria and practices applicable to long term operation at national level
- Develop an internationally agreed common framework to support safe long term operation including related processes and practices
- SC nominated WG chairpersons/secretaries

WGs OBJECTIVE

- 4 areas:
  - General LTO framework,
  - Mechanical components and materials,
  - Electrical components and I&C,
  - Structures and structural components
- Tasks:
  - Compile/collect info (national summary reports)
  - Review and compare info
  - Reconcile info
  - Formulate final reports
- Standard review process (uniformity and compatibility, PSR index)
- Homework assignments (meetings…co-ordination)

1^{st} WG 4 MEETING OBJECTIVE

- Finalize Workplan incl. schedule (mtgs., outcomes, plan WG meetings to facilitate scheduling SCMs, etc.)
- Finalize SRP (WG 4 part)
- Initiate collection of information, etc.
- Homework assignments (whole EBP)
- Future meetings-where&when
- Deadlines
  - next SC meeting: 16-18 March 2004
  - final WG 4 drafts (Workplan+SRP): **5 March 2004** (WG1: 13-15 Jan; WG2: 4-6 Feb; WG3: 10-12 Feb)
- Meeting minutes
- Butch to ‘sell’ WG results (LTO-02, 03, and 07)

6 May 2004 5

IAEA EBP
SAFETY ASPECTS OF LONG TERM OPERATION OF PRESSURIZED WATER REACTORS(SALTO)
WG-4 Structures and structural components
Kick-off Meeting
IAEA, Vienna, March 3-5, 2004

Background information
by
Paolo Contri (IAEA - NS/NSNI/ESS)
(P.Contri@IAEA.org)

The objectives

Objectives of the presentation

To provide information on the **safety background** of Long Term Operation (**LTO**) based on ageing management (**AMP**), according to the IAEA approach and documents

Content

1. Experience in Member States and feedback
2. The LTO problem
3. Strategy for LTO
4. Scoping the LTO
5. Preconditions and LTO related tasks
6. AMP in LTO programs
7. Implementation aspects and examples

1) Experience in MS on LTO/PSR

- Countries with **limited term license**: USA, Finland, Switzerland, Mexico.
- Countries without term licences control long term operation through **PSRs**
- Large divergences in the **extension** of the PSRs
- Usually licensees should maintain the licensing basis of the plant **throughout its life**. Unless the discrepancies with current rules are shown to be unacceptable in terms of risk, the upgrading is required to the extent that is reasonably practicable.

- **PSRs** have been completed in **(OECD countries)**: Belgium, Finland, France, Germany, Hungary, Japan, Netherlands, South Africa, Spain, Sweden, Switzerland and the United Kingdom
- PSRs are being performed in **(OECD countries)**: Canada (Pt. Lepreau NPP), China (Qinshan NPP), Korea (KORI 1), Mexico (Laguna Verde 1), and Slovenia (Krsko NPP)
- Other countries are either planning to use or considering using PSR within their regulatory systems: Brazil, Bulgaria, Czech Republic, India, Pakistan, Romania, Slovak Republic, and Ukraine.

Feedback

- **PSR as a rational approach** (not the only one) to deal with the cumulative effects of: plant ageing, plant modifications, operating experience, science and technology developments, site hazard modifications, but **cannot be used** for the removal of the long term technological constraint on plant operation.
- Ageing is a major **safety related program**: prevention of damage, evaluation of the real damage (in view of LTO), emphasis on long lived passive components (excluded by standard maintenance)
- Difference between ageing management (safety concern) and **life management** (optimization, return of investment)
- **Ageing evaluation** is essential for LTO, decommissioning and change in plant use
- Importance of ageing man. program set up from the **beginning** of the plant operating life, or as soon as possible. AMP needs time
- **Difficulties in the implementation** of AMP for existing plants and in their grading in a feasible time framework

PSR versus license extension

- **Full scope PSR** may be implemented every 10 years: it is expensive (about 200 man/years)
- **License extension** is done very few times, but it does not provide **continuous** confidence on the safety level of the plant. It is usually coupled with a continuous AMP

- Some countries select a **balanced mix**:
  1. Limited scope PSR (only R&D, ageing, communication) every 10 years
  2. License extension for “expected” degradation mechanisms (TLAA), safety requirements, etc. for 20 years

  (Note: the **involved SSCs** are different between the two steps!!)

The LTO may be **extended for ever**, but economical considerations usually provide an upper bound!

Experience in MS on LTO

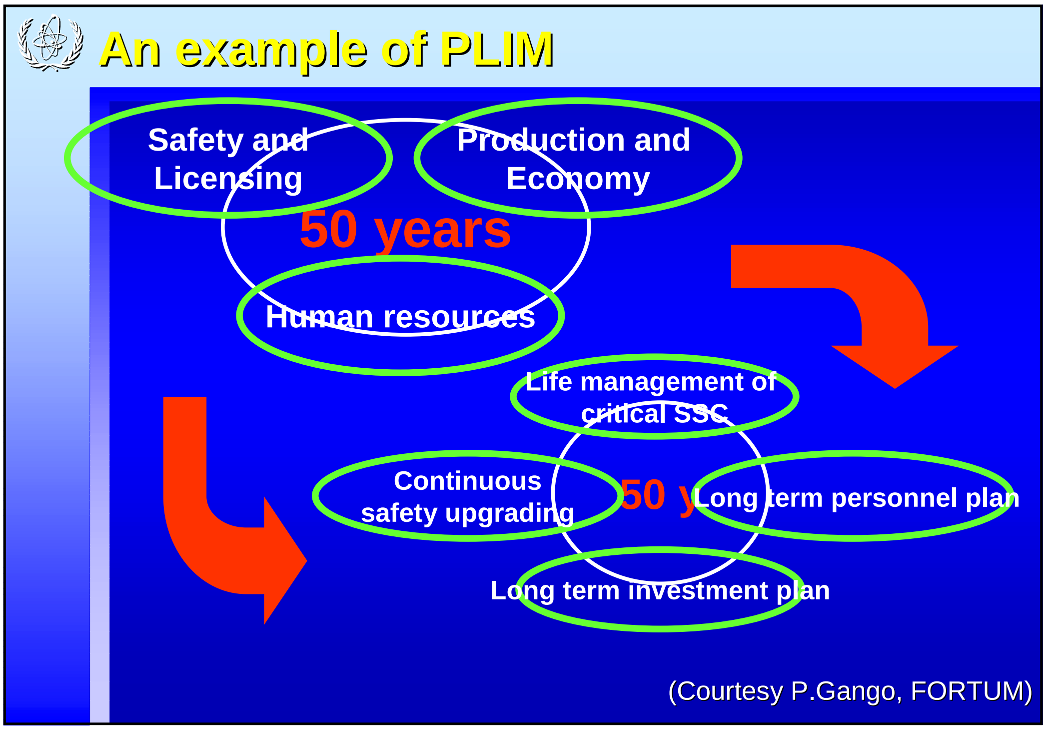
<u>Large variety of implications and approaches</u>

- **Licensing aspects**
  - Requirements
  - Legal aspects, etc.

- **Strategic aspects**
  - Long term license renewal (e.g. US)
  - Extension of Periodic Safety Review after design life (e.g. France):
    - configuration control, **safety analysis**, **equipment qualification**, **ageing**, safety performance, operating experience, procedures, organization, human factors, emergency planning, **environmental impact**

      (technological aspects, operational aspects, engineering safety aspects)

- **Implementation aspects, <u>particularly relevant to life extension</u>**
  - Ageing management
  - Economic planning



The regulatory control on LTO

Existing frameworks are rather different and a generalisation is not possible:

Regulatory system	Utility	License	LTO	Example
"Continuous" model	Continuous	Term	PLEX	USA
PSR model	Continuous	Term	PSR	France
PSR model	Continuous	No term	PSR	UK
PSR model	PLIM	Term	PSR	Finland
PSR model	PLIM	Term	PLEX+	Hungary

- In most cases PSR is applied as a standard regulatory tool but **it is not used for LTO** as it is considered not useful for a long term operation (I.e. beyond 10 years). It is then coupled with a PLEX system
- In most cases PSR provides a periodic regulatory check-up of the plant safety, but the plant applies **a continuous PLIM**

2) The LTO problem

"Long" term operation: beyond an established license term or a period established by safety evaluation

- Optimise the operation, maintenance and service life of structures, systems and components
- Maintain an acceptable level of performance and safety
- Maximize return on investment over the service life of the facility

Relevant issues

- **Technological** issue: evaluate and postpone all "expected" limitations to a safe operation
- **Regulatory** issue: prolong the regulatory control and adapt to the "beyond design life" conditions
- **Economical** issue (non safety related): need for a reasonable guarantee for at least 20-30 years to protect the investment
- **Knowledge management** issue: to preserve competences in time

Comments

- Often the "technological limit" is not declared in design documents
- Often LTO is evaluated in combination with power upgrading

Objectives of LTO programs

Some examples

- To improve plant availability through equipment reliability by managing plant equipment ageing and identifying equipment budget (US Npp)
- Objectives "safety oriented": to guarantee the safety operation of the plant meeting the safety requirements

- Equipment reliability and availability
- Max capacity factor
- Min operating cost
- Min capital cost
- Etc..

Technological aspects of LTO

Since the beginning of its operating life the plant may experience **safety related modifications** to the original design basis, such as:

1. **Expected**, well known, foreseen modifications and included in the original design basis, addressed through:
   - appropriate design and/or qualification (fatigue, relaxation, etc.)
   - rigid maintenance rules
2. **Unexpected**, known mechanisms, foreseen modifications but not included in the original design basis due to the assumptions on the design life. **Often they are plant dependent**. Addressed through:
   - **Maintenance** (but only on statistics and a posteriori!!)
   - An **ageing management program (AMP)** for material degradation, technological obsolescence and human aspects. **Advantages** over maintenance approach: unified and **systematic** management, failure **prevention**, evaluation of **real** damage, emphasis on **long** lived items
3. **Unexpected phenomena**

Unexpected issues

- Discovery of **unknown** degradation mechanisms
  - From R&D
  - From operational experience in other plants
- Discovery of **unexpected** degradation mechanisms
  - From installation and maintenance conditions, despite QA
  - From environmental conditions: internal (interactions) and external (from hazard modification and/or human changes)
  - From human errors
  - From deviations from planned operation
- Discovery of **unplanned** technological obsolescence
- **Unexpected** Modifications in standards and practice
  - In safety requirements
  - In methodologies for safety evaluation
- **Unexpected** non safety related modifications (market, economics, ownerships, etc.)

IAEA documents – Mainly ageing

- **Requirements for Design of NPPs** (2000)
- **Requirements for Operation of NPPs** (2000)
- **Safety Guide** (former O2,O7,O8)
  Maintenance, Surveillance and In-Service inspection in NPPs
- **Safety Guide** 50-SG-O12 (1994)
  Periodic Safdety Review of Operational Nuclear Power Plants
- **Safety report n.3** (1998)
  Equipment qualification in operating NPPs: upgrading, preserving and reviewing
- **Safety report n.15** (1999)
  Implementation and review of a nuclear power plant ageing management programme
- **Safety practice** n.50-P-3 (1991)
  Data collection and record keeping for the management of nuclear power plant ageing
- **Technical Report** n. 338 (1992)
  Methodology for the management of ageing of nuclear power plant components important to safety

IAEA safety requirements for an LTO

With Emphasis to safety significant issues

- **Defence in depth (DID)** is a key requirement in design and operation: good design, good operation and maintenance and strong safety culture

  INSAG-8 suggests **a two-step approach** for such a review:

  1. Preliminary review: compliance to the standards applicable at the first licence, compliance with defence in depth (site, construction, operation, defence in depth in emergency).
  2. Review in depth: compliance with current standards. Final evaluation through PSA (level 1 plus containment evaluation), deterministic safety analysis, refined evaluations of the safety margin.
- **Improving or maintaining safety?**
  1. Basic safety principles (DID) should be assessed and guaranteed.
  2. Upgrading to current safety standards should be implemented to the extent that is reasonably practicable

No LTO program is conceivable without assessment of the current safety level of the plant!

3) A general approach

A general approach to LTO, independent of the regulatory framework, can be based upon the following assumptions:

- Separation of "pre-conditions to LTO" and "LTO specific" tasks
- Separation between **regulatory** issues (PLEX, PSR, PLIM,etc.), **technological** issues (degradation) and **economical** issues
- Clarification of the **LTO scope** and therefore of the interface between maintenance, ISI, AMP, etc.
- Differences between **active and passive SSCs**, replaceable and non-replaceable components

Pre-conditions and LTO tasks

- **Preconditions for LTO**: tasks needed to **reach** the **required level** of plant safety and to prove it
- **LTO specific tasks**: tasks needed to **maintain** the **required level** of plant safety in the long term in relation to material ageing, technological obsolescence and staff knowledge, beyond the plant life defined at the design phase by the technological limits

Pre-conditions and LTO tasks

Pre-conditions – Required also for current operation during design life (see for example the **safety factors** of the PSR)

- Updated SAR
- Updated EQ
- Updated design basis
- Updated EE hazard
- Updated safety analysis
- Appropriate maintenance program

LTO specific tasks – Affected by the extension of the beyond design basis lifetime

- Trend analysis of material and component degradation
- Staff ageing
- Technological obsolescence
- Public acceptance
- Environmental issues (population, installations, emergency planning)

A) The required level of safety

- There is no consensus among MS:
  - It is the result of a deterministic approach (application of the defence in depth (DID) approach)
  - It is the result of a probabilistic approach (based on the result of PSA 1 and 2)
  - It is influenced by the "starting point" (licensing base)
  - It is suggested by the International Reviews carried out on similar plants (state of the art)
  - It is agreed with the Regulator
  - It has to meet a minimum level (the content of the licensed design)
  - It is a trade off among cost of upgrading, safety improvement, etc. (as in the UK, where the so-called ALARP approach is applied).

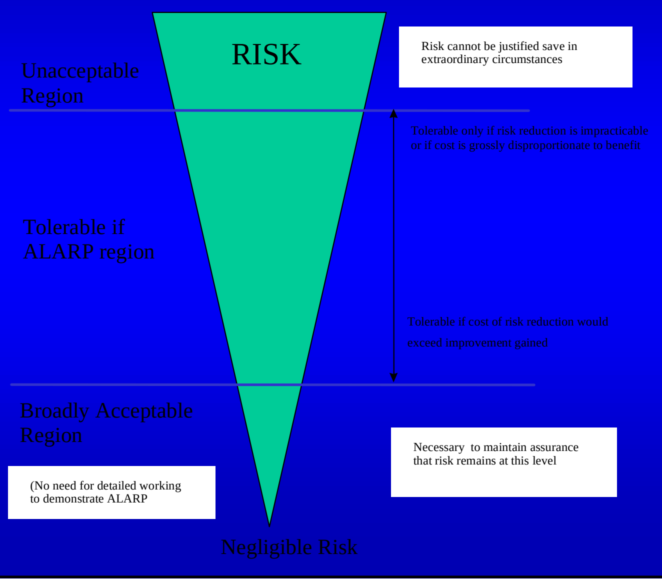
The IAEA recommends the application of the IAEA Requirements and Safety Guides, complemented by other techn. Docs (exp. "Issue books")

In general

- Deviations from the most updated technical requirements are **unavoidable**, but they must be evaluated
- Old plants have good **advantages**: trained staff, knowledge of weak areas, etc.
- A **methodology** should be set up and agreed with the Regulator to assess the basic Safety Principles and to solve the non-conformities

...one approach

- Based on risk of contamination (doses*probability)



B) Some preconditions

Two special cases

- Design Basis reconstruction
- FSAR Updating

From the Czech experience (IAEA TC)

Four main functions or steps has to be allowed by the system:

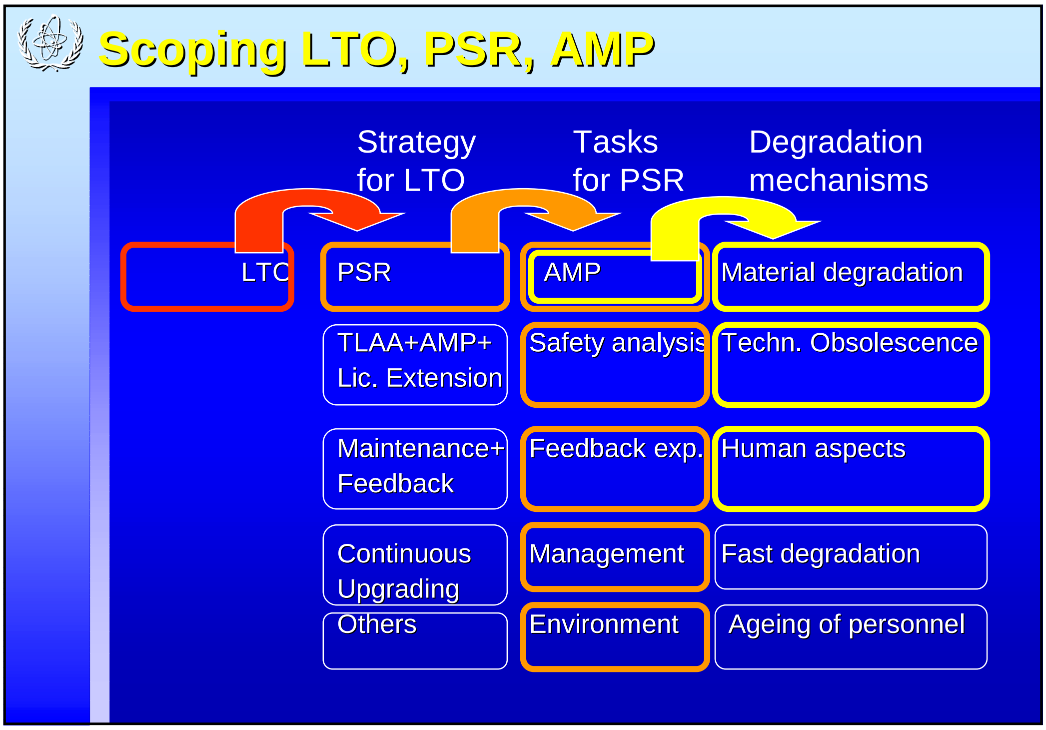
- to collate: means systematic and critical collection of DB (*if they are well documented i.e. if they have available design documents (inputs, analyses and design)*)
- to reconstitute: means reconstitution management (*discrepancies or nonavailability of documents, reconstitution process is too specificand extensive to be fully covered by the DBDMS)*
- to handle: DB information management (*application of some type of database management system)*
- to use and maintain: application to configuration management

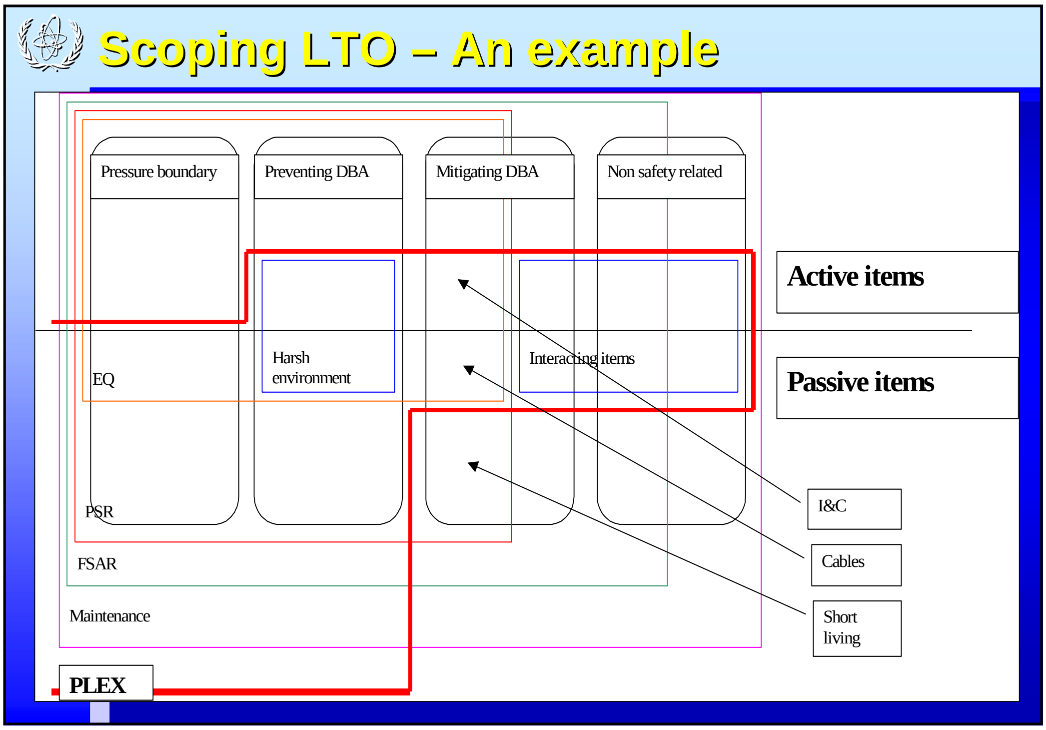
C) Objectives and scope of LTO

Again, suggestions:

- The items not covered by other programmes: passive and long-lived components, with reference to prescriptive rules (such as the so-called "GALL report") where the reference degradation mechanisms are identified. Active components are covered by preventive maintenance and are not in the LTO scope (USA).
- Items with probability of failure <10-7 are screened out (UK).
- According to the safety classification, without other prioritisation (Switzerland).
- According to their contribution to the PSA level 2 (Finland).
- Non replaceable components or only items with limitations to operation (Russia).

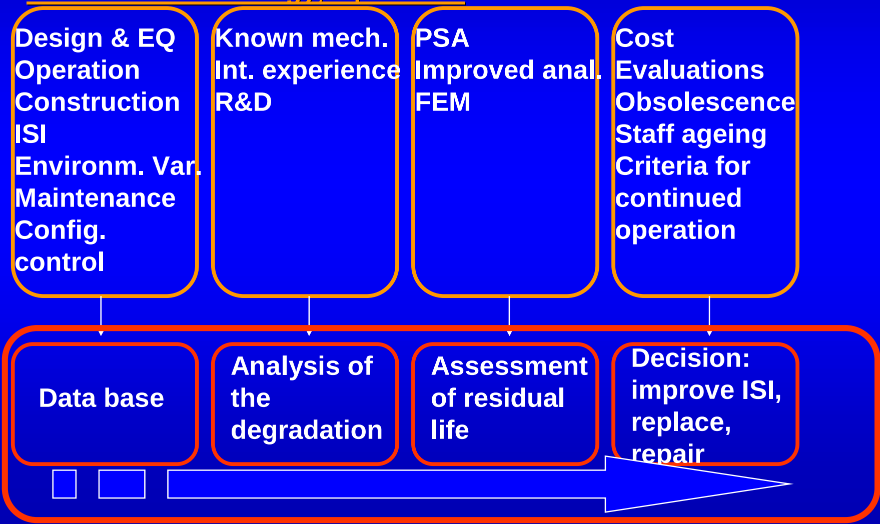
The scope of the LTO is different from the scope of the AMP, as defined by the IAEA, which includes all the safety related items and more


Scoping LTO, PSR, AMP
Strategy for LTO
Tasks for PSR
Degradation mechanisms
LTO
PSR
AMP
Material degradation
TLAA+AMP+ Lic. Extension
Safety analysis
Techn. Obsolescence
Maintenance+ Feedback
Feedback exp.
Human aspects
Continuous Upgrading
Management
Fast degradation
Others
Environment
Ageing of personnel


Scoping LTO – An example
Pressure boundary
Preventing DBA
Mitigating DBA
Non safety related
Active items
Passive items
Harsh environment
Interacting items
EQ
PSR
FSAR
Maintenance
I&C
Cables
Short living
PLEX

D) The main LTO process

The AMP shares many tasks with LTO, but it does not focus on LTO necessarily, and the scope may be different…**AMP is just a program, while LTO is a strategy, a process!**



E) Which degradation mechanisms?

- **Selected according to**:
  - The IAEA recommendations (TECDOCS)
  - The operational and R&D experience in MS (“GALL” report in US).
  - The communication channel with other plants and international organizations
  - R&D
  - If the combination component-environment never produced degradation, that mechanism can be screened out (UK).

However, some **recommendations**:

- leave the door open to **unexpected** mechanisms!! Importance of surveillance and adaptivity and prompt reaction of a good AMP to unexpected issues.
- The **screening** of a potential degradation mechanism should be motivated, while the inclusion should be automatic.
- Attention should be paid to the **plant specific** issues (influence of construction, fabrication, environment, etc.).
- In case of **inaccessible** areas: sampling, visual inspections and radar based techniques. The best: control the **stressors**!!

F) Preserving the design safety margin

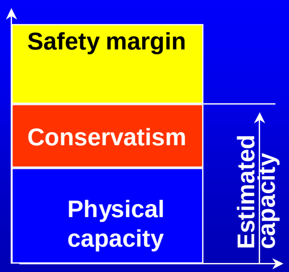
How the design safety margin can be assessed at the end of the design life?

1. By analysis (eliminating initial conservatism with more refined methods)
2. By re-evaluation test (with improved qualification methodologies)

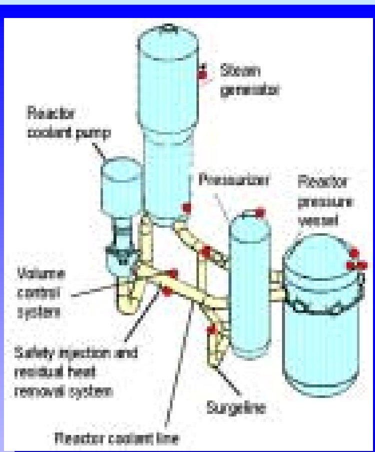
How the design safety margin can be restored at the end of the design life?

1. Replacing or restoring the degraded item
2. Changing the operational conditions and/or improving ISI

Beyond design life, the design safety margin can be maintained through **accommodation of the new issues into design conservatism** built up with rough design methods, conservative environmental conditions and conservative operation assumptions

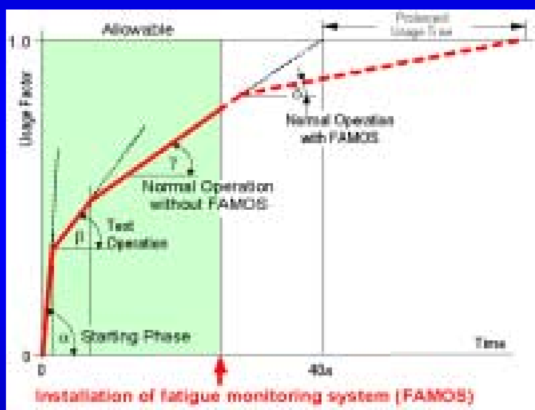


Example: fatigue monitoring system



(Courtesy B.Kastner, Framatome ANP)

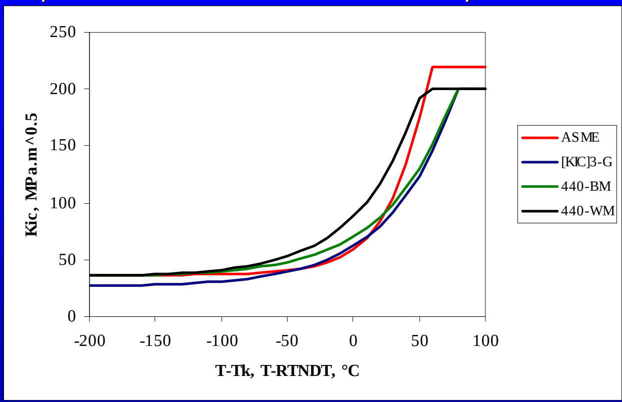
Analysis of Weak Points by Thermal Sensors (●)



Prolonged Usage Time by Fatigue Analysis

G) Trend analysis: an example

- "Unified procedure for Lifetime Assessment of Components and Piping in VVER Type Nuclear Power Plants" (VERLIFE).
- This procedure is based on former Soviet rules and codes, as WWER components were designed and manufactured in accordance with requirements of these codes and from prescribed materials.



(Courtesy M.Brumowsky, REZ)

H) Criteria for continued operation

A global evaluation has to be made with reference to a **radiological risk criterion.**

However, component-wise, the criterion can be:

- The original design basis (after conservatism is eliminated)
- The ALARP
- The unmitigated release
- The effect on PSA (but a living PSA is required then)
- Others….

The following considerations may drive the evaluation:

- The entity of life time extension
- Time required to implement corrective actions: interim measures may be taken
- PSA (but attention to the uncertainties!)
- Expert judgment (risk is often subjective)

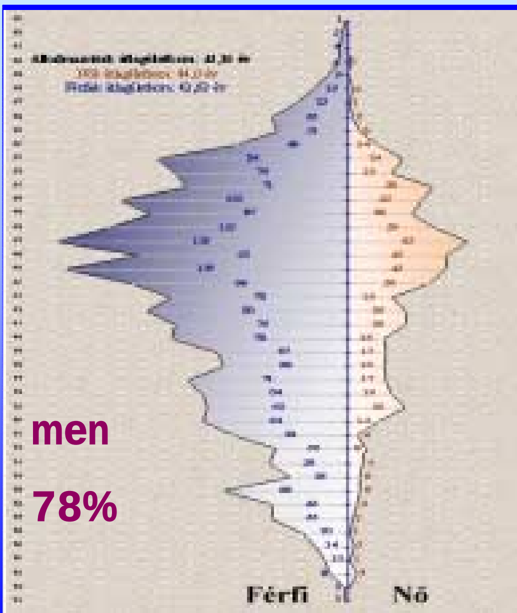
I) Human aspects of LTO

1. Sense of **ownership**

2. **Competence** of these personnel to carry out assigned responsibilities and sensitivity to indications of possible ageing phenomena

This will help to ensure that every significant repair/refurbishment/replacement decision, every change in operating or maintenance procedures and every design change is evaluated in the light of the AMP/LTO objective

An example



Age distribution of NPP Paks employees

(As of 31 December 2001)

(Courtesy A.Biro, VEIKI)

Education, qualification, training

- During the next 10 years more than 1000 employees will be retired (36%)

Therefore

- Company Policy in human resources management
  - to provide the necessary qualified labour
  - knowledge management
- In house:
  - Training center (simulators)
  - Maintenance training center
- High school at Paks
- Supporting the Universities

(Courtesy A.Biro, VEIKI)

4) AMP: the key tool for LTO

Ageing is addressed in procedures for maintenance, surveillance, ISI, QA, etc. as one of the degradation mechanisms which could lead to failure: SG-O2 and SG-QA properly address ageing as part of the MS&I

However,
Operating experience (also according to the results of IAEA CRP on ageing) shows a different policy for ageing management of SSCs:

- **Active** and short lived SSCs are in general addressed by existing **maintenance** programs (MS&I)
- For most of the **passive** SSCs (pressure boundary components, cables, etc.) neither corrective nor preventive maintenance is planned over the life of the plant as the safety margin should be guaranteed by **design**. (Visual inspections every 10 years, etc.)

Main reasons for an AMP

Why an AMP is needed at a plant with many safety related programs? Why it is so important for LTO?

Evidences from worldwide operation:

1) **A lack of operating experience** over 30-40 year design lives suggests that unforeseen ageing phenomena and error induced ageing may occur caused by shortcomings in design or manufacturing or by operating errors
2) The management tradition in general **is different from the SG-O2** scenario: different contractors and different technical teams are in charge of the MS&I tasks, with few communication channels, many components are not accessible, very few plants have a long history record, large accumulation of plant modifications and ageing effects, programs developed with both economic and safety objectives, etc.

Even with a long list of potential degradation mechanisms, there is need for a program able to discover unexpected issues, understand their trend and take corrective actions

What is added with an AMP?

The implementation of an AMP allows:

- A better chance of failure prevention
- A realistic evaluation of the current degradation, **useful also for possible LTO!**
- A more precise evaluation of the status of passive long lived items, usually excluded from routine maintenance programs
- A unified management for the degradation issues

An AMP is implemented through:

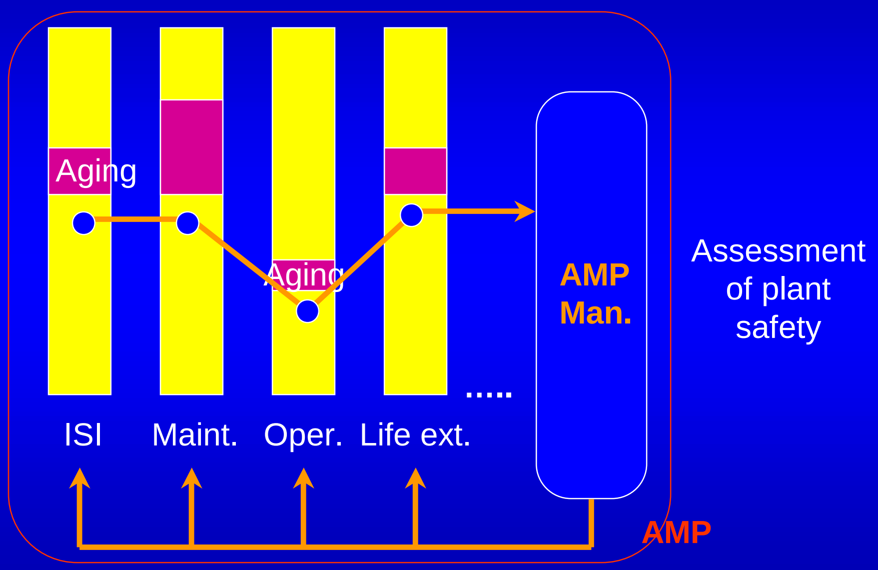
- **Communication** with R&D sources and operational experience in other plants
- **Collection of ageing oriented data** on environment, operation, technological obsolescence, etc.
- **Integration of existing activities** for maintenance, surveillance, etc.
- Evaluation of **degradation**

AMP main features

Therefore, an **AMP** is requested, in addition to normal MS&I programs, with the following main aspects

- It is **safety related**, as it is aimed at the design margins and in fact can prevent failure of safety related SSCs
- It is mainly focused (but not only!) to **long lived passive components** and structures that are not routinely inspected, maintained or replaced
- It is **transversal** to other existing programs
- It is implemented at **all levels** of the Utility Organisation (Corporate, Plant, Dept., Component team)
- It is **permanent**, due to the associated large safety concern (in principle the MS&I programs might be updated taking care of the phenomena)
- It is **reviewed** during the PSRs as part of the safety assessment of the plant

AMP and the existing programs



Example of involved programs

An AMP should coordinate relevant existing programs, such as

- preventive maintenance,
- ISI,
- surveillance,
- testing,
- monitoring,
- data collection and record management,
- equipment qualification,

•chemistry,
•Operation

•Reliabiltiy centered maintenance (RCM), corrective maintenance, predictive maintenance, spare part management

•Probabilistic safety analysis (PSA),
•failure analysis,
•Etc.

The IAEA versus other AMPs

In many countries the AMP has different features than the IAEA's AMP, namely:

- The AMP is not an "horizontal program", cross cutting existing safety related programs, but it is an additional "vertical" program. Therefore, for example, maintenance is parallel to it, not included in it!
- They are many AMP programs, as many as specific degradation mechanisms are considered relevant for the plant
- They are alternative to calculations and proofs, not necessarily implemented at a plant (while it is a mandatory safety program for the IAEA, even referenced in the FSAR)
- They are used only for LTO, not for plant operation during the design life

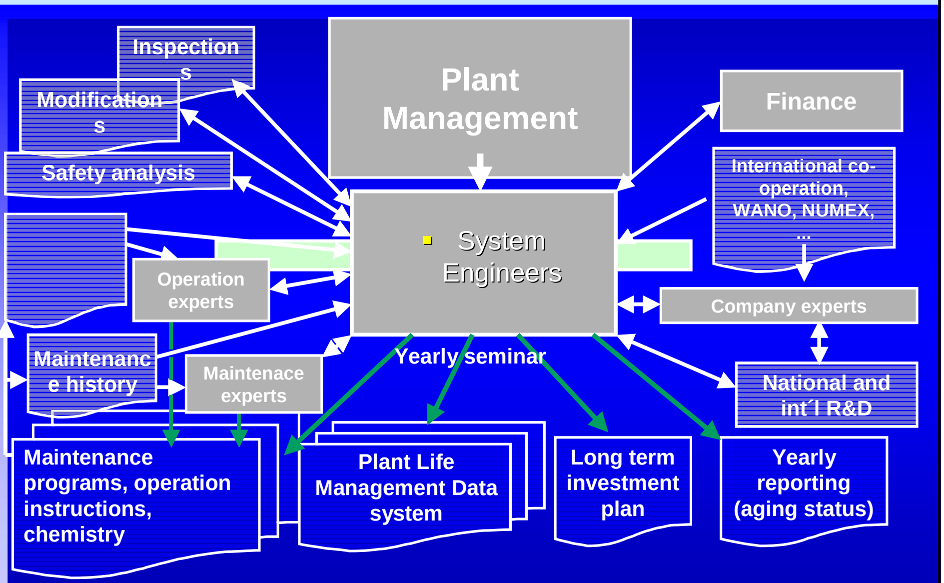
However, they may use other tools to meet the same safety objectives (for example RI maintenance, ISI, etc.) ……!!

How the AMP is managed

Key issues are:

- At **all levels** of the Operating Organisation
- Through an AMP team, with a **leader** (defined in the QA program)
- The interfaces with the other programs are critical as it is a transversal program: not only in data retrieval, but especially in the **feedback** loop of corrective actions
- Need for a heavy involvement of R&D, external TSOs, etc., but complete **control** should be retained at the operating organisation!
- Evidence is provided to the Regulator; complete evidence is provided to the club of users

Example of AMP management



(Courtesy P.Gango, FORTUM)

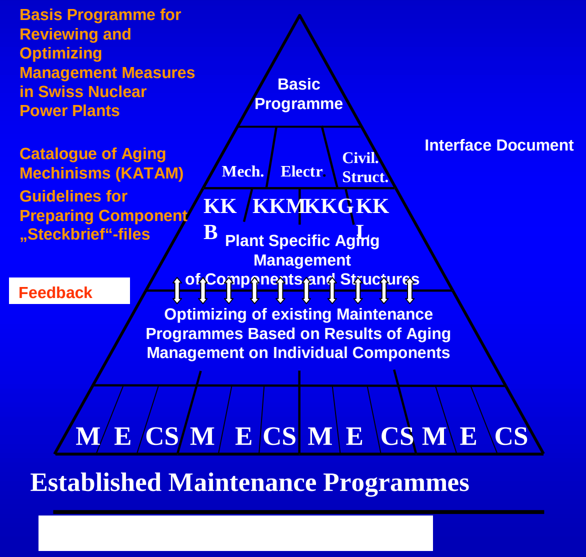
Different levels of management

Different experiences are available in MS:

- At the international level (Utility or Regulators??)
- At the utility level
- At the plant level
- Not co-ordinated: the Amp is a series of AMPs not necessarily co-ordinated (US) (chemistry, irradiation embrittlment, etc.)
- At any level, with different priorities (see the Swiss experience)

An example

- The example of the Swiss Utilities (Courtesy J.Stejskal)



5) LTO Implementation aspects

- Investigations are not always possible in old plants and all inspections techniques have "well proven" unreliability levels
- Inspections for the assessment of the "as-is" cannot be frequent: very expensive and high dose implications
- Extensive component replacement is often not feasible in existing plants with limited residual life time
- The ageing growth rate and the possibility of a premature detection (LBB?) are often unknown because of lack of data
- Data bases provide useful statistics only in the long term, but often they are not available yet
- PSAs are not always available
- Ageing phenomena are not easily quantifiable in risk assessment methodologies

The selection of the most suitable strategy for LTO is plant dependent

Some recommendations

Understanding of <u>current</u> safety level of the plant

- Maximum priority for tools which can drive the **prioritisation** of the actions and the appreciation of the **current** safety level: PSA, conservative assumptions, etc.
- Extensive use of **monitoring**, preventive techniques, premature detection, surveillance

Implement LTO oriented tasks ("pre-conditions")

- Identify the time limitations fixed by design ("expected" degradation mechanisms)
- Put in place a proper AMP to manage "expected" and "unexpected" phenomena
- Design Basis and EQ reconstitution, also by similarity and/or experience
- Collection and processing of environmental data, ageing oriented
- Start collection of available degradation data now, and identify other data that may be taken as basis for important decisions in the future
- Recovery of operational records and operational experience, particularly in plants of the same type

Cont'd

Develop national and plant dependent guidelines covering:

- The **regulatory** issues (how the LTO process has to be approved and regulated in the future, monitoring and reporting)
- The **technological** issues (which SSCs are LTO sensitive, which procedures should be developed to manage their degradation: maintenance, AMP, etc.)
- The **economical** issues: consider a long term analysis with and without replacement of the major components
- The **management** issues: personnel ageing, transfer of knowledge, public acceptance, etc.
- The **safety** issues: how the overall safety margin can be evaluated and maintained. Which are the indicators and the relevant countermeasures

….but use also the international experience as far as possible in relation to the generic technological issues (IAEA Guidelines)

Appendix A) - Basic glossary

- **Acceptance criterion**
  specified limit of a functional or condition indicator used to assess the ability of an SSC to perform its design function
- **Degradation**
  Immediate (non-ageing) or gradual (**ageing**) deterioration of characteristics of an SSC that could impair its ability to function within acceptance criteria.
- **Failure**
  Inability or interruption of ability of an SSC to function within acceptance criteria. It is usually produced by a sequential chain of causes, not a single one. The failure mechanism could be ageing-related (environmental or functional conditions, both normal or error induced) and non-ageing-related (i.e.immediate).
- **Ageing**
  General process in which characteristics of an SSC **gradually** change with time or use. Typical ageing mechanisms are: curing, wear, fatigue, creep, erosion, corrosion, embrittlement, chemical reactions, etc.

Cont'd

- **Maintenance**
  The organized activity, both administrative and technical, of detecting, precluding and mitigating degradation of a functioning SSC, or restore to an acceptable level the design functions of a failed SSC
- **Surveillance**
  Observation or measurement of condition or functional indicators to verify that an SSC currently can function within acceptance criteria
- **Ageing management program**
  It deals with the ageing degradation mechanisms. The program addresses and co-ordinates, but does not replace, existing programs and activities that address plant ageing issues.

B) AMAT service

Ageing Management Assessment Team

It is **part** of the life cycle management program (it excludes economic aspects)

It **includes** the review of:

- Legislation and regulations
- NPP policies concerning: operation, surveillance, maintenance, eq. qualification, oper. exp. feedback, QA
- NPP AMP management: co-ordination, responsibilities, resources, data collection and processing
- AMP scope: SSCs included in the AMP
- Programme quality: effectiveness of detection, monitoring and mitigation of ageing
- Reporting and record system

EXTRABUDGETARY PROGRAMME ON SAFETY ASPECTS OF LONG TERM OPERATION OF PRESSURIZED WATER REACTORS

WORKING GROUP 4
STRUCTURES AND STRUCTURAL COMPONENTS
KICK-OFF MEETING
VIENNA, AUSTRIA, 3-5 MARCH 2004

Milan Milanov, Kozloduy NPP, Bulgaria

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Presentation Content:

1. About the Kozloduy NPP.
2. Scope of Structures and Structural Components.
3. Ageing Management Activities and Programs.
4. Applicable Ageing Effects.
5. Plant-specific safety Analyses and Data.
6. Laws and Regulatory Requirements.
7. Comments to the Work Plan of WG-4.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

1. About the Kozloduy NPP

Three Stages:

- **First stage:** Units 1&2 – WWER 440, model V-230. July 1974, November 1975.
- **Second stage:** Units 3&4 – WWER 440, model V-230*. December 1980, May 1982.
- **Third stage:** Units 5&6 – WWER 1000, V-320. September 1988, August 1991.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

2. Scope of Structural Components and Structures (SCS)

2.1. Process used in developing the SCS Scope:

- Safety Analysis Reports.
- PSA - level 1, 2
- Systems Interaction.
- Classification and Seismic Categorization of Civil Structures (CS) and Hydro Technical Facilities (HTF).
- Defining of Safe Shutdown Equipment List /SSEL/.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

… Scope of Structural Components and Structures

2.2. Three Categories of Structural Components and Structures :

1. All safety-related SSC /f(safety functions…)/
2. All non-safety related SCS whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined in point 1.
3. Other areas dedicated to a specific functional purpose that may be essential to the safe plant operation.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Category 1:

For Units 1-4:

- Reactor Buildings;
- Diesel Generator Buildings;
- Circulation Pump Stations /partially/;
- Ventilation Stacks;
- New Devices – Supplementary Emergency Feed Water Supply System (SEFWSS) and Second Fire Protection Station /FPS-2/
- Underground Facilities;
- Spray Cooling Ponds.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Category 1:

For Units 5&6:

- Reactor Buildings, including Containments;
- Diesel Generator Buildings;
- Spray Cooling Ponds;
- Underground Facilities.

Common Structures (for Units 1-6):

- Spent Fuel Storage Building.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Category 2:

For Units 1-4:

- Turbine Hall;
- Auxiliary Buildings;
- Circulation Pump Stations /main part/;
- Underground Facilities.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Category 2:

For Units 5, 6:

- Turbine Hall;
- Auxiliary Building;
- Overhead Roads between AB-3 and RB;
- Underground Facilities.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

Category 3:

For all Units:

- Water Treatment;
- Bank Pump Station;
- Double Channel (Intake and Outlet);
- Underground Outlet Channels.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

3. Ageing Management Activities and Programs.

3.1. Ageing Management Activities.

- Civil Structures and HTF Monitoring;
- Analyses and Investigations;
- Reconstruction and Modernization;
- Maintenance and Repairs;

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Ageing Management Activities

3.1.1. Civil Structures and HTF Monitoring

- **Organization of activities.**

Facilities are run by the operating departments (workshops, sectors etc.), correspondingly EP-1 for Units 1-4 and EP-2 for Units 5 & 6.

Specialized maintenance is performed by:
- plant specialized Department (Dept. of HTF and CS);
- assigning separate tasks to external organizations;

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Ageing Management Activities
…Civil Structures and HTF Monitoring

- Department of Civil Structures & Hydrotechnical Facilities
  - Section "Civil Structures"
  - Section "Hydrotechnical Facilities"
  - Section "Seismic Control & Monitoring"
  - Section " Geodesic Control & Monitoring"

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Ageing Management Activities
… Civil Structures Monitoring

- **Periodic control.**

- Normative base.

Control is performed by, but not limited to the requirements of the national "Regulation on Power Plants and Networks Technical Operation ".

A number of internal instructions and control programs are established and approved .

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

… Civil Structures Monitoring

- Procedures for visual control of buildings and equipment

Visual inspections are performed by a walkdown team, including HTF and CS specialists and representatives of the relevant (operating) departments . The team inspects every accessible part of the building or facility aiming to assess the actual status of the structure, to find out, classify and document existing defects.

The main objective of the visual control is to assess the impact of the existing defects on civil structure safety and to specify measures for their treatment. The existing defects are divided into ***three categories*** according to their impact on the structure:

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

… Civil Structures Monitoring

- *A. Directly dangerous for the civil structure*.

Defects that actually decrease the bearing capacity of the structure and influence its safety and functions.

- *B. Potentially dangerous for the civil structure*.

Defects whose further progress may influence the safety and normal building or facility operation.

- *C. Not dangerous for the civil structure*.

This category includes defects, whose further progress doesn't endanger the safety and normal operation of the building or facility . In spite of that these defects may impact the equipment normal operation, personnel life and health or damage site architecture and hygiene.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

… Civil Structures Monitoring

The inspection team suggests the following measures and prescriptions in order to handle the established and classified defects on the structure. These ***measures can be directed towards:***

- ***Control*** strengthening and optimization;
- ***Repair*** works on defect elimination;
- ***Study and/or detail design*** of further corrective activities;
- ***organization measures*** to decrease the impact of a given defect on the civil structure, for example load restriction.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- HTF Monitoring Procedures

HTF monitoring is carried out in compliance with the ***Plant Instruction on Operation and Monitoring of HTF.***

A number of visual inspections, observations, and measurements are carried out by personnel of different qualification:

- daily;
- weekly;
- monthly;
- annually.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…HTF Monitoring Procedures

Different systems are established for measurement and observation of the following important parameters for the facilities:

- levels, temperatures and water quantities in the service water supply channels;
- vertical and horizontal displacements;
- underground water levels and depression curves;
- filtration direction and rate;
- framework solidity - ρ_d;
- etc.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…HTF Monitoring Procedures

The Geographic Information System (GIS)

GIS is in the process of final completion and implementation. It will allow daily entering of all new data and results in the data base, thus making possible to carry out operative and periodical analyses of HTF status and the resulting events and processes.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- Displacements Monitoring Procedures.

According to "Instruction on Geodesic Control of Civil Structures , Hydro Technical and Technological Equipment" periodical monitoring is carried out for the displacements of the civil structures of Kozloduy NPP Buildings and Facilities. Elevation reference points are mounted on facades and other accessible parts of the building and their displacements are monitored by ***geodesic methods.***

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Displacements Monitoring Procedures.

Geodesic control results are documented in special protocols, where the displacement status of the buildings is written from the initial (zero) measurement to the last measurement of the elevation reference points. Geodesic control results are interpreted by civil engineers, who give **conclusions on building or facility safety**, taking into account its functions, structure system and foundation.

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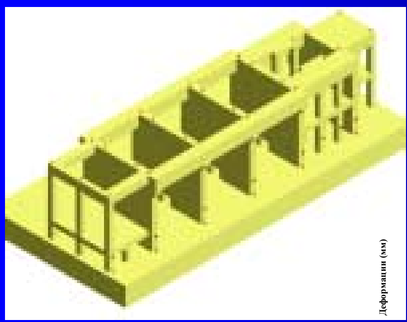
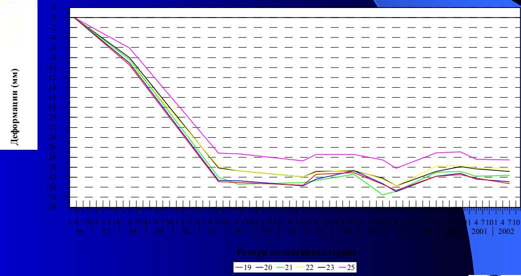
THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES



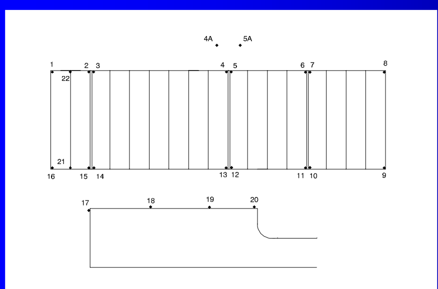
…Displacements Monitoring

Units 5&6 Turbine Foundation



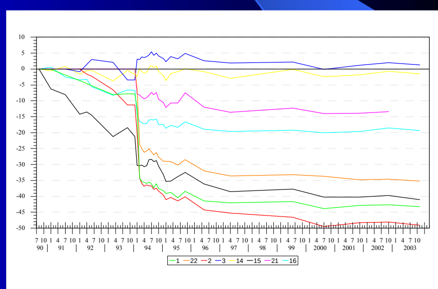
IAEA–LTO, WG-4 3-5 March 2004, Vienna, Austria KNPP Bulgaria

THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES



…Displacements Monitoring

Circulation Pump Station 3



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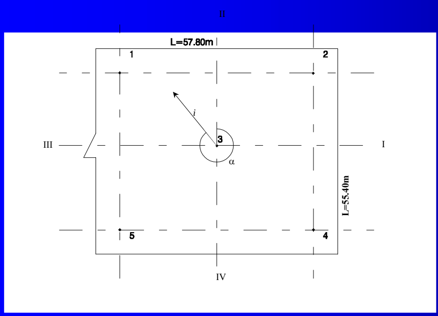
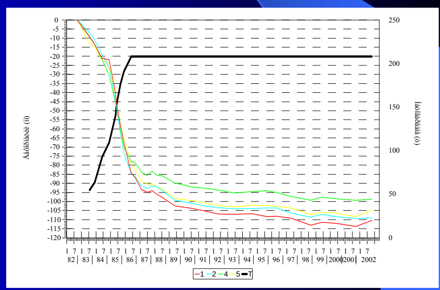
THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES



…Displacements Monitoring

Reactor Building, Unit 5.



IAEA–LTO, WG-4 **3-5 March 2004, Vienna, Austria** **KNPP Bulgaria**

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- Special control.

- **Control of Containments Stress-strain State /CSSS/**

Two methods are used :

➢ ***During operations*** **by means of Automatic Monitoring System for the Containments Stress-strain State /AMSCSSS/;**

➢ ***During the Outage*** **by means of direct measurement of the tension force in the pre-stressed tendons of the anchor devices.**

CSSS control results are interpreted in compliance with design criteria for Containment Pre-stressing System /CPS/.

IAEA–LTO, WG-4 **3-5 March 2004, Vienna, Austria** **KNPP Bulgaria**

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Special control

- **Seismic Monitoring of Civil Structures.**

❖ **meets the requirements of Safety Guide 50-SG-D15, IAEA 1992**

❖ **consists of sensors, for registration the seismic response of a free field, RB of Units 5 and 6, important structure levels of Units 1 - 6 and other structures of seismic category 1 (DGB - Unit 5&6).**

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Seismic Monitoring of Civil Structures

Three type of seismic systems are installed:

- **ISPS (Industrial Seismic Protection System) – implemented according to Unit 5 & 6 Design (Russian manufacture) and additionally installed at Units 1 to 4 ("Kinemetrics"company manufactured);**
- **- SAECSC (System of Accelerographs for Equipment and Structures Seismic Control) Unit 1 – 6 ("Kinemetrics" Co production);**
- **- SM and CS (Seismic Monitoring and Control System) at Unit 6 ("GeoSig" Co production. CAV-oriented).**

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Seismic Monitoring of Civil Structures

Seismic instrumentation designation:

- register and file the seismic movements;
- defining of parameters of seismic movement in sensor installation locations:
  - maximum absolute accelerations;
  - relative velocities and shifting;
  - response spectra;
  - floor accelerograms, velocigrams and seismograms;
  - cumulative average velocity – CAV;

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Seismic Monitoring of Civil Structures

…Seismic instrumentation designation:

- Dynamic behavior of the structures is described by these parameters;
- Comparison of registered seismic response to assessments;
- Defining the structure design seismic features;
- Defining the possible exceeding of design earthquake /DE/.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- **Incident Control.**

…In case a signal for defect of the building structure is given by the corresponding operating department or other authorized organizations.

Special observations and measurements for investigation of the civil structure status are to be performed in case of natural disaster or large industrial accidents, for example after earthquake, flooding or fire.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- Interpretation of Monitoring Results .

The results of all above-described types of object control /visual, geodesic and specialized/ are reviewed and interpreted jointly, with the aim to acquire a complete picture of its civil structure status. After completion of periodic reviews, Department of HTF and CS prepare special summary report about the status of every reviewed object.

The given in the reports measures for treatment of existing defects are given to the corresponding operating departments, with the purpose of planning, technical, organizational and financial assurance of prescribed measures implementation. During the next inspection, besides the current object status, the implementation rate of approved measures is controlled.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

3.1.2. Analyses and Investigations.

Additional activities on civil structures of objects are to be performed in the following cases:

- **national and international codes and standards are changed;**
- **plant internal normative documents are changed ;**
- **there is real change of purpose and operational load;**
- **the current object status is changed /for example – if a defect occurs/.**

IAEA–LTO, WG-4 3-5 March 2004, Vienna, Austria KNPP Bulgaria

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Analyses and Investigations

- **Units 1 - 4 Rest Lifetime Assessment:**

In 1998/99 seismic reevaluation of Seismic Upgrading of the KNPP, Units 1-4 and composing of Safety Shutdown Equipment List (SSEL) is accomplished.

The investigation is conducted by Phare BG9512 Programme from Empresarios Agrupados International S.A., representing the consortium between EA and EDF.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Analyses and Investigations

•Unit 3 and 4 Rest Lifetime Assessment:

The Research for Assessment of the rest lifetime (RLT) of equipment and facilities of units 3-4 has been performed and an Ageing management Program has been prepared. The research has been carried out by "Siemens" with Bulgarian subcontractor – "Risk Engineering" within the MP of Units 1-4.

Object of the research are BPS, CPS-2, Double Channel Feed Water, DGS-2, AB-2 and Vent Stack - 2, Main Building objects of Unit 3 and 4 – RB, TH, turbofoundations, Electric Shelves and Hydro facilities – Spray cooling Ponds, Double Channel bridges, low-pressure channels and others.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

For every one of the enumerated object has been done a quantitative assessment of the residual lifetime and have been prescribed:

- maintenance activities;
- measures for object reconstruction and modernization;
- measures for monitoring optimization

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

…Analyses and Investigations

•Management of the Hydro-technical Facilities Rest Lifetime:

Analysis of the status and engineering safety of the double channel for technical water-supply and the rest facilities is under implementation at the present moment.

This task will finish with preparing of the Program for the necessary remedial and rehabilitation activities.

THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES

…Analyses and Investigations

•Seismic Analyses.

In 1992 a new seismic excitation on the KNPP site was specified, which is defined by response spectrum on a level +0.00m. at a maximum acceleration of 0.2g. The increased value of the seismic excitation has forced a seismic capacity reevaluation of safety important buildings and facilities at Kozloduy NPP to be implemented.

All safety important buildings and facilities at Kozloduy NPP have been analyzed concerning the current seismic impact, as the result of which a certain deficiency of a seismic capacity have been proved.

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- **Units 1 – 4 Seismic Analyses:**

Seismic analyses of all safety important buildings and facilities of Units 1 – 4 with current seismic impact were performed. The places, where a deficiency of seismic capacity was proved, the relevant projects concerning Seismic Upgrading /SU/ of the civil structures have been developed.

IAEA–LTO, WG-4 **3-5 March 2004, Vienna, Austria** **KNPP Bulgaria**

BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- **Units 5 and 6 Seismic Analyses:**

All Units 5 and 6 safety important structures are analyzing mainly according to Units 5. and 6. Modernization Programme. The analysis proves that RB, reinforced concrete vent stack of AB-3 and reinforced concrete venting stack of RB , DGB and solid underground part of CPS can stand RLE and do not need of additional seismic upgrading /SU/. For the rest related to safety buildings /TB, AB and technological overhead roads between AB-3 and RB/ the conceptual design for upgrading of civil structure have been examined and accepted. Detail designs on SU of Units 5 and 6 TB, the overhead roads and AB-3

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- **Seismic Analyses of other Plant Objects:**

A seismic analysis of Spent Fuel Storage Building (SFSB) and Bank Pump Station (BPS). A deficiency of seismic capacity has been proved and relevant designs for civil structures upgrading have been developed.

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

3.1.3. Reconstructions and Modernizations.

- **Seismic Upgrading of Civil Structures.**

SU of the civil structure has been implemented for included in SSEL buildings and facilities of Units 3 and 4 (Units 3 and 4 Main Building, CPS-2 and DGS-2). After SU implementation all upgraded buildings and facilities are secured for RLE characterized with maximum horizontal acceleration on free field 0.2g and they can be considered as seismic qualified.

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Main Building
of Units 3/4
(upgraded)
IAEA–LTO, WG4
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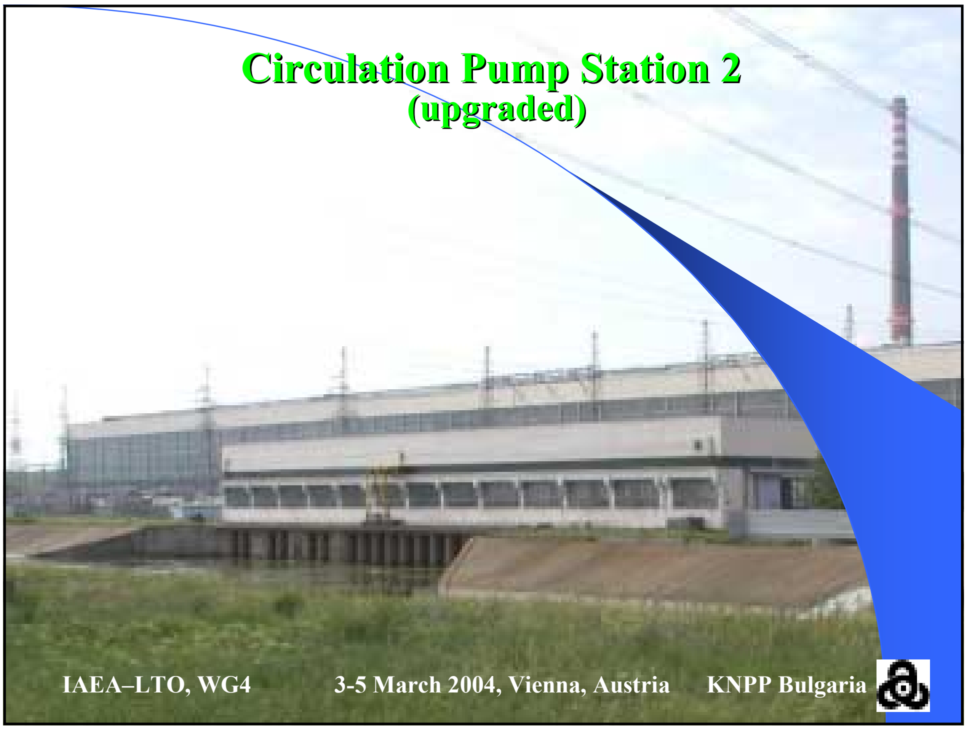
KNPP Bulgaria


Circulation Pump Station 2
(upgraded)
IAEA–LTO, WG4
3-5 March 2004, Vienna, Austria
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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

… Seismic Upgrading of Civil Structures.

Seismic Upgrading of the civil structure has been implemented for Spent Fuel Storage Building (SFSB) and Bank Pump Station (BPS).

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BULGARIAN EXPERIENCE IN WG-4 SCOPE OF ACTIVITIES

- **Construction of additional and substitute facilities.**

With a purpose:

- safety enhancement
- addition of existing safety systems
- replacement of some components

the following new objects have been installed:

- Supplementary Emergency Feedwater Supply System - Units 3/4;
- Second Fire Protection Station /FPS-2/;
- Reconstruction of Accident Localization System (ALS) - installation of jet vortex condenser (JVC) - Units 3/4;
- Reconstruction of Emergency Service Water Back-up Tank - Units 3/4.

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Supplementary Emergency Feedwater Supply System -3/4

...Construction of additional and substitute facilities.

- **The Supplementary Emergency Feedwater Supply System (SEFWSS) is a special system for accident management. Within the SEFWSS buildings basic functional equipment are located for additional emergency feedwater supply to the SG in case of loss of feedwater pipelines.**

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BULGARIAN EXPERIENCE IN THE WG-4 SCOPE OF ACTIVITIES

Reconstruction of Accident Localization System (ALS)

Functions of the ALS

The ALS is designed to avoid or limit the release of radioactive substances or irradiation in case of accident within the stipulated limitations.

Description of reconstruction

The ALS reconstruction provides for installation of jet vortex condenser (JVC) – a passive system for prevention of containment pressure increase.

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Reconstruction of Emergency Service Water Back-up Tank
Old Structure (replaced)
IAEA–LTO, WG-4
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KNPP Bulgaria


Reconstruction of ESWS Back-up Tank
New hydro-seal
Reconstruction concept:
• Replacement of SWS back-up tanks by seismic resistant hydro-seal at the service water system exit, before the spray pools.
• The hydro-seal height is sufficient to keep the water pressure in case of failure of the service water pumps.
• The Structure is designed for SSE and LE.
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KNPP Bulgaria

BULGARIAN EXPERIENCE IN THE WG-4 SCOPE OF ACTIVITIES

...Construction of additional and substitute facilities

•Units 5 and 6 Containment Pre-stressing System (CPSS)

❑ In the installed system a number of problems have been established during the containment operation:

➢ processes of the main components accelerated ageing (pre-stressing cables of 450 wires ∅ 5 mm, class B-II);

➢ cases of broken cables both during the pre-stressing works and during the operation without any initiating event;

➢ loss of pre-stressing force in some cables below the admitted design level – 85% of the nominal force P = 1000 tones.

BULGARIAN EXPERIENCE IN THE WG-4 SCOPE OF ACTIVITIES

… Units 5 and 6 Containment Pre-stressing System (CPSS)

❑ An investigation was accomplished, which specified some weaknesses in the original pre-stressing system, materials used, production technologies and elements installation.

❑ A new pre-stressing system and technology on production, installation and pre-stressing was developed and patented. This system adapted some of the main components of the original pre-stressing equipment and anchor elements and added new structures. The old pre-stressing cables are been replaced with new type cables made of 55 steel ropes with ∅ 15.2 mm, class B7.

BULGARIAN EXPERIENCE IN THE WG-4 SCOPE OF ACTIVITIES

…Units 5 and 6 Containment Pre-stressing System (CPSS)

- At the moment, step-by-step, the original pre-stressing system is replaced with the new one.

- So far (by March, 1-st, 2004) 70 cables at Units 5 and 30 cables at Unit 6 were replaced.

The replacement of CPSS is planned to be fully completed at Unit 5 in 2005 and at Unit6 in 2006.

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BULGARIAN EXPERIENCE IN THE WG-4 SCOPE OF ACTIVITIES

…Units 5 and 6 Containment Pre-stressing System (CPSS)

- Results:

- Increasing of the tension force in the cables to envisaged in design 10000 kN;
- Negligible stress relaxation;
- Negligible loss of cable tension force;
- Implementation of QA program for all technological stages;
- WWER-1000 containment rest life-time extension.

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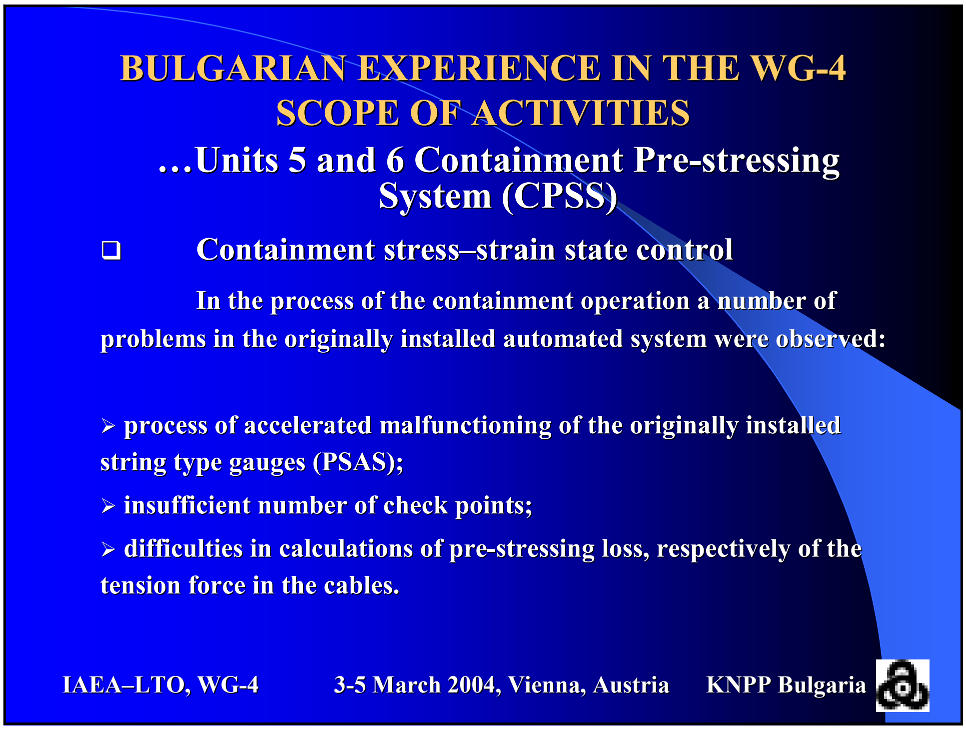
BULGARIAN EXPERIENCE IN THE WG-4
SCOPE OF ACTIVITIES
…Units 5 and 6 Containment Pre-stressing System (CPSS)
Containment stress–strain state control
In the process of the containment operation a number of problems in the originally installed automated system were observed:
process of accelerated malfunctioning of the originally installed string type gauges (PSAS);
insufficient number of check points;
difficulties in calculations of pre-stressing loss, respectively of the tension force in the cables.
IAEA–LTO, WG-4
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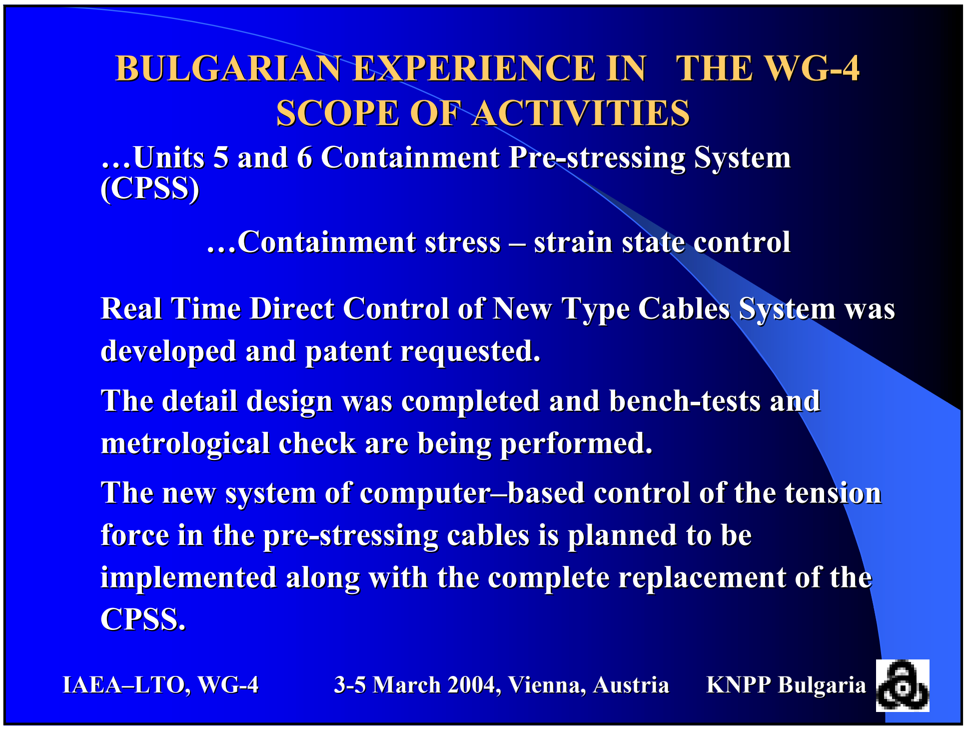
BULGARIAN EXPERIENCE IN THE WG-4
SCOPE OF ACTIVITIES
…Units 5 and 6 Containment Pre-stressing System (CPSS)
…Containment stress – strain state control
Real Time Direct Control of New Type Cables System was developed and patent requested.
The detail design was completed and bench-tests and metrological check are being performed.
The new system of computer–based control of the tension force in the pre-stressing cables is planned to be implemented along with the complete replacement of the CPSS.
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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

3.1.4. Maintenance and Repairs.

Complicated and important construction maintenance and repairs obligatory are executed according preliminary developed and accepted examinations and Maintenance Schedule, concerning the maintenance activities. When the only purpose is construction design status rehabilitation, the maintenance is carried out in compliance with the initial design, if it is still actual. Smaller maintenance and repairs, that don't require analyses, are carried out according developed by KNPP experts Technical Decision.

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

3.1.4. Maintenance and Repairs.

Some of the more significant carried out and forthcoming maintenance and repairs activities of the Auxiliary Building, KNPP, are as follows:

- **Maintenance and rehabilitation of Vent Stacks - 1, 2 and 3;**
- **Maintenance of the roof waterproof;**
- **Reinforcement of the foundation of a part of CPS-3;**
- **Maintenance of underground outlet channels;**
- **Underwater maintenance of double channel gaps.**

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

3.2. Ageing Management Programs.

An Ageing Management Program, as a part of the Modernization Program for Units 3 and 4 was developed. The task was assigned to the international CONSART Consortium, that consists of Framatome-ANP and Russian Atomstroyexport.

On the base of the program mentioned above an Plent Life Time Assurance Program for Units 3&4 was developed. This program defined the necessary activities, terms and financial means for provision of the life time of the Units till 2005, including also in perspective till 2008.
Individual Modernization Program is in progress for Units 5 & 6 to solve the issues related to their residual life time management.

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

4. Applicable Ageing Effects.

KNPP buildings and facilities ageing consists of occurrence and progress of different defects and processes related to the civil structures.

- Ageing of Reinforced Concrete Structures, Cracking;
- Defects and processes in CPSS of Units 5 & 6;
- Leakages, due to Imperfect Roof Waterproof ;
- Steel Elements and Joints Corrosion Progress;
- Partial Damages of Buildings and HTF Deformation Gaps.

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

5. Plant-specific Safety Analyses and Data.

No	Identification of the data	Type	Quality	Access
1.	Analysis of the condition and engineering security of the HTF.	Analysis		In progress
2.	GIS of the HTF.	Data base		In progress
3.	Results from the geodesic displacement monitoring. 143 objects, including: - 66 buildings; - 16 HTF; - 31 equipment units; - 30 crane reilways.	Proto-cols	good	Avai-lable

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

No	Identification of the Data	Type	Qualit y	Access
4.	Analyses about Containment Pre-stressing system (CPSS).	Analysis		Avai-lable*
4.1	Analysis of the Containment Prestressing system condition.	Analysis		Avai-lable*
4.2	Analyses of the Containment Stress-Strain State (CSSS)	Analyses		Avai-lable*
4.3	New substitution CPSS	Reports, Designs		patented
4.4	Development of new complementary Automatic Control System (ACS) for CPSS	Reports, Designs		patented

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

No	Identification of the Data	Type	Quality	Access
5.	Analysis of the condition of Turbine foundation of Units 5 and 6.	Report		Avai-lable
6.	Assessment of the Rest Lifetime for Units 3 and 4.	Report		Avai-lable
7.	Seismic Analyses …	Reports, Designs		Avai-lable
8.	Benchmark Study for the Seismic Analysis and Testing of WWER-type NPPs. Dynamic testing of RB-Unit 5.	Report		Avai-lable
9.	Composing of the Plant specific CAV – criteria.	Report		Avai-lable
10.	New seismic characteristics of the site.			

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BULGARIAN EXPERIENCE ON THE WG-4 SCOPE OF ACTIVITIES

No	Identification of the Data	Tape	Quality	Access
11.	Floor Response Spectra (FRS) – for old and upgraded SC.	Report		Avai-lable
12.	Probabilistic Seismic Analyses (PSA) – Level 1, 2	Analysis		Avai-lable
13.	Seismic Analysis Report (SAR)	Analysis		Av.
14.	SAR for Accident Localization System (ALS) after installing of JVC.	Analysis		Avai-lable

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THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES

6. Laws and Regulatory Requirements.

- Law for safety using of nuclear energy (LSUNE);
- No specific Requirements and Standards for NPP-RLT;
- International Codes and Standards are applicable;
- Guide for Seismic Reevaluation and Design of Nuclear Facilities in Bulgaria, Methodology for Seismic Qualification of KNPP is developed and regularly updated;
- Guidelines for Regulatory Review of Ageing Management Programmes and their Implementation is in progress (Developing byBritish Energy - NNC)

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THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES

… Laws and Regulatory Requirements.

- National Regulation on power plants and networks technical operation is in use;
- Local Plant Instructions and Procedures for some specific activities:

  - Instruction for exploitation of HTF;
  - Procedure for inspection and control of CS;
  - Instruction for geodesic displacement monitoring;
  - Procedure for control of CSSS.

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THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES

On the grounds of Law for Safety Using of Nuclear Energy (LSUNE) the Agency for Nuclear Regulation (ANR) is producing Licenses and Permissions for safety operation of nuclear facilities. The licenses are containing specific requirements for safety operation:

- for control and monitoring;
- for maintenance and repair;
- for exploitation and etc.

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THE EXPERIENCE IN BULGARIA ON THE WG-4 SCOPE OF ACTIVITIES

7. Comments to the Work Plan of WG-4.

- Complete and Comprehensive.
- Optimally structured;
- Sufficient for Reach the Project Goals.

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Thank You!
IAEA–LTO, WG-4
3-5 March 2004, Vienna, Austria
KNPP Bulgaria

IAEA EBP – SALTO – PWR
WG4 – Structures and structural components
IAEA – Vienna, Austria, 3 – 5 March 2004

Ageing, Maintenance, In - service Inspections and Condition Monitoring of Civil Structures

NATIONAL EXPERIENCE AND APPROACH TO THE LONG TERM OPERATION OF PWRs

MS:	Czech Republic
WG – 4 Member:	Jan Maly
	Nuclear Research Institute Řež
	- division Energoprojekt
Representing:	Czech Electric Utility (ČEZ – UJE)

Temelín NPP

Two units WWER 1000/320
In operation since 2002/03
Design lifetime 30 years
Planned operation extending – till 2045

Dukovany NPP

Four units WWER 440/213
In operation since 1985/8
Design lifetime 30 years
Planned operation extending – till 2025

Applicable laws and Regulatory Requirements

❖**Atomic Act No 18/1997**

- **gives general rules and requirements that operator has to fulfill before the request for operation license or renewing of the license**

❖**Decrees of the Regulatory Body**

- **106/1998 on Providing Nuclear Safety and Radiation Protection of Nuclear installations at their Commissioning and Operation**
- **195/1999 on Requirements on Nuclear Installations for Assurance of Nuclear Safety**
- **214/1997 on Quality Assurance in Activities Related to the Utilisation of Nuclear energy**

Requirements concerning the ageing, maintenance and in-service inspections are a part of Quality Assurance System (Decree No 214/1997)

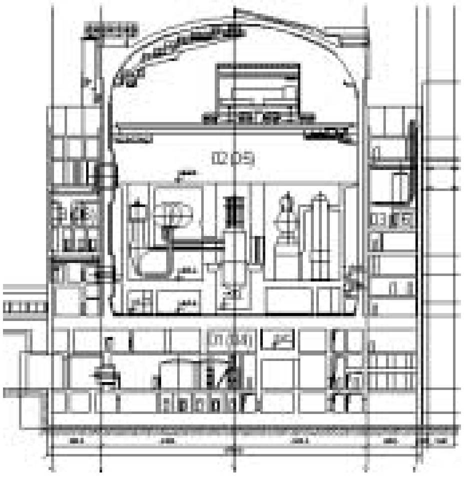
- **QA programmes have to cover all main stages starting from siting, design, construction, commissioning, operation and decommissioning**
- **For SSC important to safety the operator is responsible for their ageing, surveillance and maintenance**
- **SSC are classified according to their relation to safety into three categories**
- **QA programmes for classified structures require also condition assessment including remaining lifetime evaluation**

ČEZ – UJE – selected documents PLEX/LTO program preparation

Basic internal regulations, general approach to the management, the organisation and responsibilities.

- **PP 043 – Procedures for PLEX/LTO management**
- **PP 053 – Ageing management**
- **ME 085 – Technical – economic feasibility study for PLEX/LTO**
- **ME 086 – Data Collection and Record keeping for PLEX/LTO (in preparation)**
- **SM 025 – Providing the equipment actual condition**
- **PP 064 – Decommissioning process preparation, technical aspects**

Temelín Containment structures



- Wall thickness :
  - cylindrical shell 1,2m
  - dome 1,1m
- Number of prestressing cables
  - cylinder 96
  - dome 36
- Each cable is formed by 450 wires
- Initial prestressing force is 10 MN
- Concrete grade B40
- Carbon steel liner 8mm thick

Nuclear Research Institute Řež, div. Energoprojekt , Prague, Czech republic

Selected Utility Regulations for Containment

- **ZPP 1,2TL 001 – limits and acceptance criteria**
- **SPP 1,2TS 135 – procedures for containment periodical testing – pressure test**
- **SPP 1,2TS 136 – procedures for containment periodical testing – leak rate test**
- **CPP 1TC 014/8 - procedures for in-service testing according to limits and acceptance criteria (1. Unit)**
- **SPP 2T010/8 – procedures for in-service testing according to limits and acceptance criteria (2. Unit)**
- **Regulation 25.05 – ageing management programme**

In Service Inspection Programme for Temelín Containment Structures

❖ Inspection of containment concrete
- inspection of concrete surface
- non – destructive strength test

❖ Liner inspections
- visual inspection of coating
- thickness of liner

❖ Inspection of prestressing system
- humidity at the place of anchor and bends
- properties of grease
- inspection of anchors and wires
- lift up test

- Inspection of removed cables (first inspection after 5 years of operation)
  2 cylinder cables + 1 dome cable
  Detailed methodology is developed for removed cable investigation
- ZIK test – Structure integrity test before starting operation
- PERZIK – periodical integrity tests (Integrated Leak Rate test)
- In – service inspection programme comprises detailed time schedule for the whole design life
- During the first 4 years of operation the individual activities according to inspection programme are carried out in full extent. After the 4 years, a part of activities is carrid out on an annual basis and another part once in four years.

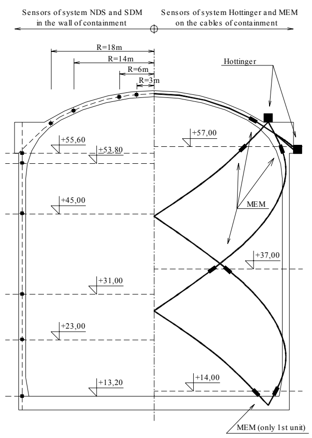
Lift up test of the cylinder cable

Inspection of dome anchor

Nuclear Research Institute Řež, div. Energoprojekt , Prague, Czech republic

Long – term monitoring systems

Systems installed on the structure that can measure displacement, strain or prestressing force in the cables (NDS, SDM, MEM, HOTTINGER)



Abbreviation of the measur. system	Type of the sensor	Static parameter measured	Projects
NDS	Vibrating wire: PSAS (on re-bars) PLDS (in concrete of the containm.) PLPS (on the inner surface of the cylinder) PTS (in concrete of the containm.)	σ_a stress in re-bars (kPa) ε_b strain of concrete U displacement approximately in the middle of the cylinder °C temperature of concrete	sensors made in USSR
SDM	Vibrating wire: -in concrete of the containment -on re-bars -measuring temperature	ε_b strain of concrete ε_a strain of re-bars °C temperature of concrete	Sensors made in the Czech Republic
MEM	sensor measuring on the base of magneto-elastic principle are placed on polyethylene tube of prestressing cable	$F_{(t)}$ prestressing force (MN)	sensors MEM of TSUS Bratislava, Slovakia
HOTTINGER	resistance strain gauge placed on anchors bolts of prestressing system	$F_{(t)}$ prestressing force in the place of the anchor (kN)	

Detailed Ageing management programme for Temelin Containment Structures (prepared in cooperation with faculty of Civil engineering of the Czech technical university – Prof. Z. Bittnar)

- **Chapter A – current procedures, review of existing information relating to the understanding of containment ageing. Methodologies for timely detection of degradation before failure.**
- **Chapter B – evaluation of mechanical properties of concrete used for Temelin containment. Assessment of laboratory test of concrete specimens.**
- **Chapter C – FEM models of Heat and Moisture transfer, creep and shrinkage models for concrete.**
- **Chapter D – Methodologies for optimum maintenance with respect to required level of safety and economy.**
- **Chapter E – Summary of methods and practices for maintenance and restoration of concrete structures.**
- **Chapter F - Guidebook for evaluation of concrete cracking, cracks mapping, acceptance critera, recommended procedures for repairing.**

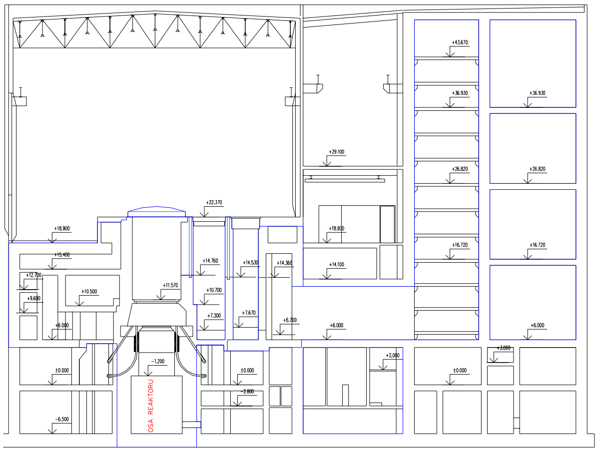
- Chapter G – Development of FEM containment model for ageing simulation (heat and moisture transfer and B3 model for creep)
- Chapter H – Procedures for efficient ageing mitigation. Review of ageing mechanisms for concrete and liners. Development of models to predict remaining service life.
- Chapter I – Data collection and record keeping for the Ageing Management. Evaluation of existing systems used for Temelin containment.
- Chapter J – Evaluation of existing methods used for Temelín containment long – term monitoring, ageing machanisms and acceptance critera.
- Chapter K – Development of ETE – FEM computer programme for containment prestressing loss simulation.
- Chapter L – Implementation and testing of FEM containment model used for simulation of ageing, developed in phase C and G.

Dukovany WWER 440/213 NPP
Selected Utility Regulations for maintenance, ageing and in - service inspections of structures

- IPZJP – J40 – individual programmes for QA of civil structures (procedures prepared for structure classified according to Decree No 214/1997) Within a frame of QA assurance programme, detailed requirements for monitoring, ageing, inspections and maintenance are developed.
- Settlement monitoring programme for civil structures
- ME 148 – classification and methodologies for equipment maintenance
- ME 069 – Dukovany ageing management
- ME 053 – Retention of records for maintenance
- P 227j – procedures for containment periodical structural integrity testing

Dukovany containment structures

- typical cross section of the reactor building



Dukovany containment ageing management Research on ageing mechanisms and studies on mitigation of ageing.

On – going programmes

- **behaviour of concrete under elevated temperatures in combination with high content of water. Mapping of temperature and moisture field of structures inside containment. Moisture migration and thermo – mechanical behaviour of concrete**
- **irradiation of concrete and it's effects to mechanical properties**

Programme under preparation

- **corrosion of liners. Development of diagnostic methods and methodology of degraded liners mapping. Development of appropriete methods for maintenance and restoration**

LICENCE RENEWAL and CONDITION MONITORING PRACTICE at Paks NPP

Structures and Structural Components

Dr. Tamás KATONA, Sándor RÁTKAI
PAKS NPP

WHY CAN WE SPEAK ABOUT LR?

- The LR is a well regulated activity
- The LM (especially the monitoring) activity started in proper time (during or just after the construction)
- Systematic condition monitoring and investigation of ageing processes in connection with LR Project
- Essential structures and structural components have been reinforced or reconstructed during the Safety Upgrading Program of the plant (more than 2000 tons of seismic structural upgrades of steel construction, upgrades if the supports, fire protection upgrades, reconstruction of the ventilation stacks) consequently, the building structures and structural components are relatively not aged

CONTENT (ABOUT)

- Some basic information about Paks NPP
- Legal frameworks, regulations
- License renewal at PAKS NPP
- Project plan (in technical sense, schedule)
- Condition monitoring programs
- Main ageing concerns (examples)

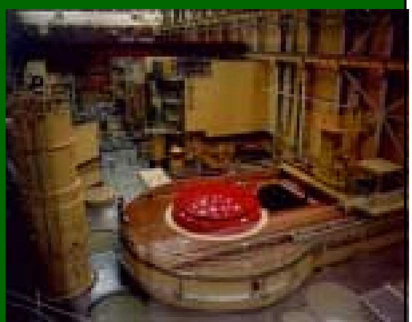
CONTENT (ABOUT NOT!)

- LICENSE RENEWAL:
  - environmental aspects
  - human resources, plant staff ageing
  - business

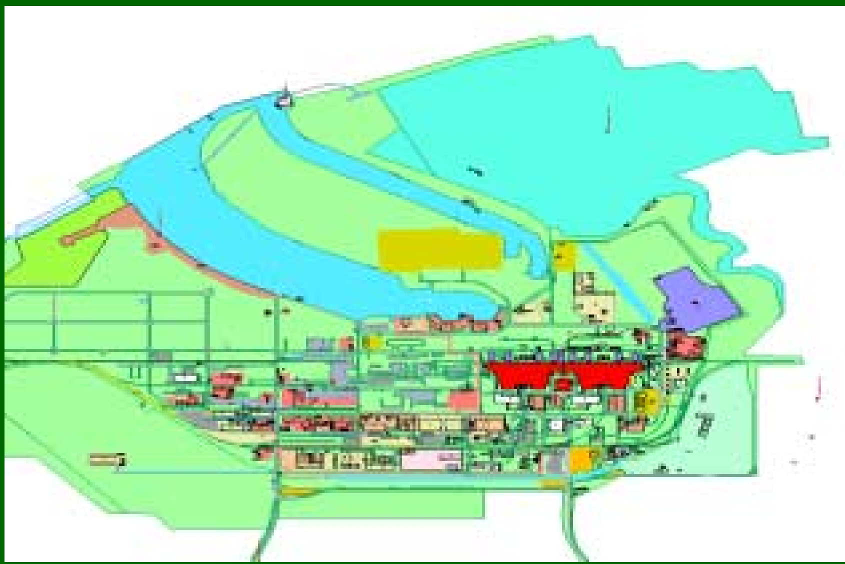
SOME BASIC INFORMATION ABOUT PAKS NPP

BASIC TECHNICAL DATA

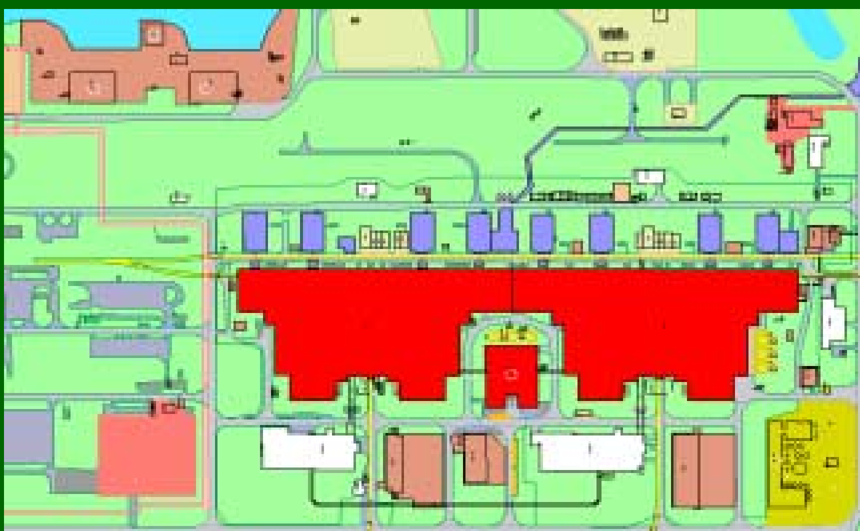
No. of Units	**4**
Type:	**pressurized (light) water cooled, water moderated, reactor WWER-440, second generation V-213**
No. of loops	**6**
Thermal power	**1375 MW**
No of turbines	**2**
Electrical power of the generators	**2 x 230 MW**
Electrical power	**470 MW**
Primary pressure	**12,4 MPa**
Pressure before the turbines	**4,46 MPa**
Average temperature of the coolant	**282 °C**
Dimensions of the core (hight/diameter)	**2,5/2,88 m**
Fuel	**42 t Uranium oxide**



MAP of PAKS NPP SITE



MAP of PAKS NPP SITE

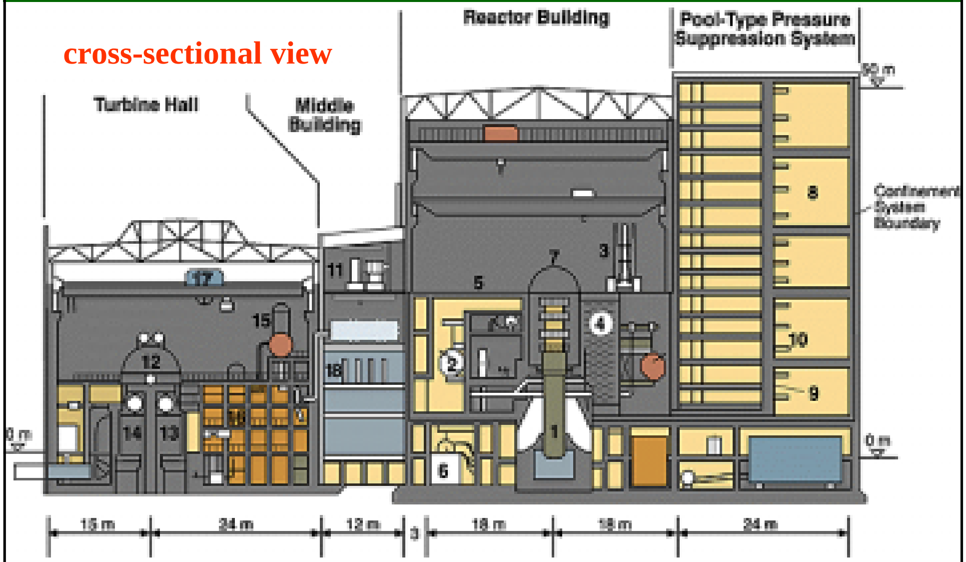


MAIN BUILDING COMPLEX

MAIN BUILDING COMPLEX

MAIN BUILDING COMPLEX

cross-sectional view



AUXILIARY BUILDING

DIESEL BUILDING (1-2)

DIESEL BUILDING (3-4)

WATER INTAKE STATION

WATER INTAKE STATION

LEGAL FRAMEWORKS, REGULATIONS

GENERAL LEGAL FRAME

- Act on Nuclear Energy, 1996, NUCLEAR SAFETY REGULATIONS, 1997
- Act on the Environment, water usage
- Act on Electric Energy (new, market liberalization beginning from 2003)

THE HUNGARIAN NUCLEAR REGULATION FOR LR

- **GOV. DECREE 108/1997, NUCLEAR SAFETY REGULATION:**
  - **LICENSE RENEWAL:** THE DESIGN LIFE TIME IS 30 YEARS; IT CAN BE EXTENDED, THE LICENSEE HAS TO SUBMIT TO THE AUTHORITY THE APPLICATION FOR THE LIFE TIME EXTENSION 5 YEARS BEFORE DESIGN LIFE TIME EXPIRES (Unit No 1, 2007),

    TWO STEP PROCESS!: PRINCIPAL APPROVAL in 2007, LICENSE RENEWAL in 2012
  - THE SYSTEM OF **PERIODICAL SAFETY ASSESSMENT** EXISTS (next in 2008), PSR AS SELF ASSESSMENT AND REPORTING OBLIGATION
  - **ANNUAL UPDATING OF THE FINAL SAFETY REPORT** EXISTS (FSR ACCORDING TO REG. GUIDE 1.70, A PROJECT FOR DESIGN BASIS RECONSTRUCTION AND REG.GUIDE 1.70 COMPLIANCE IS GOING ON, 2004)

REGULATORY GUIDELINES

1. Licence Renewal
   - 4.15 - License-Renewal program during operation of NPPs
   - 1.28 - Content of License Renewal application report
2. Preconditions to obtain the licence renewal in-principle

   (four leg philosophy of the Hungarian Regulation – absolutely necessary condition)

2.1. Ageing Management

- 3.13 - Ageing Management Considerations during Design of NPPs
- 4.12 - Ageing Management during Operation of NPPs
- 2.15 - QA in Ageing Management Program
- 1.26 - Regulatory control of AM Program
- 1.26.S1 - Scope of SSCs in AM Program
- (no) - PTS guide (new)

2.2. Design Basis Reconstruction

- No guides were issued
- The necessary requirements were declared in the QA-Manual for FSAR elaboration

2.3.Maintenance Rule

- 4.18 - Guides for Maintenance Program of NPPs
- 1.27 - Regulatory Monitoring of the Effectiveness of the Maintenance Program

2.4.Environmental Qualification

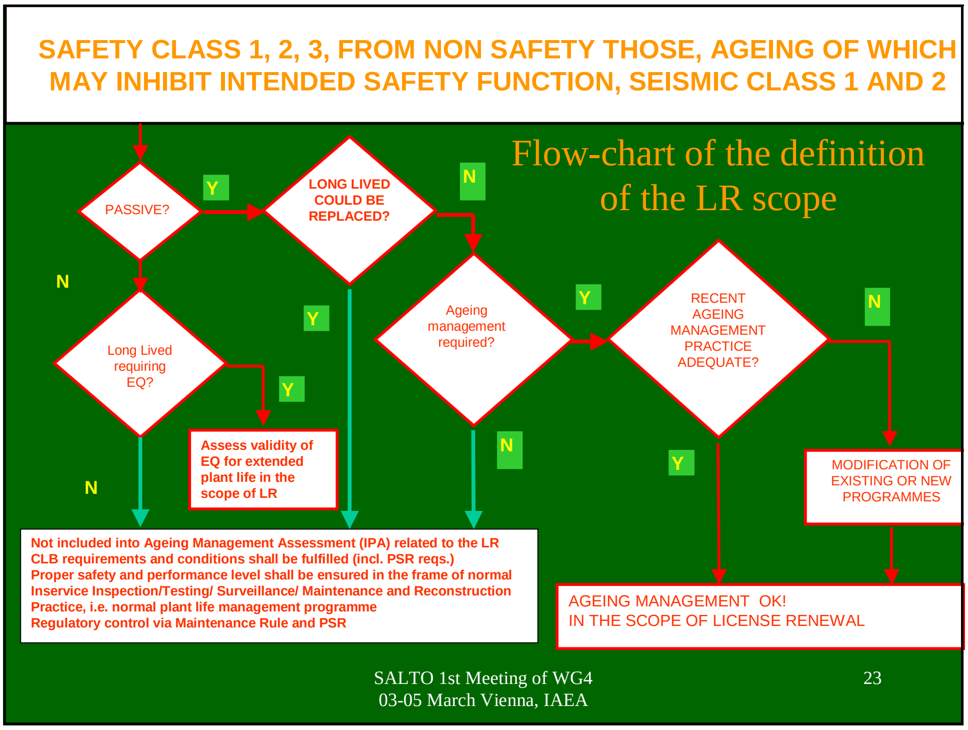
- 3.15 - E-Q requirements during design of NPPs
- 3.15.S1 - Standards for E-Q
- 4.13 - E-Q and its preservation during operation of NPPs
- 1.27 - Regulatory Control of E-Q and its preservation

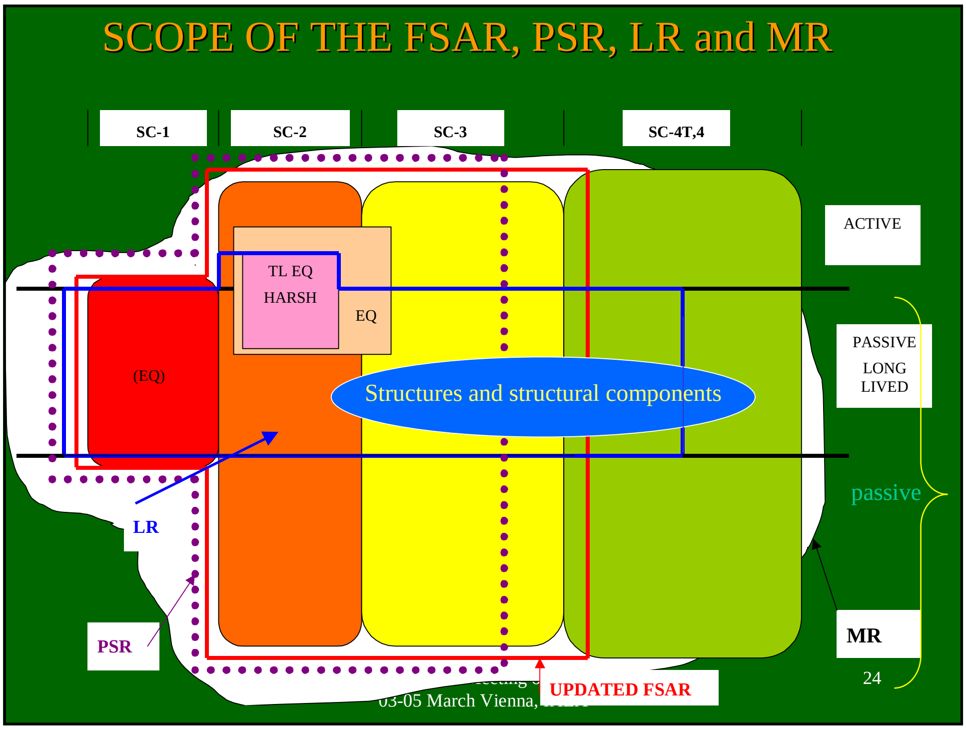
Example from the Reg. Guide 1.26

Item	place of the degradation	mechanism of the degradation	worst consequences	Reg. contr.
Reinforced concrete structures of the hermetic part of the main building	Reinforced concrete	corrosion change of the material properties due to heat or irradiation fatigue settlement	cracks cracks cracks cracks declining the reactor axis from vertical, loss of the function of the control rods	- - - - +
	support plates in the concrete	corrosion	leakage	+
	liner	corrosion	leakage	+

MAIN SOURCES of the LR BACKGROUND DOCUMENTS

- **AGING MANAGEMENT**
  - IAEA AM GUIDELINES, TECHDOCS
  - VVER AMP REPORTS
  - NPAR REPORTS
  - OECD AMP REPORTS
  - GALL REPORT
  - ACI, ASME, IEEE CODES
- **LICENCE RENEWAL**
  - NRC LR RULE
  - LR APPLICATIONS
  - NEI 95-10
  - USNRC LR STANDART REVIEW PLAN
- **MAINTENANCE RULE**
  - 10CFR50.65
  - NUMARC 93-01
  - NRC INSPECTION REPORTS
  - NUREG 1648
- **TLAA -FATIGUE**
  - PARTLY AVAILABLE ORIGINAL DESIGN CALCULATION
  - PNAE
  - ASME III
  - NPAR REPORTS
  - NUREGS
- **TLAA RPV-PTS**
  - IAEA WWER-PTS GUIDE
  - ASME XI
  - EU VERLIFE
  - LOVIISA PTS PRACTICE
- **I&C EQ IN HARSH ENVIRONMENT**
  - IEEE EQ CODES
  - IAEA CABLE AMP GUIDELINE
  - OECD CABLE AMP REPORT
  - LOVIISA PRACTICE
  - VERSAFE REPORT


SAFETY CLASS 1, 2, 3, FROM NON SAFETY THOSE, AGEING OF WHICH MAY INHIBIT INTENDED SAFETY FUNCTION, SEISMIC CLASS 1 AND 2
Flow-chart of the definition of the LR scope
PASSIVE?
Y
LONG LIVED COULD BE REPLACED?
N
N
Long Lived requiring EQ?
Y
Y
Ageing management required?
Y
RECENT AGEING MANAGEMENT PRACTICE ADEQUATE?
N
Assess validity of EQ for extended plant life in the scope of LR
N
N
Y
MODIFICATION OF EXISTING OR NEW PROGRAMMES
Not included into Ageing Management Assessment (IPA) related to the LR
CLB requirements and conditions shall be fulfilled (incl. PSR reqs.)
Proper safety and performance level shall be ensured in the frame of normal Inservice Inspection/Testing/ Surveillance/ Maintenance and Reconstruction Practice, i.e. normal plant life management programme
Regulatory control via Maintenance Rule and PSR
AGEING MANAGEMENT OK!
IN THE SCOPE OF LICENSE RENEWAL
SALTO 1st Meeting of WG4
03-05 March Vienna, IAEA
23


SCOPE OF THE FSAR, PSR, LR and MR
SC-1
SC-2
SC-3
SC-4T,4
ACTIVE
TL EQ
HARSH
EQ
(EQ)
PASSIVE
LONG LIVED
Structures and structural components
passive
LR
PSR
MR
UPDATED FSAR
03-05 March Vienna,
24

The License Renewal concept of LTO HUNGARIAN APPROACH

- The concept of Licence Renewal (LR) is usually followed by the countries where the operational licence is granted for a fixed time span limited either by the design lifetime or other considerations.
- This concept is based on the correlation between the continuous control of the CLB and the control of those aspects of the plant safety, which are depending on the unavoidable ageing of safety related SSCs.
- In these regulatory systems the CLBs are maintained and they are documented in the (annually updated, living) Final Safety Analysis Report (FSAR).
- In addition to this, the efficiency of the maintenance system is controlled with some performance criteria for the active safety related SSCs.
- The LR process itself is focused on the ageing management of long-lived passive SSCs, on the review of the validity of the time limited ageing analyses and environmental qualification of long live harsh environment SSCs.

CONDITION OF LTO – MAINTAIN CRL

DESIGN LIFETIME (30 years)

Safe operation
Condition monitoring:
- •inspections and tests,
- •ISI

Condition maintaning:
- •maintenance, upgrading
- •refurbishment

EQ (**finalisation**)

+

PLEX (+20 years)

•TLAA
Time limited EQ
Development of ageing management program

Ageing management
Environmental qualification
Monitoring the effectiveness of maintenance
Development of FSR

LICENSE RENEWAL AT PAKS NPP

(project plan in technical sense, schedule)

PLANS, SCHEDULES

- 2000: feasibility study (review of plant technical status + business)
- 2001: PREPARATORY PROJECT LAUNCHED
- 2002: final business decision of the owner, development of the detailed project plan
- 2002: development of detailed Regulatory Requirements

  2002-2007: preparation of LR, development of the life time management programme, preparation of the documents for licensing, partial implementation of measures, environmental protection licensing
- 2007(2006): application for in-princ
  operation
- (2008: PSR)
- 2012: approval and license for 50 years

TIME SCHEDULE IS DRIVEN BY REGULATORY PROCESS

REVIEW OF THE PROJECT TASKS

No.	Tasks of the project
1.	Determination of the scope of the license renewal and methodology
2.	Overall review of the current ageing management practise
3.	Solving the currently known unresolved issues (from feasibility study)
4.	Time Limited Ageing Assessment (TLAA)
5.	Other TLAA tasks
6.	Currently known ageing management measures
7.	Introduction of the new maintenance rules: evaluation, methodological task, development of programs
8.	Finalisation of the programs for equipment qualification + methodology development
9.	Condition maintaining activities (making reconstruction plans)
10.	Elaboration of the measures derived from the comprehensive review of the current ageing management programs
11.	Activities to obtain the nuclear safety licence-in-principle
12.	PR activities
13.	Implementation of the reconstruction and investment plan
14.	Finalisation of the EQ (deficiencies)
15.	Fulfilment of the new maintenance rules (effectiveness)

SCOPE of LM and LR

- All building structures and structural components are long lived (30-50 years design life)
- All building structures and structural components are in the scope of LM

Project tasks (building structures)

- Scoping (1)
- Review of the ongoing condition monitoring (+maintain) programs (2)
- Identification of the non-pressurized components relating to the scope of license renewal (2)
- Analysis of the necessity of the soil stabilization by injection of the main building of the Unit 4 (3)
- Analyses of the liners from corrosion point of view at the hidden surfaces (3)
- Introduction the IP for non pressure retaining components (e.g. pipeline supports) (6)

Project tasks (building structures)(cont.)

- Surveying of the reinforced concrete structures (environmental temperature is above 70 °C) (6)
- Status survey of the penetrations (6)
- Analysis of embedment of mechanical equipment taking into account the result of the survey reports (issues: high temperature, sinking of MBC, leaked coolants and lubricants) (6)
- Developing and elaboration of the upgrading and reconstruction plans (9+13)
  - short term (2003-2007)
  - intermediate term (2008-2012)
  - long term (2012-)

CONDITION MONITORING PROGRAMS

CONDITION MONITORING

- Program (plan) of the monitoring
- Tailor made procedure of the monitoring for each significant structure and ageing mechanism
- Methods:
  - – visual (walk-down)
  - – instrumental:
    - non-destructive:
      - – control of the geometry, eddy-current, etc.
    - destructive (sampling and laboratory investigations)

MONITORING PROGRAMS

- Control of building movement
- Control of cracks in concrete (definition of the critical areas)
- Control of the reinforced concrete behaviour in boric acid environment
- Control of the corrosion of the liner

CONTROL of BUILDING MOVEMENTS and SETTLEMENT

- Geodetic control of the settlement, started during the construction and periodically performed 4 times per year, evaluation yearly
- Findings:
  - uneven settlement in NW-N direction at unit No 4 (no problem with control rods, but cracks in the nonstructural walls)
  - settlement is consolidated at all buildings
  - stacks are consolidating after the reconstruction

CONTROL of CRACKS in CONCRETE

- Mapping the cracks
- Identification of the critical places
- Periodic control (opening, passive, etc.)
- Correlating the cracks with building relative settlements, loads, etc.

CONTROL of CORROSION of the C-STEEL LINER

- Liner corrosion inside the hermetic zone:
  - Liner corrosion (at the hidden-side) in the area of heavy-concrete (shielding) could be an issue
  - eddy-current scanning applicable
  - evaluation of the corrosion rate
- Liner corrosion outside of the hermetic zone:
  - full scope control performed, limited repair 7 m^2

CONTROL of the REINFORCED CONCRETE BEHAVIOR in BORIC ACID ENVIRONMENT

- Root-cause: leakage of the pools, boric acid penetrated into adjacent area of the reinforced concrete structure
- Reconstruction of the pools (no leakage now)
- Periodic control of the reinforced concrete behaviour subjected to the effects of boric acid environment: specimens taken, laboratory testing, slight increase of porosity of the concrete and the pH,
- Conclusion: no significant effects of that amount of boric acid

CONTROL of the CONCRETE BEHAVIOUR in the AREAS of WATER LEAKAGE

- Root-cause: water leaking at different places
- Some repair and reconstruction of the roofs needed
- Periodic control of the reinforced concrete at the area of leakage: specimens taken, laboratory testing,
- Conclusion: no significant safety effects

OTHER MONITORING PROGRAMS

- Control of the decontaminable coating
  - Instrumental and visual (walk-down) control of the coating
  - 15% of the surface should be repaired
- Fire protection doors
  - visual and fluorescent examination
  - repair needed

Condition and condition monitoring of buildings other than reactor building

- Walk-down and instrumental investigation performed, some repair identified in case of:
  - Diesel-buildings,
  - cooling-water in and outlet structures,
  - Facade panels

MONITORING of the VIBRATION EFFECTS

- Critical areas of operational vibration identified
- Steady-state vibration and transients (starts and shut-downs) measured
- Vibration load assessed
- No significant effect

MAIN AGEING CONCERNS (examples)

MAIN DEGRADATION MECHANISMS OF CONCRETE, CONVENTIONAL REINFORCING, STRUCTURAL AND STAINLESS STEEL COMPONENTS (REF: ACI 349.3R-96, GALL REPORTS ETC.)

- **Concrete**

1. Abrasion/erosion
2. Chemical attack*
3. Thermal exposure
4. Cracking(fatigue…)
5. Cement-aggregate reaction
6. Freeze-thaw cycling
7. Irradiation
8. Leaching*
9. Volume changes
10. External Loads
11. Fire damage
12. Steam impingement
13. Settlement*

- **Steel**

1. Corrosion*
2. Fatigue
3. Thermal effects
4. Irradiation

MAIN CONCERNS

Concern No:1
Concrete: chemical attack; leaching
Steel: corrosion

Checking hole for borical leakage and concrete (hematit) on a wall near the main source of liquid(spent fuel pool).

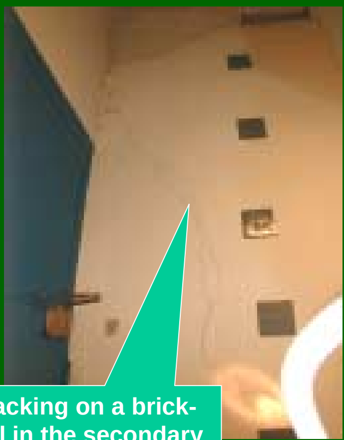
Corrosion of steel liner can also he seen.

Checking hole for control of borical leakage and concrete condition on a floor near the main source of liquid.

Exposure of concrete ceiling to flowing water resulting in leaching of certain salts.

Exposure of concrete floor to flowing water resulting in leaching of certain salts

Concern No2:
Concrete: cracking



Cracking on a brick-wall in the secondary circuit, due to settlement.

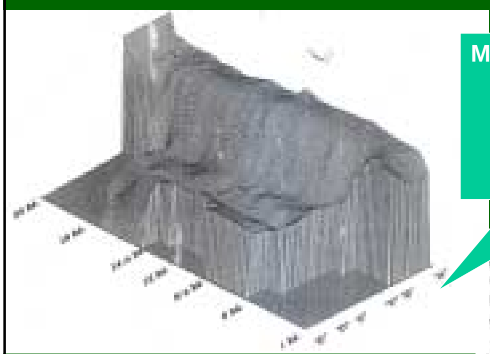
The wall has been reinforced by installing a vertical steel structure.

Recurence of shrinkage crackings on the monolite concrete wall of a long corridor

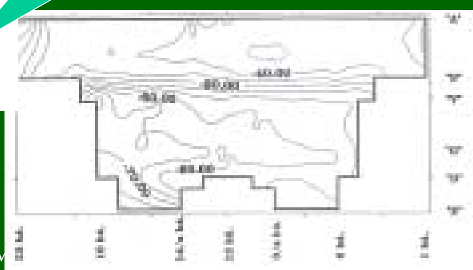
Shrinkage cracking of monolite concrete wall and ceiling

Shrinkage cracking on a monolite concrete floor

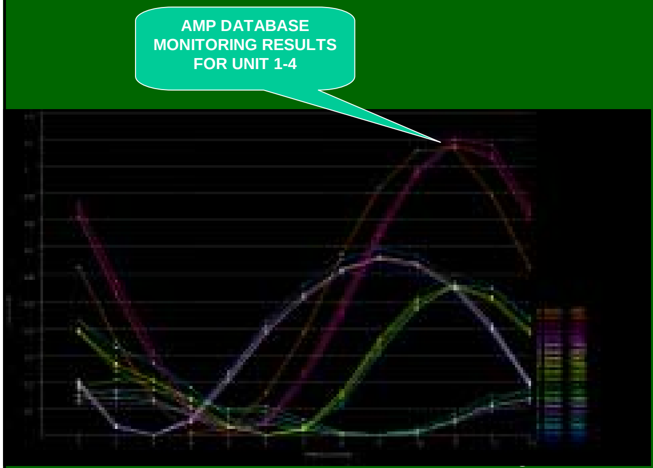
Concern No3
Settlement of buildings,
RPV main flange plate movement

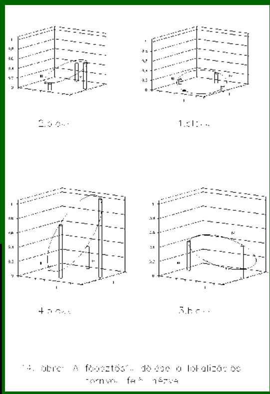


Maps of total settlement of the main buildings of Units until 2002.



RPV Main flange plate movement of the NPP Paks Units





SUMMARY

- The license renewal for 20 years is feasible.
- The recent practice of condition monitoring maintenance and upgrading ensure the good condition of the plant.
- The use of international best practice and the international acceptance is a very important success condition.
- The LR procedure ensures the future of nuclear power generation in Hungary (at PAKS site)

Life management of NPP structures	1

Principle valid and being developed normative documents on substantiation and prolongation of service life for NPP

#	Developer of document		Name of normative document
1	Gosatomnadzor of RF	ПНАЭГ-01-011-88/97(ОПБ-88/97)	"General provisions of safety assurance of nuclear plants" (НП-001-97)
2		ПиНАЭ-5.6	"Regulations of civil design of nuclear power plants with different types of reactors", 1986
3		НП-017-2000	"Basic requirements to service life prolongation of NPP power unit"
4		НП-024-2000	"Requirements to justification of possible prolongation of specified service life of NPP structures in use"
5	"Rosenergoatom" concern	РД-ЭО-0281-01	"Provisions on control of life characteristics of NPP power unit elements"
6		РД-ЭО-0283-01	"Typical program of comprehensive survey of NPP power unit for service life prolongation"
7		РД-ЭО-0447-03	"Procedure for estimate of state and remaining life of NPP safety-related reinforced concrete structural elements"
8		РД-ЭО-0141-98	"Typical technical requirements to procedures for estimate of technical state and remaining life of NPP power unit elements"
9		РД-ЭО-0007-93	"Typical service instructions on NPP production buildings and structures"
10		РД-ЭО-0129-98	"Requirements to maintenance and repair of prestressing system in containment of NPP with reactor plant RU320"
11		РД-ЭО-0130-98	"Requirements to maintenance and repair of prestressing system in containment of NPP with reactor plants RU302; RU338 ;RU187"
12	Being developed ones	РД-ЭО-0000-00	"Procedure for service life substantiation of NPP containments with WWER-type reactors"
13		РД-ЭО-0000-00	"Monitoring of NPP structural elements"

Life management of NPP structures	2

NPP buildings and structures are assigned to three categories in terms of their radiation and safety related effects and plant systems which are functioning within them.

Category I	Buildings, structures, structural components whose collapse or damage having a dynamic effect on normal operation systems may lead to release of radioactive products in quantities resulting in radiation doses for personnel and population beyond the specified values in case of a design basis accident or failure of safety systems maintaining the reactor core in subcritical condition and providing emergency heat removal from the reactor and confining radioactive products.
Category II	Buildings, structures and their components (not included into the first category) whose failure may lead to interruption of power generation by the nuclear power plants or radiation doses beyond the permissible annual doses specified for normal operation in regulatory documents.
Category III	All other buildings, structures and structural components not included into category I and II.

Life management of NPP structures | 3

Klassification of structural elements of buildings and structures of NPP with WWER-440 reactor

№№	Name of buildings structures and elements	Class per ОПБ 88/97	Classification designation per ОПБ-88/97	Category per ПиН АЭ-5,6	Name of system
1	2	3	4	5	6
1	**Reactor building**				
1.1	**Hardware compartment**				
1.1.2	Raft, including:		2N		Component of the localizing safety system and safety-related normal operation system
	Within SG compartment including the reactor cavity part lower the raft (room A001)		2NL		
1.1.3	Walling of air-tight rooms				
1.1.4	Internal structural elements of air-tight rooms	2	2N	I	
1.1.6	Civil structural elements of hardware compartment in the central part between SG compartments		2N		
1.1.7	Civil structural elements of emergency boron storehouse		2O		Component of the safety-related normal operation system
1.1.8	Civil structural elements of exhaust ventilation center		2N	I	
1.2	Civil structural elements of turbine building in axes "12-33"				
	Ditto, in axes "1-12" & "33-42"	3	3N	II	
1.3	Civil structural elements of longitudinal stack assembly for electrical devices	2	2N	I	Componentof the safety-related normal operation system
1.4	Civil structural elements of transversal stack assembly for electrical devices		2N	I	
2	Civil structural elements of RDGP and communication channels with the reactor building	2	2O		
3	Civil structural elements of the reactor auxiliary building	3	3N	II	
4	Trestle				

Life management of NPP structures | 4

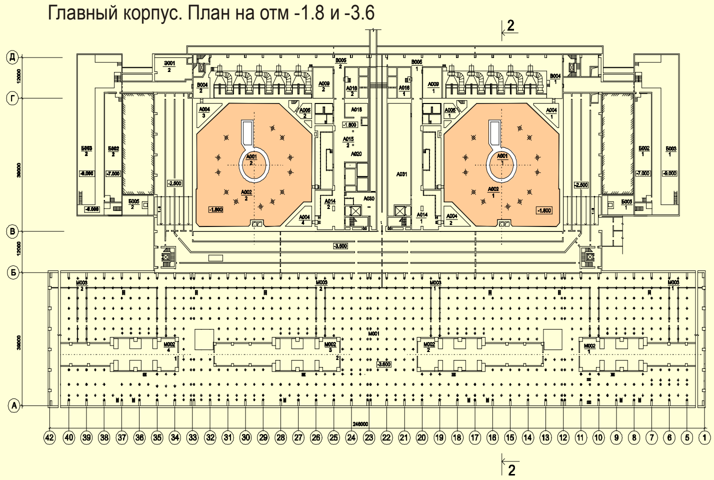
Classification of structural elements of buildings and structures of NPP with WWER-1000 reactor (B-320)

№№	Name of buildings structures and elements	Class per ОПБ-88/97	Classification designation per ОПБ-88/97	Category per ПиН АЭ-5.6	Name of system
1	**Reactor building**				Component of the safety-related normal operation system
1.2	Raft				
1.3	Walls and floors of the raft,				
1.4	Inner structural elements of the pressurized compartment, including:	2	2N	1	
1.4.1	Reactor cavity				
1.4.2	Spent fuel storage pond				
1.4.3	Inspection pit of protection piping and wet refueling with all components				Component of the localizing safety system and safety-related normal operation system
1.5	Structural elements of the containment system		2LN		
1.5.1	Prestressed containment with all components except i.6.1.5.1.1	2			
1.5.2	Containment bedplate with all components				
1.5.3	Emergency boron storage tank with all components		2LN		
1.6	Walls and floors of rigging	2	2N	I	
2	Reactor building frame bearing structural elements (turbine cmpt, deaerator cmpt, annex of electrical facilities	3	3N	II	
3	Reactor auxiliary building		3N	II	Component of the safety-related normal operation system
3.2	Raft in liquid waste storage building				
3.3	Liquid radwaste storage building RWT with all components		2N	I	
3.4	RWT unit structure				
3.5	Other structural elements of the reactor auxiliary building	3	3N	II	
4	Structural elements of the reserve diesel-generator plant with service water pump house for essential loads, with compressor pneumodrives and communication channels with the reactor building		2N	1	
5	Structural elements of the fresh fuel storage building with all components			I	
6	Structural elements of the solid radwaste storage building with all components		2N 3N	II	

Управление ресурсом строительных конструкций	5

АЭС с ВВЭР 440

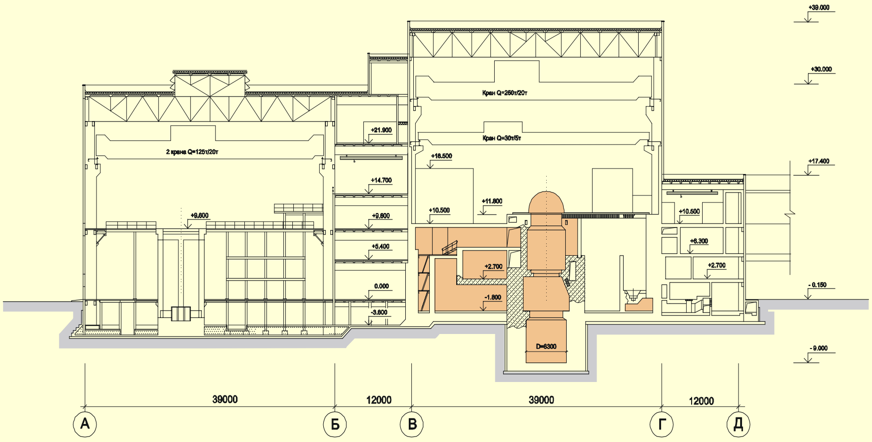
Главный корпус. План на отм -1.8 и -3.6



Управление ресурсом строительных конструкций	6

АЭС с ВВЭР 440

Поперечный разрез главного корпуса

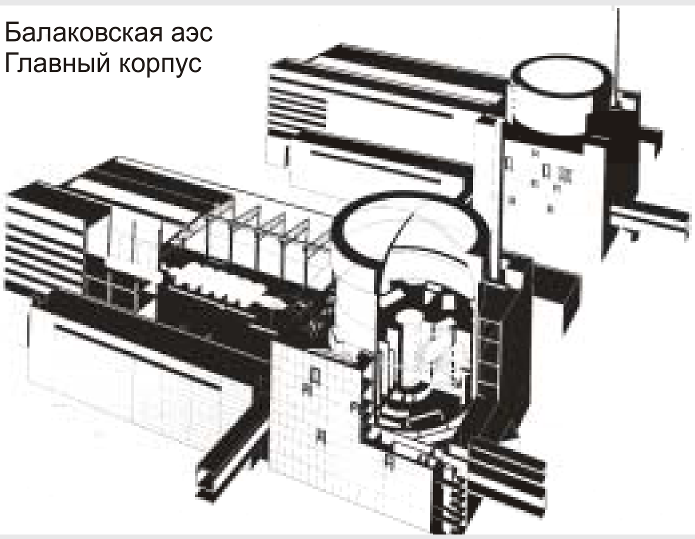


Управление ресурсом строительных конструкций 7

Нововоронежская аэс
Главный корпус

Управление ресурсом строительных конструкций 8

Балаковская аэс
Главный корпус



Life management of NPP structures | 9

Plan of substantiation of remaining life for Novovoronezh NPP power unit structures

Development, coordination and approval of list of structural elements of the NPP power unit for assessment of their technical condition and remaining life

↓

Accumulation and analysis of design and operation documents

↓

Operation modes of loading	—	Mechanisms of ageing	—	Unsoundness	—	Physico-mechanical properties	—	Design strength analyses

↓

Definition of zones with maximum operation damaging and ascertainment of main mechanisms of ageing, governing parameters and criteria of assessment for these zones

↓

Selection of procedures and means of field monitoring for designed zones with regard to dominant mechanisms of operation damage
Development of executable plan for condition survey

↓

Performance of element checking (condition survey)
(Physico-mechanical properties, microstructure, unsoundness, etc.)

↓

Forecast of element material change of state for prolongable service life based on study of change of physico-mechanical properties and microstructure with regard to service impact for the entire planned term

↓

Calculated experimental estimate of technical condition and remaining life

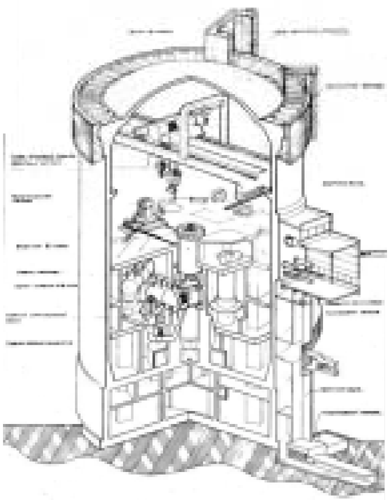
↓

Issue of conclusions on technical condition and remaining life of structural elements

↓

Issue of design solutions on ability and conditions of further service of structural elements as a part of Novovoronezh NPP power unit systems

Управление ресурсом строительных конструкций | 10



Общий вид защитной оболочки

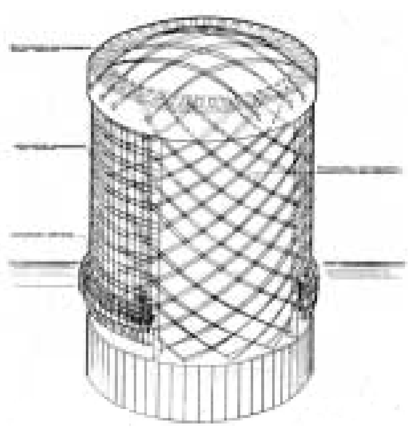
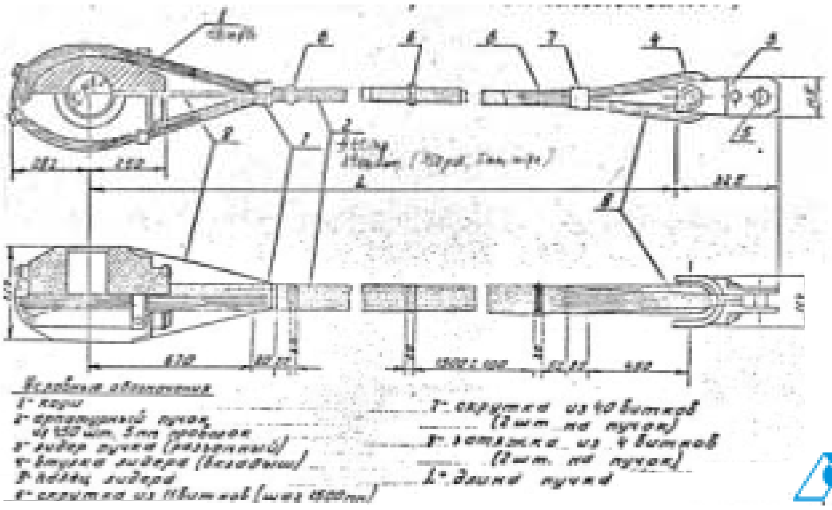


Схема
расположения каналообразователей
системы преднапряжения

Управление ресурсом строительных конструкций	11

Схема арматурного пучка



Life management of nuclear containments	12

GENERAL BASE OF LIFE MANAGEMTNT OF STRUCTURES OF NPP-
SYSTEM OF SURVEILENCE OF THEIR TECHNICAL STATE:

Type instruction on maintenance of buildings and structures of nuclear plants

RD EO-0007-93

Main measures of surveilance:

- technical inspections (NPP staff),
- regiment observations (NPP staff, special organizations),
- surveys (special organizations)

Life management of nuclear containments | 13

TECHNICAL INSPECTIONS OF STRUCTURES OF NPP

Are made on regular base twice a year (in sprig and in autumn)
by commission under management of Chief Engineer of NPP

Target of technical inspections:

- to reveal defects of construction,
- to reveal disadvantages of maintenace,
- to propose measures for restoring of capacity of construction .

Result of technical inspection -
list of defects of construction.

Inspection of inner surface of containment
is made once a year in period of
control and preventive works (KPR)
at cooling of reactor.

Inspection of inner surface of containment
must be made at least each 3 monthes

Life management of nuclear containments | 14

REGIMENT OBSERVATIONS ON THE NPP SITE

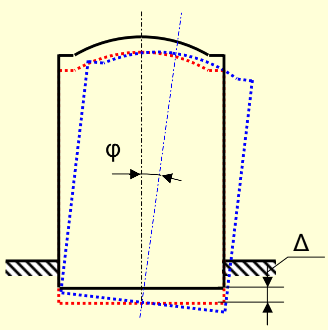
- measurement of table and chemical analysis of soil water,
- measurement of set and roll of structures.

Periodicity of measurement of set Δ and roll φ of reactor building

Before stabilization of set Δ:

- first year – 3 times;
- second year – 2 times;
- next years – 1 time;
- checking by special organization – once in 4 years.

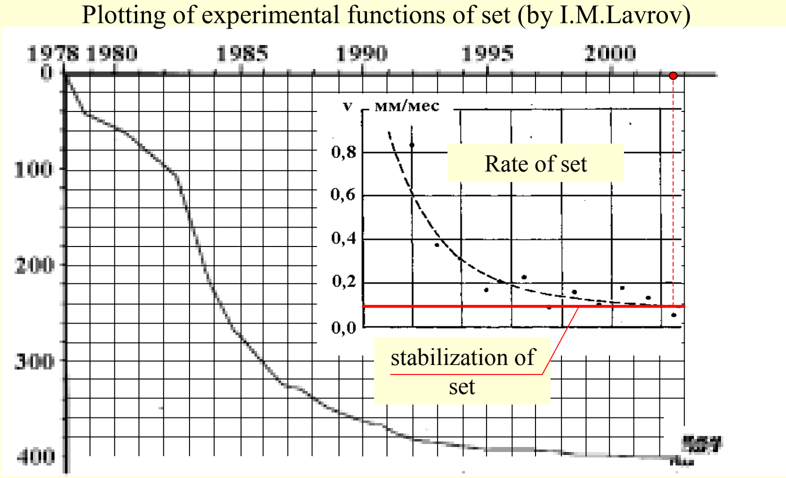
After stabilization of set Δ: once a year.



Stabilization: rate of set $v = d\Delta / dt \leq 1$ mm/year.

Life management of nuclear containments 15

Plotting of experimental functions of set (by I.M.Lavrov)



Development of forecast of set on the base of measured data

$\Delta_t = 373 + 14{,}95 \ln(1+0{,}71\, t)$, mm,

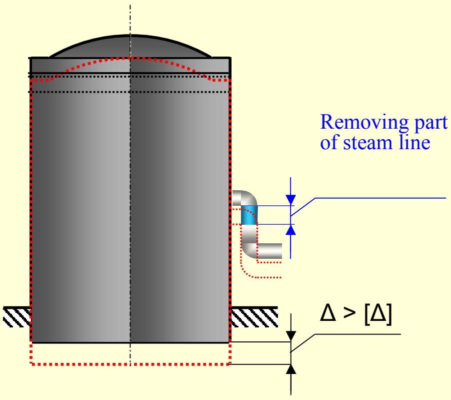
where *t* – time in years from 1990 year

Life management of nuclear containments 16

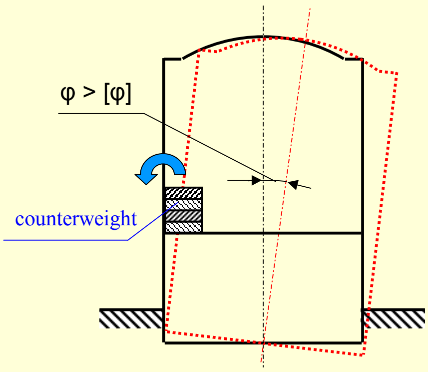
Compensation of set and roll of nuclear containments

Compensation of set

Dangerous consequence – disturbance of communications



Correcting of roll



Life management of nuclear containments 17

SURVEYS

Are fulfilled in necessary cases after decision of NPP directorate;
Complex surveys are fulfilled before life extension.

Target of surveys:

- to reveal degree of ageing of construction,
- to evaluate ability of its further use,
- to propose measures for restoring of capacity of constructions,
- to develop recommendations for improvement of maintenance.

Stages of survey: 1) visual,

2) instrumental.

Life management of nuclear containments 18

Visual stage of survey:

- revealing of ageing defects:
  - ✓defects of coating layer;
  - ✓disturbance of heat protection;
  - ✓corrosion of steel liner;
  - ✓zones of wetting and leach of concrete;
  - ✓cracks in concrete;
  - ✓surface caves of concrete;
  - ✓damages of protective layer of reinforced concrete constructions;
  - ✓symptoms of corrosion of reinforcement (characteristic cracks on the surface of constructions).
- revealing of factors of ageing:
  - ✓overloading of constructions ;
  - ✓action of aggressive chemical agents ;
  - ✓action of steam, leak, water, oils ;
  - ✓intense heating/

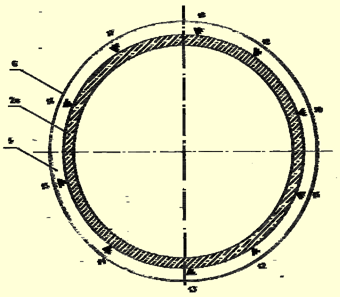
Life management of nuclear containments | 19

Instrumental stage of survey :

- ✓ geometric measurements of defects (length and width of cracks etc.);
- ✓ physical and chemical analysis of concrete specimens (for revealing of leach and other forms of corrosion);
- ✓ definition of mechanical characteristics of concrete (by nondestructive and destructive examinations);
- ✓ sampling of reinforcing specimens for definition of its mechanical characteristics;
- ✓ evaluation of degree of corrosion of reinforcement.

Life management of nuclear containments | 20

Definition of real strength of concrete



Location of testing points of concrete

№ of zone	R_{av}, MPa	ν, %	$R_n = R_{av}(1 - 1{,}64\nu)$, MPa	Class
Evaluation 63,4 m				
11	60,8	13	48,0	50
12	59,2	8	51,5	50
13	68,3	8	59,4	60
14	63,6	11	52,2	50
15	46,4	12	37,1	35
16	50,0	5	47,0	45
17	57,0	8	49,6	50
18	67,5	12	54,0	55
19	63,1	10	53,0	55
20	75,7	8	65,9	60
Average	61,2	10	51,8	51 (50)

Life management of nuclear containments | 21

New type of survey –

Measurement of natural frequencies of structure as an integral indicator of its ageing

Natural frequencies are defined on the base of registration of natural micro-oscillations by sensitive transducers (by prof. G.E.Shablinsky)

Registration apparatus –

Modified ceismometer

CM-3

Working range of freqencies: 1,0 - 100,0 Hz

Record and treatment of signal – by IBM PC

Life management of nuclear containments | 22

ROUTINE MONITORING OF STRESS STATE OF CONTAINMENT

All containments of Russian NPPs are provided with system of instrumentation, which includes:

- string sensors embedded in concrete of containment,
- cables of measuring channels,
- record equipment (in special compartment in reactor bouilding),
- program software.

Set of string sensors includes:

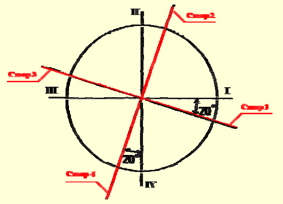
- sensors of strain in reinforcement (type PSAS),
- sensors of linear strain in concrete (type PLDS),
- shrinkage cones with transducers of linear strains,
- sensors of temperature (type PTS).

Total number of sensors: 381-160 pc.

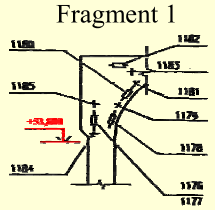
Life management of nuclear containments | 23

Location of sensors of type PSAS

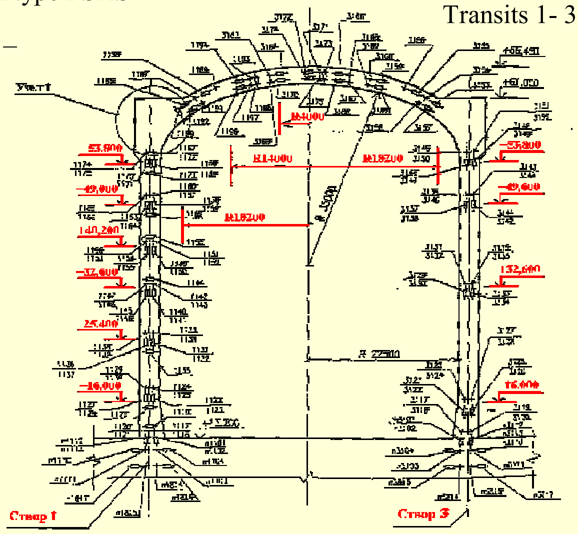
Planes of location of sensors – instrumental transits



Fragment 1

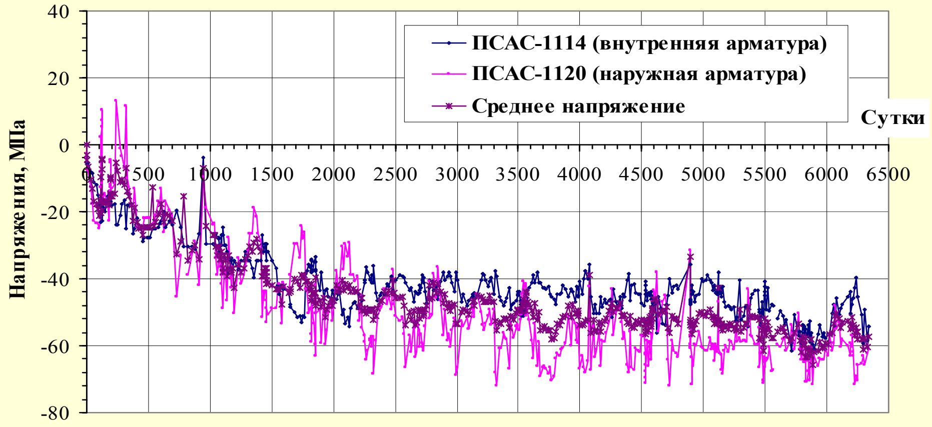


Transits 1- 3



Life management of nuclear containments | 24

Increment of meridional stresses in reinforcement after prestressing of containment, period from 18.04.1986 to 02.09.2003, Kalinin NPP, unit 2, transit №1, elev. 18 m.



General growth of compression in reinforcement characterizes creep of concrete c

Life management of nuclear containments | 25

CONTROL OF TENSION IN PRESTRESSING TENDONS

Requirements for technical maintenance and repair of prestressing system of nuclear containments

RD EO-0129-98

CONTROL BY USING OF HYDRAULIC JACKS

Is fulfilled in accordance with regiment of control and preventive works KPR-1 and KPR-2

Amount of control:

- 16 tendons of cylindrical part,
- 6 tendons of dome.

Periodicity of control:

- first 5 years – once a year,
- next period – once each five years.

DIRECT CONTROL BY FORCE SENSORS NV005

Force sensors are located between anchor sleeve and supporting slab.

Amount of equipment:

- ~⅓ tendons of cylindrical part,
- ~⅓ tendons of dome.

Life management of nuclear containments | 26

CONTROL OF TIGHTNESS OF CONTAINMENTS

Testing of tightness of containments

- by full design pressure – at the finish of construction and periodically once each 10 years;
- by less pressure (as a rule ½ of design pressure), - each year.

Results of tightness testing of Russian containments

NPP	Unit №	Leak, %/day			Remarks
		design	norm	fact	
Novovoronezh	5	0,3	0,84+0,18	0,866±0,036	2001year
Balakovo	1	0,3	0,3	0,1026	2000 year (test pressure 0,7 atm. recalculated to 4,0 atm.)
	2	0,3	0,3	0,1233	
	3	0,3	0,3	0,0861	
	4	0,3	0,3	0,0816	
Kalinin	1	0,3	1,43	0,293	2000 year
	2	0,3	0,85	0,609	2000 year
Rostov	1	0,3	0,3	0,217±0,0595	2000 year (at 4,0 atm)

Life management of nuclear containments | 27

Algorythm of substantiation of remaining life for prestressed containment

Organizational measures

↓

Data base analysis on current state of structural elements
comprehensive survey strategy formation

↓

Analysis of technical documentation (including 'as-built' one	Execution of the prestressing system survey at KPR2 level	Design substantiation analysis

↓

Preparation of working program for comprehensive survey of structural elements

↓

Visual inspection	Strength test	Instrumental survey including material prototype tests

↓

Assessment of technical state of reinforced concrete structural element

↓

Execution of confirmatory (substantiating) analyses

↓

Making up conclusion

↓

Elaboration of proposals for execution of repair works

↓

Decision on estimate of remaining life of structural element

Approach to NPP's Building Structures Long Term Operation in Ukraine

Presented by
Olena Mayboroda (State Scientific and Technical Centre on Nuclear and Radiation Safety) and
Mikhail Semeniouk (NAEK "Energoatom)

Meeting of WG-4 on WWER Structural Components and Structures Long Term Operation
Vienna, 3-5 March 2004

Ukrainian NPPs

	Reactor type	Year of putting into operation
Khmelnitsky -1	WWER - 1000	1985
Khmelnitsky -2	WWER - 1000	in building
Rovno -1	WWER - 440	1981
Rovno -2	WWER - 440	1982
Rovno -3	WWER - 1000	1987
Rovno -4	WWER - 1000	in building
Zaporizhzhya -1	WWER - 1000	1985
Zaporizhzhya -2	WWER - 1000	1985
Zaporizhzhya -3	WWER - 1000	1987
Zaporizhzhya -4	WWER - 1000	1988
Zaporizhzhya -5	WWER - 1000	1988
Zaporizhzhya -6	WWER - 1000	1989
South-Ukraine -1	WWER - 1000	1983
South-Ukraine -2	WWER - 1000	1985
South-Ukraine -3	WWER - 1000	1989

Safety categorisation of building structures

- Buildings structures and structural components subdivide into 3 categories according to impact on radiation and nuclear safety as well as to influence on inside placed equipment and systems functionality. (PiN AE-5.6 “Norms of structural design of NPP with different reactor types”, item 1.5)
- The reactor hall structures rank as 1-st category structures.

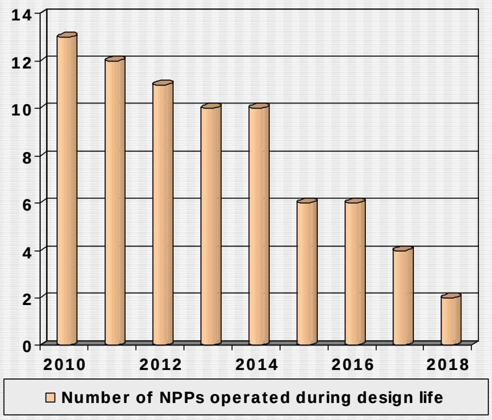
Reactor hall structures

The are 3 types of reactor hall structures at Ukrainian NPPs:

- Reinforced concrete confinement building for WWER–440
- Pre-stressed single containment for WWER-1000/V-302 and WWER-1000/V-338
- Pre-stressed containment placed at containment shell support plate at level 13,2 m for WWER-1000/V-302

Design lifetime

- NPP design lifetime is 30 years, but NPP's building structures design lifetime is equal 40 years (PiN AE-5.6 "Norms of structural design of NPP with different reactor types", item 1.24)
- According PiN AE-5.6 the extreme loads taking into account for 1-st safety category building structures have reiteration 1 time in 10 000 years.



Regulatory guides on NPP's building structures design and safety operation

- Rules of organisation and operation of NPP's localisation safety systems. PNAE G-10-021-90, 1990.
- Norms of structural design of NPP with different reactor types. PiN AE-5.6, 1986
- Norms of aseismic NPPs design. PNAE G-5-006-87, 1987.
- Fire-prevention norms of NPPs design. VSN 01-87, 1987.
- Norms of NPPS localisation safety systems concrete structures design. PNAE G-10-007-89, 1989.
- Norms of NPP reactor hall foundation design, 1989.
- Typical contents of NPPs technical safety justification. PNAE G-1-001-85, 1985.
- Requirements to SAR contents of WWER type Ukrainian NPPs, 1995.

Norms and rules for industrial building structures

- A set of Building norms and rules (SNiP) issued in former USSR
- A set of State building norms (DBN) issued in Ukraine
- A set of documents issued in Ukraine for assessment of industrial structures technical state:
  - Rules of industrial building structures inspection, technical state assessment and certification.
  - Regulations on specialised organizations for inspection and certification performance of existing building structures aimed to their reliability and safety exploitation.
  - Regulations on directing organisation for co-ordination activity, regulations development and on issues of inspection and certification of building structures aimed to their reliability and safety exploitation.

Criteria, requirements and conditions of possibility to continue an NPP unit operation

Criteria:

- NPP unit satisfy the modern safety principles, criteria and requirements of nuclear and radiation safety norms and rules in force;
- technical conditions of SSC ensure acceptable risk level;
- residual life of critical SSC, which can not be replaced or repaired, is sufficient for continuation of operation;
- appropriate approved Strategy of the unit operation continuation;
- positive results of Cost - Benefit analysis and estimation of economical and human factors.

Criteria, requirements and conditions of possibility to continue an NPP unit operation (continue)

Basic requirements and conditions:

- Fulfillment of activities on assessment and prognosis of technical conditions of safety important NPP unit elements should be done in the frame of AMP;
- Licensee performs periodic safety review of NPP unit and develops a safety reassessment report (SRR) in order to receive a permission on NPP unit operation during above design period. SRR is an appendix to a safety analysis report (SAR). SRR should substantiate that set of organizational and technical measures implemented at NPP ensures unit safety during above design period.
- Operated during above design period NPP unit should be equipped by up-to-date means of control and diagnostic of current technical conditions. Programs of technical maintenance should be revised for the purpose of timely identification of aging processes and defects that could cause violations of limits and conditions of NPP unit safety operation

Requirements for periodic safety review aimed to license extension

- Periodic safety review carried out in accordance with IAEA safety guide No.50-SG-O12.
- PSR aimed to safety substantiation of the unit operation continuation during above design period, should include additional information on:
  - list of the critical systems, components and structures
  - reactor pressure vessel special consideration
  - specification of residual life time of SSC and limits and conditions of the unit safety operation.

  Development a regulatory guide with detail requirements to PSR contents and scope is planned.

Approach to NPPs long term operation

- For selection of the SSC that planned to operate in above design period NAEK “Energoatom” developed “Technical requirements to working lists of the unit elements (systems) for technical state assessment” .

This document is require to develop

- list of SSCs that planned to operate in above design period.
- list of SSCs that planned to replacement.

- The lists have to be prepared by NPPs based on
- design documentation
- connection layouts and operation plans
- certificates and other technological documentation
- acting SSCs classifiers depending on their influence on unit safety

Recommendations to listing of the structures and structural components

It is recommended to include in the list SSCs that planned to operate in above design period the mentioned below structures.

- Structures of the 1-st and the 2-nd safety class:

- hermetically filer system;
- Fundamental plate of reactor hall;
- reactor cavity;
- walls and floors of reactor hall;
- supporting structures for main equipment;
- structures of cooling pond and pits of wet reloading ;
- NPP common buildings where safety important systems are placed;
- transportation equipment.

- Structures where placed normal operating systems.

Documents for building structures technical assessment

NAEK "Energoatom" use or develop a set of documents for building structures technical assessment:

- Regulations on safety and reliability industrial buildings and structures of industrial buildings and structures.
- General instruction on technical inspection and supervision for industrial buildings and structures industrial buildings and structures (TI 34-70-049).
- Rules of industrial building structures inspection, technical state assessment and certification.
- Technical operation of electric power stations and networks. Rules.
- Technical requirements to general programs of NPP unit elements technical state assessment and lifetime reassignment.
- Technical requirements to working lists of the unit elements (systems) for technical state assessment.

NPP structures inspection

- During the unit operation the systematic inspection of NPP structures are performed. This activity includes

  - periodic inspections and maintenance during planned preventive repair;
  - special inspections;
  - settlement and slope monitoring.

- Periodic visual inspections are carry out during all unit shutdowns and periodic instrumental control are performed not less then one time per year.
- The periodic inspections aimed to inspect the structures into line with design parameters, to observe the attachment points state, to determine defects such cracks and corrosion damages.
- The information on all defects and damages are registered in technical certification documents.

NPP structures inspection (continue)

- Special inspections carry out in the case when the data from periodic inspections is not enough for decision making on the structures current state.
- Special inspections performs on the basis of program that have to be developed according NPP senior engineer direction.
- The data from special inspections are included in technical certification documents.

- During the operation settlement and slope monitoring of reactor hall structures is carried out.
- After the commissioning settlement and slope monitoring frequency is following:
  - during 1-st year one time in month;
  - during 2-nd year one time in 2 month;
  - after 2-nd year one time in 3 month.

Methods of the concrete structures instrumental inspection

The concrete structures instrumental inspection include the following operations:

- to measure the concrete strength of available structures zones by non-destructive methods (method of plastic deformations (Kalashnikov hummer, springs clerometers Poldi or Shmit), ultrasonic method, method of elastic rebound) and/or by destructive methods (tear method, method of the structure edge break off).
- to sampling of concrete from walls for laboratory morphologic analysis of concrete structure. The samples is cut off from more stressed structure zones, which are determined by account schemes of operation loads.

The stages of the structures technical state assessment

- analysis of design and operating documentation;
- visual inspection of the structures state and selection the structures for instrumental inspection;
- instrumental inspection by use the standardised and certified measurement instrumentation;
- analysis of the results of visual and instrumentation inspections;
- verifying accounts;
- conclusion on the structure technical state.

Ageing management programs

The directorate of NAEK “Energoatom” start to develop the main technical and management document that need for the units LTO “General ageing management program of the unit SSC”.

Structural components and structures WG 4 Swedish PWR

Topics

- Research and development programs
- FSAR and technical specifications
- Inspections and tests
- Experiences from events in the nuclear industry
- National data

Ringhals

Structural components and structures WG 4 Swedish PWR

Research and development programs

- Investigation of containments – design, damages, inspections and tests (Swedish nuclear Inspectorate SKI 02:58) Summary in English
- CONMOD-project
  - » Combination of structural analysis and none destructive testing. EU-project cooperation between Scanscot Technology, Barsebäcks Kraft AB, Force, EDF.
- Material project
  - » Testing of material properties for concrete in a containment (Barsebäck 1). The project is a cooperation between Scancot Technology, force University of Lund division of structural Engineering, The Swedish nuclear power industry and Swedish nuclear Inspectorate

Ringhals

Structural components and structures WG 4 Swedish PWR

Research and development programs cont.

- ISP 48 International Standard Problem on containment capacity.
  - » Objectives are to extend the understanding of capacities of actual containment structures based on results of the recent PCCV Model Test and other previous research.
- Long time properties of containments with prestressed concrete. Research program at the University of Lund division of structural engineering.
  - » The research has so far been concentrated on the distribution of forces along curved tendons

Ringhals

Structural components and structures WG 4 Swedish PWR

FSAR and technical specifications

- Pressure and tightness test.
  - » The test program follows the rules in 10CFR50 App J. So far the test has been done 3 times every ten year. Ringhals are trying to get permission from the authorities to use option B in the future instead of Option A. Some data are shown fore Swedish NPP next picture.
- Inspections of tendons.
  - » Inspections of tendons is done every ten year now a days. Rules of the number of tedons that are tested follows Reg. Guide 1.35.

Ringhals

Structural components and structures WG 4 Swedish PWR

Containment	Design pressure	Tightness test	Leaktightness maintained
Oskarsh. 1	4,5	2,75	6,5 - 7
Ringhals 1	5,2	3,0	7,5
Barsebäck 2	5	3,0	7
Oskarsh. 2	5	3,0	7
Forsmark 1,2	5,5	3,6	8
Oskarsh. 3	6	3,5	8,5
Forsmark 3	6	3,4	9
Ringhals 2	5,14	3,02	8
Ringhals 3	5,22	2,83	7
Ringhals 4	5,22	2,83	7

Ringhals

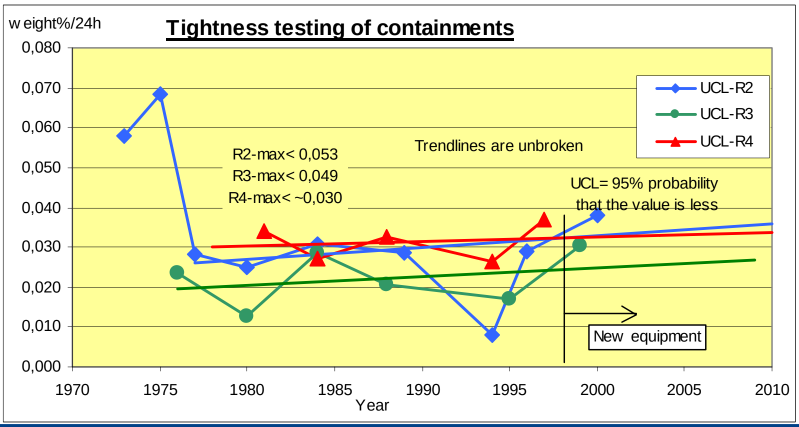
Structural components and structures WG 4 Swedish PWR

Inspections and tests

- Pressure and tightness tests
  - » Before operation a pressure test were done at design pressure. There after tightness tests has been per formed at half design pressure. The last tightness test was done at design pressure in order to fulfil the requirements in option B 10CFR50 App. J for test interval 10 years instead. Special tests are done for penetrations. Results from the tightness tests unit 2 – 4 are shown in picture 6.
- Visual inspections of concrete structures
  - » Visual inspections of all buildings takes part every four year.

Ringhals

Structural components and structures WG 4 Swedish PWR



Ringhals

Structural components and structures WG 4 Swedish PWR

Inspections and tests cont.

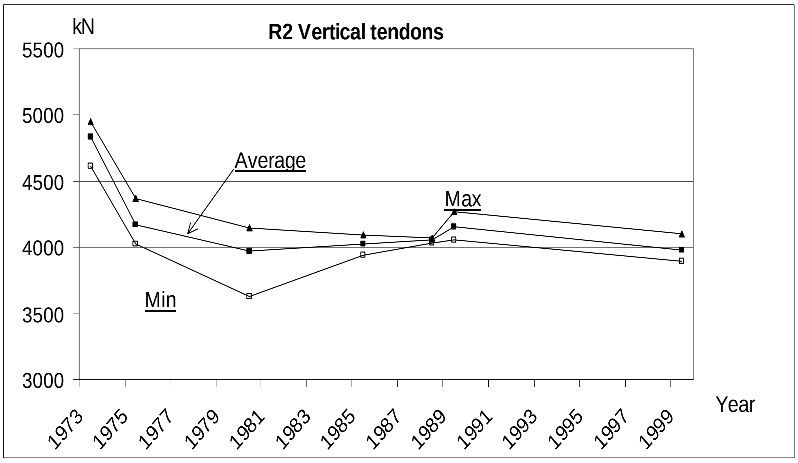
– Inspections of tendons

» Inspections of tendons have been done almost according to the rules in Reg.Guide 1.35. The first three or four inspections were done every fifth year and now the interval is 10 years. The number of randomly chosen tendons were 22 (4%) for the first three or four inspections. Now we test only half the number. Examples of results see picture 8 – 12.

» In the program there is stated that a visual inspection of the concrete surfaces near tendons anchorage areas.

Ringhals

Structural components and structures WG 4
Swedish PWR



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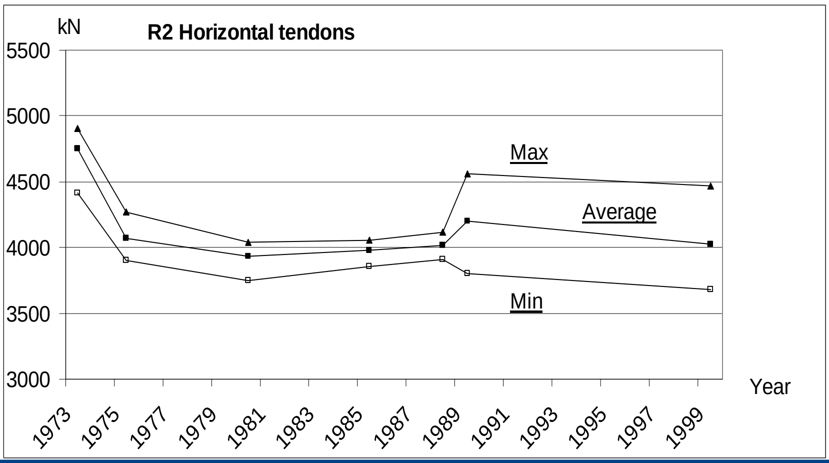
Structural components and structures WG 4
Swedish PWR



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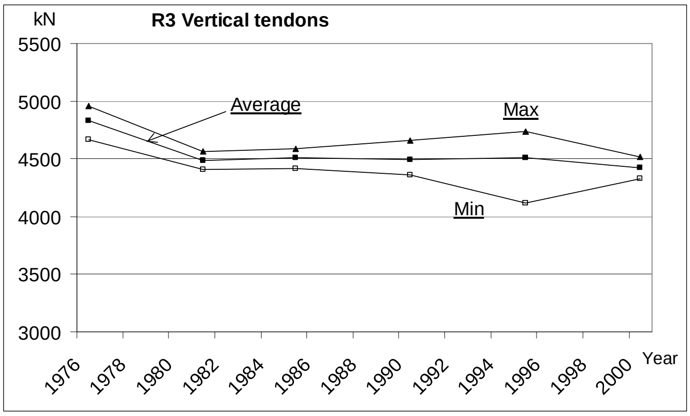
Structural components and structures WG 4 Swedish PWR



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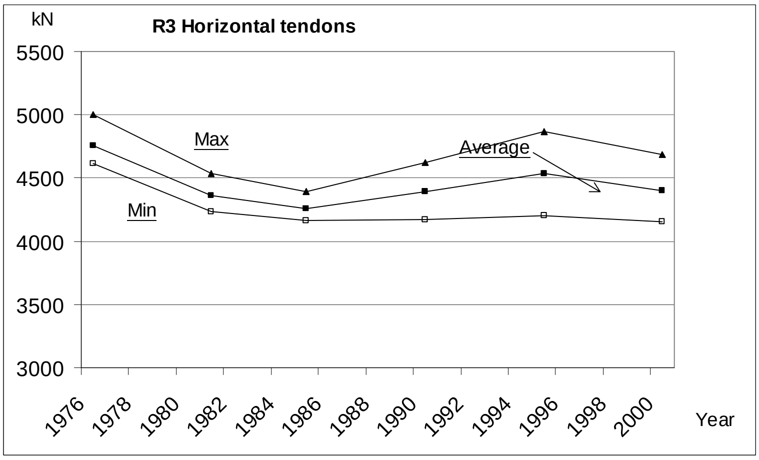
Structural components and structures WG 4 Swedish PWR



Ringhals

Structural components and structures WG 4
Swedish PWR

Experiences from events in the nuclear industry

- Corrosion of the liner
  - » One case of corrosion of the liner has happened in Sweden. In Barsebäck 2 (BWR) 1993 they had leakage at the containment air test. There had been voids during grouting of holes for the penetrations. The voids contained water and air and the corrosion started almost immediately.
- Corrosion of toroid
  - » At Forsmark 1 (BWR) 1997 the toroid had corroded so there was hole through two plates. In this case there was voids behind the plates that contained insulation partly filled with water since the construction.

Ringhals

Structural components and structures WG 4
Swedish PWR

Experiences from events in the nuclear industry cont.

- Steamgenerator replacement R2 and R3
  - » Control program was established to control some properties of the concrete and status of the liner. Results from that control is that the carbonation depth is very low as chloride penetration. The compressive strength of the concrete is 50 – 70 % higher than the nominal. There were no signs of ongoing corrosion on the steel liner.
- Leakage from suppression pool in B2 and R1.
  - » This is damages that isn't applicable on PWR.

Ringhals

Structural components and structures WG 4
Swedish PWR

National Data

- The report from SKI 02:58 is available via SKI homepage
- Procedures and results from tightness tests, tendon inspections, other inspections and test that is carried out in Ringhals is available via Jan Gustavsson.
- Results from research and development will mostly be available.

Ringhals

International Atomic Energy Agency

Long-Term Operation Of Nuclear Power Plants

Working Group 4 – Structures

Vienna

4 March, 2004

1

AGING MANAGEMENT OF STRUCTURES AND STRUCTURAL COMPONENTS

UNITED STATES EXPERIENCE

William Burton

4 March, 2004

License Renewal Experience In The United States

- NRC Mission
- Background
- Regulations And Guidance
- Key License Renewal Principals

3

License Renewal Experience In The United States (Con't)

- License Renewal Review Process
- Structural Issues
- Information Sources

4

NRC MISSION

- Ensure Public Health and Safety
- Protect the Environment
- Provide for the Common Defense and Security

5

Background

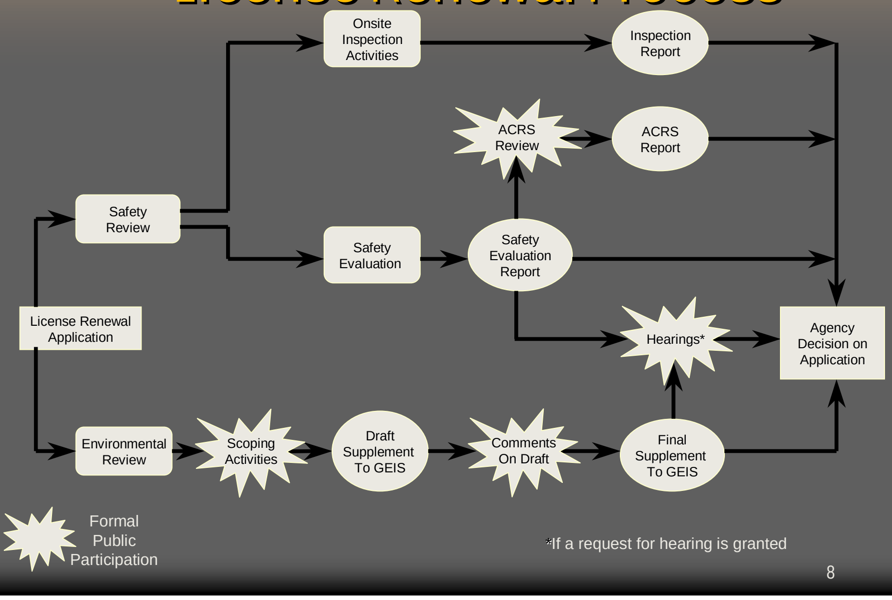
- Atomic Energy Act Of 1954
  - Allows for Additional 20 Years
  - Allows Plant Operation for 40 Years
- Nuclear Plant Aging Research
- 23 Units Have Been Relicensed At 12 Sites
- 19 Units at 11 Sites Currently Under Review
- License Renewal Process

6

Nuclear Plant Aging Research (NPAR) Reports

- 117 Reports Developed by NRC and Nuclear Industry
- Mechanical, Electrical, and Structural Systems and Components Were Evaluated
- Used to Develop License Renewal Program

License Renewal Process



*If a request for hearing is granted

Regulations And Guidance

- Title 10 Of The *Code Of Federal Regulations*, Part 54 (10 CFR Part 54)
- Standard Review Plan (SRP), NUREG-1800
- Generic Aging Lessons Learned (GALL) Report, NUREG-1801

Regulations And Guidance

- Regulatory Guide (RG) 1.188
- Nuclear Energy Institute (NEI) 95-10

Key License Renewal Principals

- Current Regulatory Process Is Adequate To Ensure Safety (With Possible Exception Of Aging)
- Current Plant-Specific Licensing Basis Maintained
- Continuous Safety Reviews

11

Detailed License Renewal Review Process

- Scoping And Screening
- Aging Management Review
- Aging Management Programs
- Time-Limited Aging Analyses

12

Scoping

- Scoping – Identify Structures, Systems, and Components That Are Within The Scope Of The License Renewal Rule
  - Safety Related
  - Non Safety-Related that Could Affect Safety
  - Certain Regulated Events
  - Methodology Review and Audit, Inspection

13

Screening

- Identify Structures and Components That Require Aging Management Review
  - Passive
  - Long-Lived
  - Methodology Review and Audit
  - Inspection

14

Aging Management Review

- Identify Materials and Environments
- Identify Aging Effects
- Identify Aging Management Programs
- Audits and Inspections

15

Aging Management Programs (AMPs)

- All AMPs Have 10 Attributes
  - Program Scope
  - Preventive Actions
  - Parameters Monitored or Inspected
  - Detection of Aging Effects

16

Program Attributes

- Monitoring and Trending
- Acceptance Criteria
- Corrective Actions

Program Attributes (Con't)

- Confirmation Process
- Administrative Controls
- Operating Experience

Time-Limited Aging Analyses

- Analyses That Assumed a 40-Year Life
- Three Options
  - Confirm that Current Analysis is Valid for Extended Operating Period
  - Re-Evaluate to Demonstrate that Analysis is Acceptable for Extended Operating Period
  - Manage Aging Effects

19

Structural Issues

- Aging Management of Inaccessible Areas
  - Foundations
  - Below-Grade Exterior Walls
  - Concrete Cover By Liner
  - Assess Condition Based on Accessible Areas
  - Inspect When Opportunity is Available
- Erosion of Porous Concrete Subfoundations
  - Use of De-Watering Systems

20

Structural Issues

- Containment Tendons – Loss of Prestress
  - Time-Limited Aging Analysis
  - Concrete Shrinkage
  - Creep
  - Relaxation of Prestressing Steel

21

Information Sources

- NRC Website (WWW.NRC.GOV)
  - 10 CFR Part 54
  - NUREG-1800
  - NUREG-1801
  - RG 1.188
  - NEI 95-10

22

Information Sources (Con't)

- NPAR Reports
  - Through NRC website (Slow)

23

Summary

- NRC Mission
- Regulations And Guidance
- Key License Renewal Principals
- License Renewal Review Process
- Structural Issues
- Information Sources

24

National experience and approach to the long term operation of PWRs

MS: Slovak Republic

Ing. Milan Prandorfy, VÚEZ a.s. Levice, prandorfy@vuez.sk

Nuclear power plants in the Slovak Republic

- In the Slovak Republic nuclear power plants with reactors (Water-Water Energy Reactors) VVER 440 V230 and V213 have been built:
  - V230 reactors in Jaslovske Bohunice (2 units)
  - V213 reactors in Jaslovské Bohunice (2 units) and Mochovce (2 units in operation and 2 units under construction)
- All the VVER type NPPs have been designed in accordance with Soviet (Russian) standards valid at the time of plant design and components manufacture.
  „Regulations for Design and Safe Operation of NPP Components, Testing and Research Reactors and NPPs (1973)".

Applicable laws and Regulatory Requirements

- SLOVAK REGULATORY BODIES:
  - National Labour Inspectorate of SR – NIP (former SUBP)
  - Nuclear Regulatory Authority of SR (former CSKAE)
- **Legislation**
  - Act No. 130/98 of NRA SR on Peaceful Use of Nuclear Power
  - Decree 317/2002 of NRA SR
  - Decree No. 74/96 of SUBP on Ensuring Safety at Work with Pressure, Gas, Electric and Lifting Equipment
  - Decree No. 66/89 of SUBP on Ensuring Safety of Technical Equipment at NPP
  - Decree No. 436/90 of CSKAE on Quality Assurance of Classified Equipment for NPP Nuclear Safety Reasons:
    - Defines Quality Assurance Programmes
    - Defines criteria for classification of NPP equipment and systems into 3 safety classes
    - Defines requirements for elaboration of list of classified equipment and systems
    - Defines requirements for Quality Assurance
  - Slovak Technical Standards - STN

3

National approach to the long term operation of PWRs in the Slovak Republic

- Nowadays several Ageing Management Programmes aimed at ageing of structures and structural components (SSCs) are under preparation in the Slovak Republic
- It is expected that collection of SSCs specific information by all participants will contribute to increased quality and unification of national programmes.
- Materials for the Slovak NRA are prepared expected to be used to elaborate national regulations for management of ageing and evaluation of safe long term operation (LTO).
- In the process of AMP preparation and implementation NPPs Operators also research organisations (VUEZ, a.s, Levice; VUJE, a.s., Trnava) and universities have been involved.

4

The experience in the Slovak Republic on the WG-4 scope of activities

- <u>**Scope of SSCs that are subject to the LTO Review**</u>

Development of Ageing Management Programmes and monitoring of residual lifetimes depends on classification of individual building structures and selected rooms into one out of three classes.

To classify a civil structure or its part, criteria in accordance with relation to **nuclear safety, operating safety and extension of NPP lifetime** have been taken into account.

Classes 1 and 2 include civil structures and their parts (SSCs) ranked within the "List of Classified Equipment" in safety classes 2 and 3 (BK 2,3) defined by the Slovak NRA (UJD SR) upon which extraordinary requirements are imposed in accordance with **Decree 317/2002**

5

The experience in the Slovak Republic on the WG-4 scope of activities

- <u>**Collection of information on SSCs**</u>

For the most important civil structures (classes 1 and 2) summarising information sheets are being prepared in Slovakia. The summarising information sheets for each SSC should contain the following data:

-designation of the civil structure
-characteristics of the civil structure (purpose, architectural solution)
-design (technical description of the structure and materials used)
-identified potential ageing mechanisms and their relevance
-selection of hot spots stressed the most with degradation mechanisms – in a tabular form
-ways of degradation (encountered degradation mechanisms) and risks issuing from deffects
-description of implemented tests and inspections of the civil structure,
-results of tests and inspections (monitoring) of the SSCs and material properties,
-data on performed, planned or extraordinary repairs and maintenance (from standpoint of LTO)
-data on planned repairs, reconstruction and modifications,
-acceptance criteria for evaluation of individual ageing mechanisms
-summary of legislative regulations and safety analyses
-and other

6

An example of activities performed on CCB within the scope of ageing management of SSCs

- Defect remediation - leaks on hermetic boundary

In 1996, the programme of hermetic boundary leak-tightness enhancement was brought to the fore as well as activities related to leak elimination. Due to ageing of hermetic boundary materials, hermetic boundary leak-tightness has been reduced step by step. Management of hermetic boundary and its components ageing is a priority in order to maintain required leak-tightness.

Detection of defects on the hermetic boundary necessitates the application of very costly methods able to localise and repair leaks because, in most cases, the defects are hidden leaks of the hermetic liner.

In the case of hidden leaks, a qualitatively higher level of leak detection and repair is required compared to common methods which need to be complemented.

7

An example of activities performed on CCB within the scope of ageing management of SSCs

- Process of assessment and elimination of ageing effects

To monitor the status of reinforced-concrete structures, various instruments and destructive and non-destructive test methods are used.

VUEZ disposes of devices enabling the following measurements:

✓ Localization of steel in concrete (diameter, depth) – PROFOMETER 4
✓ Identify of corrosion intensity – DIGITAL HALF CELL
✓ Measure of concrete strenght – SCHMIDT, VOLMO (Digital tester)
✓ Detection with pull-out test – DYNA Z16E
✓ Measure of concrete volume with ultrasound (homogenity, cracks, cavity, changes fire, frost, chemical effect) with ultrasound – PUNDIT6
✓ Measure permeability of concrete (gas) - TORRENT
✓ Measurement tenseness of concrete - ELE

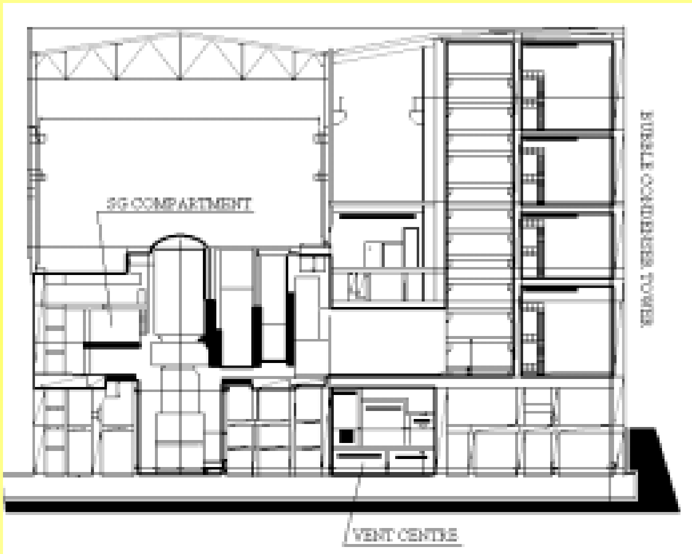
8

Construction of the containments of VVER 440 NPP

- In the Slovak Republic nuclear power plants with reactors VVER 440 V230 and V213 have been built.
- The containment structure consist of a system of mutually interconnected reinforced-concrete hermetic compartments.
- The containment of VVER 440 NPP is created by reinforced-concrete walls consisting of cast reinforced-concrete blocks forming a monolith.
- The hermetic boundary is provided by a steel liner and metallic components such as hermetic doors, hatches and other sealing items

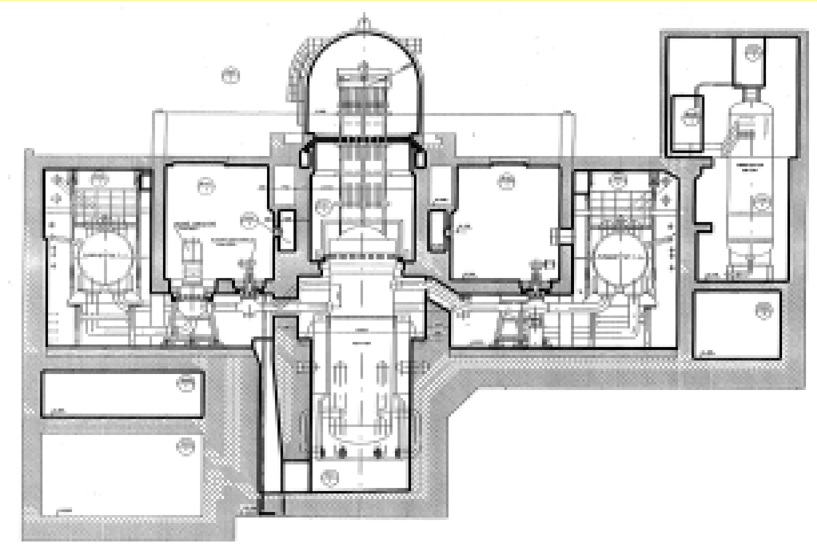
9

Sectional view of VVER/V213 NPP



10

Sectional view of VVER/V230 NPP



Difference between containments

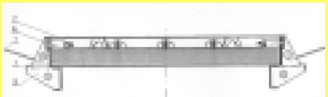
- The difference between the containment of VVER 440 NPPs and the containment in NPP's all over the word consist of all its shape and layout, that is why the leak-tightness of the VVER 440 containments is lower compared to the western-type containments
- Concrete of containment is a durable material and its performance when fulfilling containment function in a NPP is good but, there is necessity to control potential age-related degradation of concrete containments

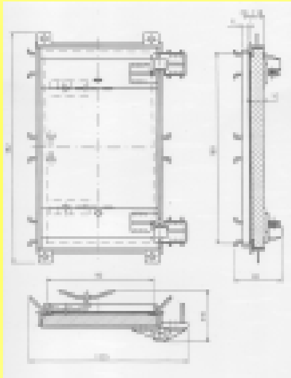
12

Leak-Tightness enhancement

Is based on:

- Analisys of the technical documentation of the hermetic boundary components





- Structural sealing elements
- Programs
- Methods and a schedule for sealing works prepared, individually for each unit

13

Local leak identification methods

Following methods of local leak tests are used:

- Visual inspection
- Leak test with compressed nitrogen
- Leak test with vacuum chambers
- Leak test with ultrasonic detector
- Leak test with adhesive dye

To identify leaks new method has been developed in pressurisation of the volume between the hermetic liner and the concrete with the tracer gas (NO_x). Potential tracer gas detection on the other side of the liner means presence of leaks.

14

Integral leakage test for leak detection

These tests are divided to:

- Overpressure Integral leak test (ILT) for the purpose of leak identification on external hermetic liner of hermetic compartments
- Underpressure ILT for the the purpose of leak identification to identify leaks on the internal hermetic liner.
- This pressure drop is then used for leak identification (localization) on the hermetic liner applying common methods of leak detection
- During ILT a new detection method of the leaks is applied when air pressures under both the hermetic and nonhermetic liner are monitored and hidden leaks covered the concrete are detected using trace gas

New methods for leak detection

New methods for leak detection have been adopted enabling to locate areas with major leaks:

- Monitoring of air in-leakage by division of the containment compartments
- Monitoring of the pressures under the hermetic liner (between liner and concrete)

This method has been applied by VÚEZ within the scope of ILT during underpressure and overpressure testing phases

Leak repair methods

To repair the leaks the following methods for leak repairs are applied:

- Repairs of hermetic liner leaks by welding or by application of sealing compounds
- Repairs of hidden leaks after the removal of cover concrete or inclined concrete
- Repairs of hidden leaks by injection of epoxide resins and expanding polyurethane materials

17

Leak repair methods

Injections of epoxide resins

Double component epoxide resin injection into the cracks and gradual filling of the gaps

Injections of polyurethane materials

Repairs by means of injection materials able to assure the leak-tightness of the reinforced-concrete walls

18

High-pressure injection (on the basis of a double-component polyurethane material Bevedan-Bevedol WF):
DV 97, S 35 PU 01, SUPER FINISH 1500, IBO-REP CG2, GLASGRAFT

Low-pressure injection (on the basis of a double-component epoxide resin Sikadur 52):
MBT, model 20-3N, CHIP 2000, model 4.30

19

Leak repair methods

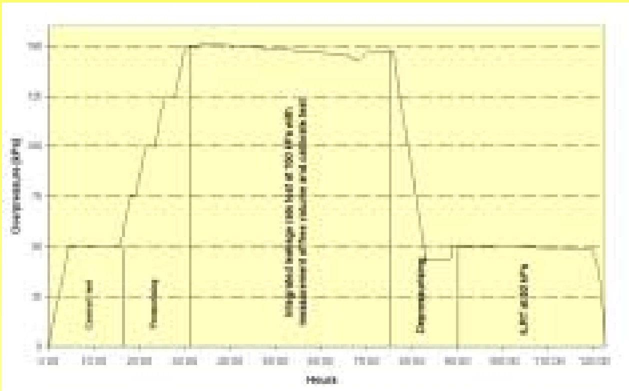
Repair of hidden leaks after removal of cover concrete

Removal of the cover concrete

20

Containment integral leakage rate test

- For ILRT we use Code of Federal Regulation and standard ANSI/ANS 56.8
- In the Mochovce NPP Unit 1,2, for the first time in VVER 440/V213 NPP CILRT was performed at a maximum overpressure (150kPa) and reduced overpressure (50 kPa)
- Periodical ILRT are performed at a reduced overpressure of 50 kPa



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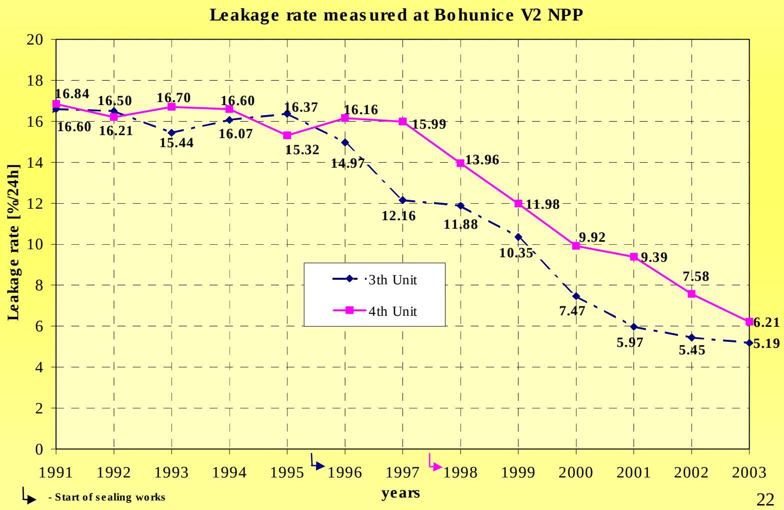
Results of Leak-Tightness enhancement

J. Bohunice V-2 NPP



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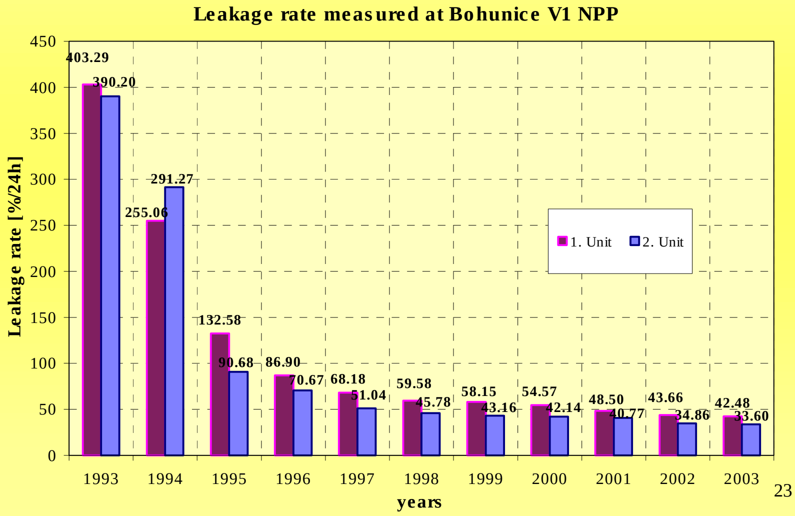
Results of Leak-Tightness enhancement

J. Bohunice V-1 NPP



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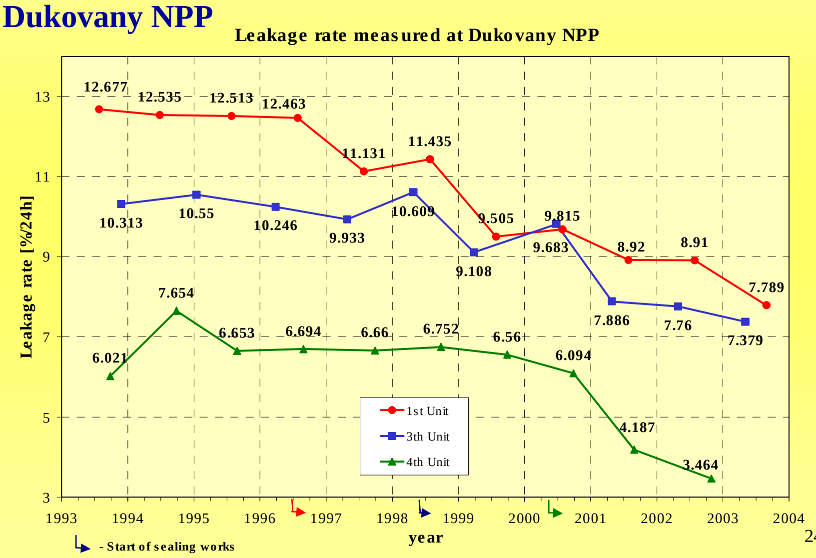
Results of Leak-Tightness enhancement

Dukovany NPP



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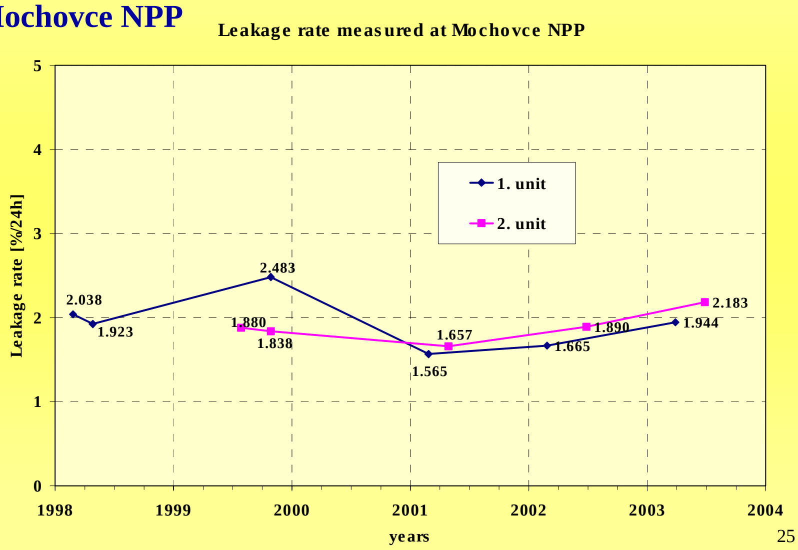
Results of Leak-Tightness enhancement

Mochovce NPP



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Conclusion

The achievement in the field of VVER 440 containment leak-tightness in the Mochovce NPP and step-wise enhancement of leak-tightness in the Bohunice and Dukovany NPPs enable to rank the VVER 440 NPPs among those reaching the world standard from the standpoint of its nuclear safety.

Thank you for your attention

26

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EC Contribution to Nuclear Safety & Nuclear Power

by
Mr. Claude RIEG (EC/JRC-IE)

IAEA Extrabudgetary Programme on Safety Aspects of Long Term Operation of Pressurised Water Reactors

Structural Components and Structures WG4

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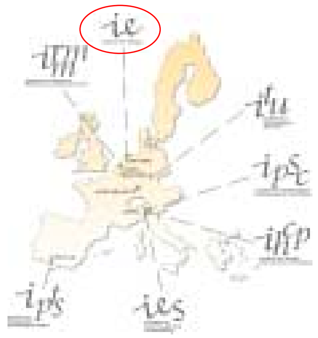
Summary

- *About the EC/JRC-IE*
- *Activities in the "sector"*

EUROPEAN COMMISSION
Joint Research Centre

About EC/JRC-IE

- *IE is one of the 7 Institutes of the JRC, located in Petten (NL)*



Nuclear Energy
HFR
Nuclear safety in the enlarged EU
New nuclear energy systems
Support to TACIS & PHARE

Non-Nuclear Energy
Energy from waste and biomass
Waste incineration
Alternative fuel storage and distribution
Fuel cell performance

Sustainable Energy Technologies Reference and Information System (SETRIS)

- The Institute for Energy provides scientific and technical support for the conception, development, implementation and monitoring of community policies related to ENERGY
- Special emphasis is given on the security of energy supply and sustainable and safe energy production

06-05-2004

EUROPEAN COMMISSION
Joint Research Centre

About EC/JRC-IE (Cont[d])

HFR and Reactor Applications
- Fuel & Material irradiation
- New systems
- Materials ageing
- Medical applications
- Neutron methods

Technical & Scientific Support for TACIS & PHARE (TSSTP)
- Design safety
- On-site assistance
- Regulatory authorities and TSOs
- Industrial radioactive waste manag[nt] and decommissioning
- Dissemination of projects results

✓ Assistance to PM cycle (AIDCO / ELARG)
✓ Performance of Projects (DIS./RPV)

Nuclear Safety
- Structural integrity
- Inspection management
- Accident analysis
- PSA / risk assessment
- Computational fluid dynamics
- Advanced reactor concepts
- Data management & dissemination

SAFELIFE
An Integrated JRC-IE Approach to Plant Life Management

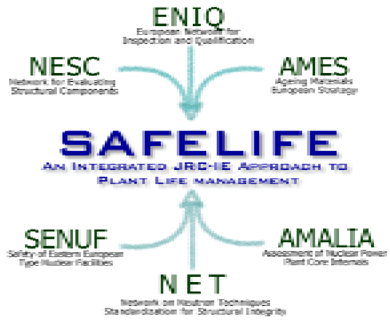
Perfect
IP & NoE

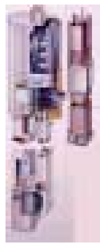
06-05-2004

Joint Research Centre

Activities in the sector

- *SAFELIFE focuses on PLIM & includes:*
  - ***Networks**, used to bring together the key players in technical fields, to establish consensus R&D issues and promote best practices*
  - ***Contributions to related Share-Cost R&D Actions (Integrated Projects and/or Networks of Excellence)***
  - ***Promoting actions to ensure for best integration of Acceding Countries (Training & Collaboration)***
  - ***Maintain and Develop the JRC research capabilities & R&D tools (HFR-LYRA, Neutron diffraction & radiography, TEM, SANS)***





But no ongoing research activity upon STRUCTURES

Joint Research Centre

Activities in the sector (Cont^{d})

EURATOM TREN – RTD FWP 5 & 6

- *Share-Cost Actions*

✓ **MAECENAS: Modelling ageing in Nuclear Power Plant Structures (U-Sheffield, U-Glasgow, EC-Nantes, TU-Prague, ICMS-Udine [+ U-Padova], HSE, BE & U-Roma)**

✓ **CONMOD: Concrete containment management using finite element technique combined with in-situ non-destructive testing with respect to design and construction quality (Scanscot Technology[S], Force Technology [D], EDF [F] & Barsebaeck AB [S])**

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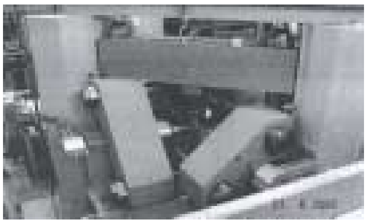
MAECENAS: Modelling ageing in Nuclear Power Plant Structures

Development of advanced transient hygro-thermo-mechanical ageing deformation analyses for pre-stressed CNR & Containment



- ✓ Fully-coupled 3D finite element framework
- ✓ Domain decomposition methods providing the possibility to tackle large problems by separate advanced computer clusters (influence of temperature and pressure-driven moister transport on the physical and mechanical properties
- ✓ Pioneer experimental work is going on: drying creep under multiaxial compression & static fracture energy measurement on 3-point bending notched beams
- ✓ Reliability-based tool is planned for assessing real structures (2 reference cases: unlined cylindrical containment structure & AGR CNR)

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06-05-2004

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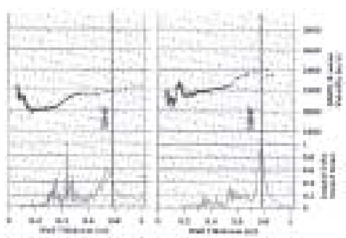
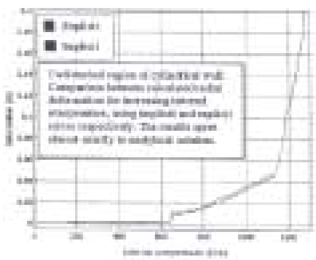
CONMOD: Concrete containment management



- ✓ Inventory, survey & initial analysis (definition of the as-built structure
- ✓ Collection of the tests results (NDE, material properties, leak-tightness and integrity)
- ✓ Detailed evaluations & analysis
- ✓ Maintenance plan optimisation
- ✓ Follow-up (periodic inspections)
- ✓ Actions (corrective mitigation?)

Develop appropriate Diagnostic methods for the evaluation of ageing phenomena and degradation mechanisms in concrete containment

- ✓ Methodology plan
- ✓ Inventory of promising ND Techniques (Radiography, radar scanning, hammer impact)
- ✓ Preparation of ad'hoc FE models (global / local) : benchmarking and experimental validation on MAEVA



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Activities in the sector (Cont[d])

RELEX
AIDCO – ELARG
(1991 -)

- *TACIS / PHARE Nuclear Safety Programmes*

✓ R1.10/91: VVER 440/230 - Confinement leak tightness & performances

✓ R2.08/92: VVER 1000 – Recommendations on specifying minimum pre-stressing level

✓ R2.06/93: VVER 440/213 & 1000 – Confinement penetrations for cables

✓ R2.08/95: VVER 1000 – Fission Products Retention System

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R1.10/91: VVER 440/230 - Confinement leak tightness & performances (EA-Belgatom-NNC)

✓ Pre-phase:

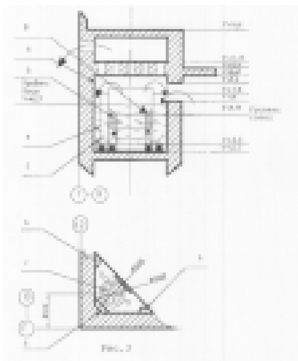
- **Applicable criteria, means & methods for improving the leak tightness and performance on the basis of a comparison of the RA requirements**

✓Conceptual phase:

- **Review of the procedures in used for global tests and existing proposals for improving the leak tightness and performance**
- **Collection & analysis of recent test results**

✓ Conceptual phase:

- **Assistance for the development and generating acceptance by GAN of the selected (Jet Vortex Condenser) system (VNIIAES)**
- **Recommendations to consider other safety issues: confirmation of leak tightness, H_2 treatment, ventilation system, spray system, post-DBA instrumentation, qualification of Equipment for new DBAs, improvement of the sump reliability.**



Implemented at Kozloduy 3 & 4, NVZ 3 & 4 and Kola 1

Planned at Kola 2

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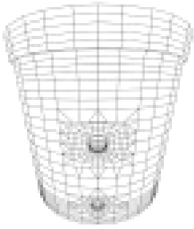
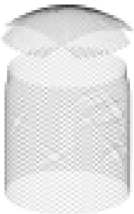
R2.08/92: VVER 1000 – Recommendations on specifying minimum pre-stressing level (COB)



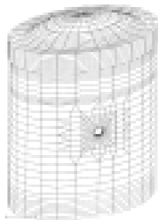


Standard series
Balakovo NPP

- ✓ Simple wall (Φ_{cyl} # 45 m / Ep_{cyl} # 1.20 m / Ep_{dome} # 1.10 m) made from B 30 concrete
- ✓ 2 pre-stressing systems (cylinder / dome) with high strength steel grade B II tendons (Φ # 5 m m)
- ✓ Inner carbon steel liner (ep. # 8 mm / class 3)

- ✓ Validation of the minimum pre-stressing level:
  - Loads: (DBA [temp. + Pressure (0,39Mpa for Std & 0,355 for Small Series)] + seismic effect (DIAPROM)
  - Double criteria:
    - ➢ Minimum pre-stressing forces must compensate the force coming from the internal accidental pressure with 15% margins
    - ➢ Stress-strain status must be within the TS limits in any section

- ✓ Pre-stressing forces (7,7/7,6 MN – 7,2/6,9 MN) determined with respect to the 1st criteria are sufficient to guaranty the 2nd criteria in all sections
- ✓ Necessity to take into account the rheological pre-stressing losses
- ✓ Implementation of monitoring gauges under the anchors



Small series
South Ukraine NPP

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R2.06/93: VVER 440/213 & 1000 – Confinement penetrations for cables (AUXITROL)

Know-how transfer from AUXITROL to ELOX for manufacturing and testing all types of electric cable penetrations including the feedthroughs

- ✓ Replacement of the cable penetrations of operating VVER 440/213 & VVER 1000 by new Russian products
- ✓ Concept also appropriate for the construction of new plants

- ✓ License agreement between ELOX & AUXITROL
- ✓ Supply of manufacturing equipment
- ✓ Know-how transfer & personal training
- ✓ Feedhtroughs manufacturing & testing of a set of prototypes by ELOX (KOMSOMOLSKY) under supervision of AUXITROL
- ✓ GAN certification for VVER 440/213 & 1000

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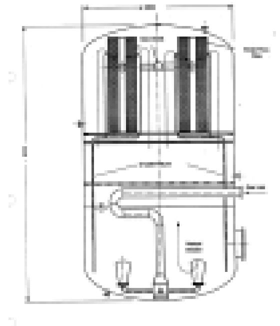
R2.08/95: VVER 1000 – Fission Products Retention System (Siemens KWU)

Design of a Fission Product Retention System to be able to cope with a steam gas mixture (steam-air-H_2-CO) in accidental conditions with high efficiency rates (aerosols{99,9%}, elemental iodine{99%}, organic iodine{90%})



- ✓ **Venturi Scubber with integrated metal fibre filters installed within the Reactor Building, connected to the ventilation system penetration (isolation valve) and the stack**
- ✓ **Alkaline scrubber solution providing high fission product retention due to prior dispersion + metal fibre filters ensuring for high retention of aerosols**
- ✓ **Validation scenarios leading to the activation of the FPRS haven been established using MELCOR**
- ✓ **The retention process has been verified within the ACE programme by EPRI, Westinghouse & PNL**
- ✓ **Validation of the efficiency of the system has been part of a dedicated international programme (BMU) with the active participation of TUV, KfK & GRS (JAVA facility)**