Activities of OECD/NEA in the Field of Integrity and Ageing of Components and Structures

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ABSTRACT

The Integrity and Ageing of Components and Structures Working Group (IAGE) of the Organisation for Economic Cooperation and Development (OECD)/ Nuclear Energy Agency (NEA) was established, under the Committee on the Safety of Nuclear Installations (CSNI), to advance the current understanding of those aspects relevant to ensuring the integrity of structures, systems and components, to provide for guidance in choosing the optimal ways of dealing with challenges to the integrity of operating as well as new nuclear power plants, and to make use of an integrated approach to design, safety and plant life management.

The working group operates through three subgroups dealing with a) integrity and ageing of metal structures and components, b) integrity and ageing of concrete structures and c) seismic behaviour of components and structures.

The group operates through annual plenary meetings and technical workshops and by issuing state-of-the-art reports and topical opinion papers. Among other items, the recent and planned activities of the group include the following:

– updating of the IAGE integrated plan
– conducting a meeting of specialists on seismic hazard assessment in April, 2008 in Lyon, France, with planned publication of the proceedings
– conducting a specialist meeting on risk informed piping integrity management in June, 2008, Madrid, Spain, with the planned publication of the proceedings
– publishing reports on: a) summarising the main findings and conclusions of a series of OECD/NEA workshops and extracting the seismic information most relevant to current nuclear practices; b) a decade of CSNI Activities in the Area of Ageing of Nuclear Power Plant Concrete Structures;
– discussing the worldwide implications on nuclear facilities of the July 16, 2007 Niigata-ken Chuestu-oki earthquake and its effects at the Kashiwazaki-Kariwa Nuclear power Station,
– supporting a benchmark, SMART 2008, being conducted in Saclay, France, on seismic design and assessment analysis for multi-story reinforced concrete buildings subjected to torsion and nonlinear effects
– supporting the IAEA extra-budgetary programme on seismic safety of existing NPP’s.
– conducting a specialist meeting on ageing management of thick walled concrete structures in October 2008, Prague, Czech Republic, with the planned publication of the proceedings
– improving robustness assessment methodologies for structures impacted by missiles
– thorough exchange of information on PTS Rules /Fitness for service criteria on different member countries for LTO of RPV; fatigue; plant ageing; LB LOCA redefinition / LBB break exclusion for operating and new plants
– joint IAEA/NEA catalogue on nuclear facilities that have experience an earthquake
This paper will detail some of the recent activities and products of the IAGE group with special emphasis on the metal and concrete activities, since another SMIRT 20 paper will detail the activities of the seismic group.

1 INTRODUCTION

The Nuclear Energy Agency (NEA) is one of bodies that make up the Organisation for Economic Co-operation and Development (OECD), located in Paris, France. The members of the OECD/NEA are a group of 28 like minded, developed countries which at the start of 2009 operated 346 reactor units in 17 OECD countries, with 11 more under construction. NEA Member countries account for approximately 85% of the world's installed nuclear capacity. In the OECD area, nuclear energy represents nearly a quarter of the electricity supply.

The mission of the NEA is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and its sustainable development.

The NEA programme of work covers a very full range of topics, with nuclear safety and regulation as the top priority in the current Agency’s Strategic Plan. Two committees are responsible of the nuclear safety and regulation programme of work of the NEA. These are the Committee on the Safety of Nuclear Installations (CSNI) and the Committee on Nuclear Regulatory Activities (CNRA).

The technical fields of nuclear reactor safety interest into which the CSNI has designated specific Working Groups are: risk assessment, analysis and management of accidents, integrity and aging of components and structures, fuel cycle safety, human and organisational factor, and fuel safety.

The CSNI/IAGE has as a general mandate to advance the current understanding of those aspects of nuclear safety relevant to ensuring the integrity of structures, systems, and components, to provide for guidance in choosing the optimal ways of dealing with challenges to the integrity of operating as well as new nuclear power plants, and to make use of an integrated approach to design, safety, and plant life management.

The specific elements of mandate of IAGE as articulated in the current operating plan for the CSNI are:

- The Working Group shall constitute a forum to exchange views, information and experience on generic technical aspects of integrity and ageing of components and structures, and to review, as necessary, national and international programs concentrating on research, operational aspects and regulation.
- The Working Group shall stimulate, in relevant technical areas, new research, and recommend possible international co-operative projects.
- The Working Group shall develop common technical positions on specific integrity issues for operating and new nuclear power plants, and shall identify areas where further work is needed.
- The Working Group shall discuss the potential impact of ageing and other challenges to integrity on the safety, regulation, and operability of operating and new nuclear power plants.

2 RECENT AND CURRENT ACTIVITIES

Risk-Informed Piping Integrity Management Workshop

The IAGE metal group sponsored a workshop on risk-informed piping integrity management in Madrid, Spain on 2-4 June 2008. About 63 specialists from 12 countries and international organisations attended. The Meeting was sponsored by the OECD Nuclear Energy Agency Committee on the Safety of Nuclear Installations and the European Commission Joint Research Centre (JRC) hosted by the Consejo de Seguridad Nuclear.

The main objectives of the Meeting were to examine and discuss the results and conclusions of the OECD/NEA and EC-JRC co-ordinated risk-informed in-service inspection methodologies benchmark (RISMET) and to discuss and present the results and applications of the OECD Piping Failure Data
Exchange (OPDE) Joint project along with other related activities in NEA member countries. Participants in the Workshop discussed the applications of risk-informed piping integrity management, and the regulatory, utility and industry aspects, as well as related research and development activities.

The principal findings and recommendations of the workshop are:

- Risk-informed in-service inspections is widely used in many countries and based on the consequence assessment on a plant specific PSA model have the capability of identifying risk important inspection locations that might otherwise be ignored. The economical benefit for the plant of moving to a RI-ISI depends on the present ISI scope, rules and regulations.

- It was noted that in order to benefit the most of a risk-informed approach, the plant specific PSA model should be of high quality and cover also low power and shut-down analyses, and internal and external hazards, including seismic PSA.

- The RISMET report should be promptly disseminate in order for the member countries to be aware of the main differences in the RI-ISI methodologies and to improve their inspection programmes.

- The OPDE project constitutes a good international project for the collection of pipe degradation and failures in commercial nuclear power plants at the participating OECD member countries. The database supports various analyses including trend analysis, aging analysis, statistical analyses to determine pipe failure rates and rupture frequencies, source of data parameters for input to probabilistic fracture mechanics codes, and degradation mechanism analysis in ISI applications.

- It was noted that a successful implementation of a quantitative structural reliability analysis is strongly dependent on an in-depth knowledge of structural integrity management and piping system degradation susceptibilities. Therefore it was recommended that any application of such structural models should be performed by practitioners with deep physical understanding of the degradation mechanism, identifying and assessing the uncertainties associated with data used, models and tools, for example by means of sensitivity analysis.

- The use and application of probabilistic fracture mechanics tools and computer codes should be done with cautious, by experienced users, with clear understanding how they works, their limitations and should not be treated as “black box”. The predictive power of these models is highly correlated with the underlying assumptions about flaw initiation, flaw growth (propagation), etc. and these aspects have to be clearly understood.

- Continuous understanding of international lessons learned from service experience and research and developments results should be systematically used to develop a better understanding of degradation mechanisms and their associated uncertainties and in consequence to make improvements and enhancements to probabilistic fracture mechanics models and computer codes.

**Probabilistic Structural Integrity of a PWR Reactor Pressure Vessel: PROSIR round robin**

The US pressurized thermal shock (PTS) screening Criteria on RTNDT of Reactor Pressure Vessel (RPV) of PWR is based on a probabilistic fracture mechanic approach. In the other hand, if a plant is supposed to over-pass the screening criteria, the Regulatory Guide RG 1.154 defines the requirements based on a justification through a probabilistic approach.

The aim of these round robins is to issue some recommendation of best practices in this area and to assure an understanding of the key parameters of this type of approach, like transient description and frequency, material properties, defect type and distribution, fracture mechanic methodology. Another possible result will be to identify the consequences of different parameter uncertainties on the probability of failure of a RPV.

This round robin is a complementary step to previous NEA exercises such as FALSIRE [1] and ICAS [2] program on RPV integrity.

The main objectives of the benchmark on "Probabilistic Approaches of RPV" (PROSIR) were to:

- confirm performance of probabilistic approaches for RPV structural integrity;
• compare and improve probabilistic fracture mechanic tools;
• identify the major parameters and uncertainties that play a role in these approaches (e.g. flaw-type and distribution, toughness models and uncertainties, crack arrest, warm pre-stressing);
• issue some recommendations on best practices.

The benchmark consisted of four phases over a period of 4 years:
• Phase 1: Fitting of the methodology used by different participants through deterministic cases;
• Phase 2: Probabilistic cases;
• Phase 3: Sensitivity studies;
• Phase 4: Reporting workshop.

A pre-requisite set of deterministic approaches has been proposed and discussed with the different PROSIR partners before moving to probabilistic approaches. Different sensitivity studies around the base case (longitudinal weld) has been done and discussed. The final recommendations of phase 1 and 2 have been developed during a workshop in September 2006 [3]. The final report of PROSIR will be published at the end of 2009.

RISMET Project

Various RI-ISI methodologies have been developed, although the only widely applied methods are those developed by the Pressurized Water Reactor Owners Group (PWROG)/ASME and by the EPRI in the USA. There had not been any direct comparisons of several RI-ISI methodologies applied to an identical scope of components (system, class, etc.). Recommendations and support for benchmarking various RI-ISI approaches have been given by several international bodies. In consequence the CSNI agreed in December 2006 on a proposal to benchmark the different RI-ISI methodologies (RISMET) in order to identify how they impact reactor safety and whether they lead to significantly different results.

The overall objective of the project is to apply various RI-ISI methodologies to the same case (namely, selected piping systems in one nuclear power plant). The comparative study aims at identifying the impact of such methodologies on reactor safety and how the main differences influence the final result (i.e. the definition of the risk-informed inspection programme).

To achieve the project objectives, the benchmark was organised into Application Groups, responsible for applying the methodologies, and Evaluation Groups, to analyse the information provided. The benchmark was limited to include four systems at Ringhals unit 4 (R4), a Westinghouse NSSS designed PWR nuclear power plant (NPP). The systems are:
• Reactor Coolant System (RCS)
• Residual Heat Removal System (RHR)
• Main Steam System (MSS)
• Condensate System (CS)

The following approaches to define the ISI program were considered in the benchmark exercise:
• Swedish regulatory requirements (“SKIFS”)
• PWROG original methodology (“PWROG (original)”)  
• PWROG methodology adapted to Swedish regulatory requirements (“PWROG-SE”) 
• EPRI methodology (“EPRI”)  
• EPRI streamlined RI-ISI methodology (“Code Case N-716”)  
• ASME Section XI (deterministic) (“ASME section IX”)  

The general conclusions of the project are:
• RI-ISI process itself is a valuable exercise, since it forces the project team to review the piping degradation potential and identify both direct and indirect consequences of piping failures.
When applying RI-ISI, it is important that the owner defined or augmented programs are integrated into or coordinated with the RI-ISI program in a logical manner.

It should be noted that RI-ISI evaluations often identify risk-significant segments or sites where other safety management measures than inspections may be more useful. For instance components subject to a fast degradation mechanism, such as vibratory fatigue, or components that are difficult to inspect because of materials or design may require alternative approaches. Other ways to address the risk may be e.g. continuous monitoring, improved leak rate detection, improved water chemistry treatment and follow-up.

Even if in some cases ISI is not the best safety management solution of some risk-significant segments or structural elements, and they would be excluded from a further evaluation from a NDE perspective it is important to assign such items a “high risk” status in the risk ranking phase. The plans for further treatment of those items should be clearly documented.

Within the RISMET benchmark it was not possible to judge or compare the full documentations that would come as output of a RI-ISI application, but a transparent and traceable documentation of the RI-ISI should be highlighted.

Ageing Management of Thick Walled Concrete Structures
The IAGE Concrete sub-group sponsored a workshop on Ageing Management of Thick Walled Concrete Structures, including In Service Inspection, Maintenance and Repair – Instrumentation Methods and Safety Assessment in view of Long Term Operation’. The workshop was held in Prague, Czech Republic on 1-3 October 2008 and hosted by the Nuclear Research Institute Rez.

The objective of this workshop was to present and discuss the state of the art techniques for the integrity assessment of concrete structures, and to recommend areas where further research is needed. Special emphasis was given to performance-based ISI based on NDE methods (such as impact echo, ultrasound and high frequency radar) and instrumentation. Limits of applicability were extensively discussed. The management of ageing programs based on suitable structural monitoring was also addressed in the framework of a safety assessment of the installations in the long term. Probabilistic methods oriented to the reliability structural assessment were also discussed for consistent management of the integrity assessment of civil structures, both repairable and not.

The principal findings and recommendations of the workshop are:

- The performance of structures in NPPs has been good, with the majority of identified problems initiating during construction and corrected at that time. However, as structures age and the scope of inspection programmes has increased, there have been instances of degradation. Most of leak rate is still concentrated around penetrations, gaskets, and discontinuities.
- Demonstration of continued safe and reliable operation of NPPs concrete structures requires the implementation of a plant life management programme that effectively manages aging to ensure availability of design safety functions throughout plant service life. The plant life management programme should address not only safety but durability and cost control at the same time.
- Two technical objectives of the PLiM programme for concrete structures should be considered. Monitor degradation for durability and planning covering the whole life of the plant, from design to construction and operation; and Proof safety (leak tightness, integrity) even in the absence of visual evident degradation.
- Especially for new reactors, concrete durability should be considered since the design phase, either implicitly through prescription on water content, concrete cover, etc., or explicitly.
- It was noted the need to establish research projects aimed to collect information and data for use in ageing assessments of concrete structures from nuclear power plants under decommissioning and plant modifications in order to: assess construction quality; monitor and benchmark specific plant performance; assess and validate NDE methods; evaluate performance of repair materials; and help improve characterisation of service environments and understanding of degradation mechanisms.
Efforts should be devoted to assess the effects of long-term thermal loadings at moderate temperature levels. Similarly, prolonged exposure of concrete to irradiation can result in decrease in tensile and compressive strengths.

Some areas have been identified where improvements in NDE methods are desired, for example: for thick heavily reinforced concrete section in terms of flaw detection and characterisation, honeycomb and embedded items, and void adjacent liner; for basemats and other inaccessible areas based on indirect approach for environmental qualification; for global inspection methods for liners; and for prestressing tendons to be able to make force measurements and estimate the time-dependent prestressing force losses.

Improving Robustness Assessment Methodologies for Structures Impacted by Missiles

The IAGE Concrete sub-group have just initiated an activity aimed to improve the robustness assessment methodologies related to structures impacted by missiles. The purpose is to develop guidance that outlines effective methods of evaluating the integrity of structures impacted by missiles. It is proposed to compare various methods in a three round-robin study. The project will use publicly available data from simple reduced scale tests. Different computer codes and modelling approaches will be compared to the data as a means of partially validating the methods applicable to missiles impact assessments.

Public acceptance of existing and new nuclear installations in part depends on demonstrating the adequate structural robustness of the installation, the effectiveness of emergency response strategies to avoid or mitigate the effects of aircraft or missiles impact, and the reality of the mutualisation of resources and results by the civil nuclear community.

To overcome the difficulties with the sensitivity of this activity, it was agreed to consider structures similar to NPP’s ones but of smaller size, and missiles with characteristics adapted to produce flexural and/or shear rupture mode. Soft and hard impactors will be considered in the velocities range from 100 m/s to 200 m/s. Distributions and impact velocity (or loading diagrams) will be adjusted in order to damage the structures according to postulated rupture modes: flexural and/or shear rupture mode.

Three small teams have been established. The first has been assigned to the selection of interesting tests (Sandia tests, Meppen tests, Manchester University, others...), the second to the definition of the benchmark rules, results formatting, etc., and the third one to the creation of a website to facilitate communication and sharing of information.

A scientific committee was established with the participation of well recognised experts on the field to provide background information and guidance to the group. A first workshop/meeting of the task group was held on April 20-21, 2009 where all the task group participants and experts gave presentations on the impact research and the project plan and deliverables were defined.

3 FUTURE ACTIVITIES

The IAGE working group will shortly initiate, subjected to the approval of the CSNI, the following activities:

1. Study on post-tensioning methodologies in containments. The aim of the activity to develop a systematic study that investigates the comparative advantages and disadvantages of various post-tensioning techniques in reactor containments. It is proposed that post-tensioning methods be compared in a round-robin study of advantages and disadvantages of bonding of the tendons.

2. Soil Structure Interaction (SSI) knowledge and effect on the seismic assessment of NPPs structures and components. The objective of the activity is to improve the understanding of the SSI effects on the seismic behaviour of the NPPs buildings, which affects the dynamic response of the internal components and structures. Main deliverable will be a document summarizing the state of the knowledge in SSI simulation capability and identifying the research and/or benchmark needs to reach the goal of effective accounting of SSI effects in the seismic assessment of the NPPs structures.
3. Fatigue of components and structures. The aim of the activity is to assess fatigue data transferability from standard specimen to structures and components including environmental effects. After a long process, mainly in Japan and USA, on fatigue of standard specimen, the remaining question that will be addressed by the activity will be how to transfer these results to industrial components and structures. All type of fatigue will be considered, high and low cycle fatigue, mechanical and thermal fatigue, without or with environmental effects.

4. Study on High Energy Arcing Events (HEAF). The aim is to develop deterministic correlations to predict damage as a result of these events and establish a set of input data and boundary conditions for more detailed modelling which can be agreed to by the international community. The output of this project may directly support development of improved treatment methods in fire Probabilistic Risk Assessment (PRA) for nuclear power plant applications.

5. Leak-Before-Break Research. The main objective of this task is to identify technical areas of mutual interest related to either 1) the structural integrity evaluation of piping systems using deterministic and/or probabilistic methods or 2) the demonstration that flaws in piping systems will exhibit leaks prior to failure.

6. Development of SharePoint software as a communication tool for seismic issues. The objective is to suggest a means to facilitate technical exchanges on seismic related issues, requests for advice allowing collaboration, and supply access to information that would facilitate international cooperation.

4 CONCLUSION

The joint CSNI and CNRA strategic plan has identified the necessity to ensure safety over plant life cycle as one of the main challenges for nuclear safety that regulatory authorities and the research community will face. The management of plant ageing, life extension and license renewal are of direct interest to all member countries. The physical and mechanical properties of most materials and components change with age and these changes are often exacerbated by environmental factors. It is important to develop methods for identifying, testing and modelling the ageing mechanisms that affect materials and components important to the safety of nuclear power plants.

The IAGE working group have been addressing these integrity and ageing issues by exchanging views, information and experience on generic technical aspects of integrity and ageing of components and structures, and review, as necessary, national and international programmes concentrating on research, operational aspects and regulation.

This paper has outlined some of the CSNI/IAGE activities aimed: to develop an understanding of the ageing degradation mechanisms; to identify appropriate methods for in-service inspections; and to generate and assess the capability to model the ageing mechanisms. This could significantly improve the member countries ageing management programmes required for a safe long term operation of nuclear power plants. The IAGE working group will continue addressing the technical aspects of ageing for long term operation in close cooperation and coordination with the IAEA and the European Union.

5 RECENT PUBLICATIONS

The following list constitutes the recent publications of the CSNI/IAGE working group:

- A Decade of CSNI Activities in the Area of Ageing of Nuclear Power Plant Concrete Structures, NEA/CSNI/R(2008)14
- Differences in Approach between Nuclear and Conventional Seismic Standards with Regard to Hazard Definition, NEA/CSNI/R(2007)17


• Status Report on Developments and Co-operation on Risk-Informed In-Service-Inspection (RI-ISI) and Non-destructive Testing (NDT) Qualification in OECD/NEA Member Countries, NEA/CSNI/R(2005)9

• Report on Thermal Cycling in LWR Components in OECD Member Countries, NEA/CSNI/R(2005)8


• Review of Developments and Co-operation on Risk-Informed In-Service-Inspection (RI-ISI) and Non-destructive Testing (NDT) Qualification in OECD/NEA Member Countries – Responses to the Questionnaire, NEA/CSNI/R(2005)3

• FAT3D - An OECD/NEA-CEA Benchmark on Thermal Fatigue in Fluid Mixing Areas, NEA/CSNI/R(2005)2

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[1] FALSIRE: CSNI project for Fracture Analyses of Large- Scale International Reference Experiments, 1996, NEA/CSNI/R(96)1
