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International Forum on Reactor Ageing Management (IFRAM)

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Content

1 IFRAM and the European Engagement Workshop

Globally there are currently 440 commercial nuclear power plants (NPP) in operation in 30 countries. These plants, which have an average age greater than 20 years, were initially licensed to operate for 30 to 40 years. In order to meet the growing global demand for electricity, particularly to support economic development, it is projected that about 2300 GWe of new generating capacity would need to be built over the next 20-30 years. Currently there are about 40 new NPPs under construction around the world and at least 222 new NPPs are considered. Since the costs for such projects will be significant and since the recent economic downturn might delay or even cancel many of these projects the extension of the service life of existing NPPs beyond their design lifetime becomes an extremely interesting issue.

The USA has 104 commercial nuclear reactors in operation (status May 2009) and 52 of them have received license extensions to operate until 60 years. Currently the US Nuclear Regulatory Commission (NRC) is reviewing another 18 applications for lifetime extension to 60 years and another 15 applications are announced. Within the next 5 years the US NRC expects the first NPP operators to ask for license extension until 80 years. License extension also becomes a realistic scenario for other countries with commercial NPPs, in Asia and also in Europe.

In Europe there are currently 194 nuclear power reactors in operation, 141 in the EU, 5 in Switzerland, 15 in the Ukraine, 32 in the Russian Federation and one in Armenia. The EU member countries with nuclear power reactors are (in alphabetical order) Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Hungary, The Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom. The extent to which nuclear power contributes to the overall electricity generation in these countries differs quite considerably. The same applies for the future plans of these countries to further use nuclear power for electricity generation. Several EU member countries are currently building new nuclear power reactors and in parallel plan for or have granted recently lifetime extensions for their operating NPPs. Lifetime extension until 60 years is a scenario that is considered in the EU.

In countries with NPPs regulatory authorities and the nuclear industry are carrying out various programs for managing material degradation of NPP structures, systems and components (SSC) and for related topics such as Long Term Operation (LTO) and Plant Life Management (PLiM). International exchange on these activities or international programs related to these topics have been initiated through the IAEA, the OECD-NEA and through projects partly sponsored by the European Commission (EC) in the EU (e.g. NULIFE). In 2006 US NRC together with the Pacific Northwest National Laboratory (PNNL) launched a program to review all these activities on ageing management (AM) and long term operation of NPPs. The

name of this program was “Pro-active Management of Materials Degradation (PMMD)” and some summarizing reports have been issued[1].

While reviewing past programs on AM/LTO US NRC and PNNL discovered that there is quite an overlap between existing national programs, and that it is too challenging for one (or two organisations respectively) alone to review all the existing work on AM/LTO. At this stage it was felt that an international network involving a larger number of nuclear organisations around the world would be beneficial, not only in reviewing past and existing national or international programs related to AM/LTO, but also to bring together experts who exchange information on operating experience, best practices and emerging knowledge.

It was proposed to establish the “International Forum for Reactor Ageing Management (IFRAM)”. It is intended to be an international network (umbrella) to consolidate the present knowledge on AM/LTO and to keep this knowledge available for the next generation of nuclear staff. Information and knowledge on AM/LTO of the various countries could be shared. It is however recognised that concerns about intellectual property (IP) may limit this exchange. IFRAM should also identify open gaps for AM/LTO and prioritize the necessary R&D work to fill these gaps. IFRAM is also seeking to avoid the duplication of efforts since the human and financial resources available for AM/LTO are limited.

The first step in establishing IFRAM was the Asian Engagement Workshop, organised in Seoul, Republic of Korea from 11th – 13th October 2009. In total 36 experts from Japan, Republic of Korea, the Peoples Republic of China, Taiwan, India and the USA participated in this event. The aim of the workshop was to discuss the idea of IFRAM and how such an international forum could be established, what are its objectives and what are the benefits for its members.

The Asian Engagement Workshop was followed by the European Engagement Workshop organised in Petten, the Netherlands from 25th – 27th May 2010. In total 29 persons from 13 European countries, the USA, IAEA and the European Commission (EC), General Directorate Joint Research Centre (JRC) participated in the European Engagement Workshop. The aims of this workshop were the same ones as for the Asian Engagement Workshop. In addition to the establishment and objectives of IFRAM also scientific and technical issues on AM/LTO for 60 years were discussed.

The following chapters summarize the different sessions of the European Engagement Workshop. In the first session all the participating organisations presented their activities related to AM/LTO. In the second session the establishment, organisation, objectives and benefits for members of IFRAM were discussed. The third session was dedicated to scientific & technical issues on AM/LTO for 60 years.

[1] Bond, L., Doctor, S.R. & Taylor, T.T., 2008. *Proactive Management of Materials Degradation – A Review of Principles and Programs*, PNNL report no. 17779. Richland, WA: PNNL.

2 Individual Presentations of the Workshop Participants

The 29 participants came from the following countries or international/European Organizations: IAEA, Belgium, Czech Republic, Finland, France, Germany, Hungary, The Netherlands, Romania, Slovakia, Spain, Sweden, Switzerland, Ukraine, USA and EC/JRC (see Appendix 2). There was a large variety in organisation types, i.e. utilities, safety authorities, TVOs and research institutes, providing a large variety in the presentations.

Mr Michel Bièth (EC-JRC) as the host of the European Engagement Workshop gave a welcome presentation. He gave an overview on the tasks and structure of the European Commission with special emphasis on the Joint Research Centre (JRC) and in particular the Institute for Energy (IE), which is one of the 7 institutes of the JRC. Then he presented in more detail the activities of his Unit, the Safety of Present Nuclear Reactors (SPNR) Unit, which are: The European Clearinghouse, which is related to operational experience feedback, the Plant Operation Safety Action (POS), which is related to activities on plant operation safety including network activities on AM/LTO and the JRC participation to NULIFE, and activities related to the TACIS & PHARE programs.

Mr C.E. (Gene) Carpenter (US NRC) gave a presentation on IFRAM pointing out the reason why this forum is needed, its concept and structure, its objectives and targets and its development so far including a summary of the Asian Engagement Workshop. He also spoke about the AM research activities and license renewal processes at US NRC.

Mr Ki-Sig Kang (IAEA) gave an overview on past and on-going IAEA projects related to AM/LTO and the resulting publications, i.e. guidelines, tecdocs, etc. Two on-going projects were explained in more detail, a benchmark project on codes to predict flow accelerated corrosion (FAW) and the International Generic Ageing Lessons Learned (IGALL). Mr. Kang also presented a planned IAEA common research project (CRP) on LTO to 60 years, which should be launched shortly, and made a proposal how it could be linked to IFRAM. To the end of his presentation Mr. Kang provided a list of scientific & technical issues related to LTO to 60 years.

Mr Michel de Smet (Tractebel, Belgium) outlined the present situation of nuclear power generation and plans for LTO in Belgium. However a decision by Belgium legislation a couple of years ago to phase out nuclear power generation was put on hold.

Mr Milan Brumovsky (NRI Rez, Czech Republic) outlined in his presentation the LTO program of the Dukovany NPP in the Czech Republic. He described the necessary tasks for obtaining a license renewal. This included all the stages, i.e. technical-economical evaluations and risk assessments, of the renewal process and all the required documents. Towards the end of his presentation Mr. Brumovsky summarized the integrity procedures for primary circuit components of VVER type reactors developed within the VERLIFE project. He also presented a list of on-going R&D projects, both national and European/international projects

with Czech contribution, and a list of scientific issues related to LTO of nuclear power reactors to 60 years.

Ms Päivi Karjalainen-Roikonen (VTT, Finland) started her presentation with the current situation regarding nuclear power generation in Finland and current plans for new builds in the future. She then outlined briefly how VTT fits into the research environment in Finland and the cooperation with STUK, the Finish nuclear safety authority, and other organisations in the SAFIR program on nuclear safety. Most of her presentation was dedicated to activities related to material degradation and in-service-inspection (ISI) at VTT.

Mr Jan van der Lee (MAI, France) gave an overview on the Materials Ageing Institute (MAI), which is a relatively new research institute located in Les Renardières, France, dealing with material ageing problems on the nuclear field. It is backed by EDF, the Electric Power Research Institute (EPRI, USA), the Tokio Electric Power Company (TEPCO, Japan) and Kansai Electric Power Company (KEPCO, Japan). In his presentation Mr. van der Lee spoke about the objectives, i.e. research and training, on-going research projects and experimental facilities (chemical labs and autoclaves, microscopes, etc.) of his institute.

Mr Gerd Dobmann (Fraunhofer IZFP) gave a technical presentation on a research project related to non-destructive examination (NDE) of reactor pressure vessel (RPV) steels. He and his co-workers developed an electromagnetic test method for the non-destructive characterization of neutron induced embrittlement in RPV steels, which allows characterization through austenitic RPV cladding.

Mr Michael Hoffmann (Materialprüfungsanstalt Universität Stuttgart (MPA Stuttgart)) gave an overview on activities related to AM and structural integrity of NPP components of his institute. MPA Stuttgart is involved in drafting the German safety standard KTA 1403 on AM of NPPs and in a couple of research projects dedicated to fatigue of RPVs and piping systems, together with the German ministries for economics & technology and environment & reactor safety.

Mr Ferenc Gillemot (KFKI Atomic Research Institute, Hungary) gave a presentation on the LTO experience of the Paks NPP in Hungary. The Paks NPP accounts for 40% of electricity generation in Hungary and it is planned to upgrade its power by 8% and extend its lifetime to 50 or even 60 years. Mr. Gillemot outlined in his presentation the process of lifetime extension in Hungary including the organizations involved. Towards the end of his presentation he listed technical issues that could limit the lifetime extension of the Paks NPP and VVER type reactors in general, and linked them to a list of on-going research projects dedicated to AM/LTO at the KFKI Atomic Research Institute.

The presentation of Mr Ignacio Marcelles Ramirez (Tecnatom, Spain) consisted of two parts. The first part was a general presentation on the AM/LTO methodology adopted for NPPs in Spain. In the second part of his presentation Mr. Marcelles Ramirez outlined a concrete

example for AM/LTO, the monitoring and surveillance of electrical cables in NPPs. He described an extensive R&D undertaken in Spain recently on ageing and monitoring of electrical cables in the Spanish NPPs.

Mr Imrich Krajmer (Slovenske Elektrarne, Slovakia) spoke in his presentation about a power upgrade and extensive modernization program in the Bohunice NPP, which is currently underway. In the second part of his presentation Mr. Krajmer was presenting a severe accident management program and a LTO program for the Bohunice NPP, which were both launched recently.

Ms Marta Serrano Garcia (CIEMAT, Spain) started her presentation with an overview on nuclear power production and the current status of license renewal of NPPs in Spain. She then gave a brief introduction into CIEMAT, especially the materials division, including its aims and scopes. In most of her presentation Ms. Serrano Garcia described on-going research projects, mainly on stress corrosion cracking (SCC) of Alloy 690 and irradiation assisted SCC (IASCC), and presented planned research projects, mainly on fatigue.

Ms Mirela Nitoi (formerly INR, Romania, presently EC - JRC) gave a presentation on behalf of Mr Vasile Radu (INR, Romania) and started her presentation with an overview on all the nuclear organizations and nuclear facilities in Romania. She then presented in more detail the on-going research programs and the experimental facilities of INR, especially the TRIGA reactor. The final part of her presentation was devoted to the plant life management (PLiM) program and LTO issues of Romania's only NPP in Cernavoda (CANDU).

Mr Björn Brickstad from the Swedish Safety Authority (SSM, Sweden) outlined in his presentation the degradation experience in Swedish NPPs. He pointed out that so far there have been no major safety incidents and that nearly all the degradation events have been detected by in-service inspection (ISI). However, the evolution of degradation events shows that the knowledge base on materials degradation must be updated, which requires adequate research. Thus at the end of his presentation Mr. Brickstad showed some on-going research projects on materials degradation sponsored by SSM.

Mr Johan Stjärnsäter (Studsvik Nuclear AB, Sweden) started his presentation with an overview on the test facilities of Studsvik Nuclear AB for SCC before describing in more detail on-going projects and Studsvik's expertise on IASCC. Other topics of his presentation were on-going projects related to the surveillance testing of RPV steels, SCC in BWR and PWR water conditions and other corrosion problems (SCC of nickel based alloys).

Mr Klaus Germerdonk from the Swiss Federal Nuclear Safety Inspectorate (ENSI) gave a presentation on AM/LTO of his organization. He started his presentation with an overview of the nuclear power reactors in Switzerland and the regulatory framework for LTO. In the second part of his presentation Mr. Germerdonk spoke about the experience with AM programs in Swiss NPPs and joint research projects with Paul-Scherrer-Insitute (PSI,

Villingen, Switzerland) on LTO. The topics of these research projects were SCC and RPV integrity and safety.

Mr Valeriy Kharchenko from the G.S. Pisarenko Institute for Problems of Strength of the National Academy of Sciences of the Ukraine gave a presentation on on-going research activities on LTO of the Ukrainian nuclear power reactors, which are VVERs. After a short introduction about the development and present status of his institute, he talked very deeply about structural integrity assessment of passive metallic components of NPPs, mainly RPVs, piping systems and steam generators. He presented results of finite element analyses together with the associated models and results of material tests related to the mentioned NPP components.

Mr C.E. Carpenter (US NRC) gave the presentation of Mr Bob Nickell (formerly with ASME), who could not attend the workshop. The presentation was a summary of the joint ASME-EPRI LTO Workshop "Extending the Life of current Nuclear Plants to 60 Years and beyond" held in Crystal City, Virginia, USA on 17th/18th February 2010. After presenting the agenda of the workshop Mr. Carpenter gave summaries on all six sessions of the workshop, which were life limiting issues, life cycle management, material ageing issues, modeling and simulation, safety and security and strategic risk management. At the end of the presentation Mr Carpenter summarized the major findings & recommendations of the workshop. This also included identified material ageing issues critical for LTO and future LTO actions. Among these is the establishment of IFRAM.

The presentation of Ms Christiane Bruynooghe (EC-JRC) consisted of three parts: The involvement of JRC in nuclear energy issues, PLiM programs and the current situation of nuclear power generation in Europe and LTO supporting studies at JRC. In the first part of her presentation Ms Bruynooghe spoke very briefly about the obligations coming from the Euratom treaty and subsequent legislation and how JRC supports other more political general Directorates of the EC in their nuclear activities, i.e. nuclear related legislation and funding to non-EU member countries to improve the safety of their NPPs. In the second part of her presentation Ms Bruynooghe presented different scenarios on the development of nuclear power generation in Europe and gave a summary on programs for increasing the safety of NPPs as well as power upgrade programs of all the EU member countries with nuclear power reactors. In the last part of her presentation Ms Bruynooghe talked about on-going research programs and activities related to LTO with JRC involvement.

In the last presentation Mr Rauno Rintamaa (VTT, Finland) presented the European Network on LTO NULIFE. At the beginning of his presentation he described the steps/incidents leading to the establishment of NULIFE, the motivation and objectives of NULIFE, to integrate R&D on LTO in Europe. In the second part of his presentation Mr Rintamaa described how NULIFE works including its structure and listed all the member organizations. Next he gave an overview of research projects within NULIFE, past pilot studies and on-going projects. In the last part of his presentation Mr Rintamaa outlined the further roadmap

of NULIFE, i.e. its evolution into a virtual R&D Institute with customer driven programs, its engagement in the further development of Generation III reactors and its links to the "Sustainable Nuclear Energy Technology Platform (SNETP)".

3 Discussion 1: Establishment of IFRAM

The sessions with individual presentations of the workshop participants was followed by a panel discussion on the establishment of IFRAM, i.e. need for an international forum on reactor ageing management, benefits for the members, structure & organization, relationship with national and international organizations, intellectual property issues, etc. The discussion was led by C.E. (Gene) Carpenter (US NRC) and Leonard Bond (PNNL) and was more a brainstorming session in character. The following four larger topics were discussed, although there was no strict separation between them:

- Topic A: Define the Benefits of the International Forum—what are the likely returns for those who participate?
- Topic B: Describe ways national programs could be linked to the International Forum—how to leverage so that benefits are greater?
- Topic C: Describe the best ways for International Forum to share and exchange information—Recommended "next steps" for cooperation.
- Topic D: Develop matrix of individuals/organizations technical programs—who is doing what?

Topics A & B: Benefits of IFRAM and sharing of data

Leonard Bond (PNNL) started the discussion with some introductory remarks. He pointed out that there is a lot of material available (reports, proceedings, etc.) nowadays on AM/LTO and named some specific examples from the US, e.g. the US GALL report, EPRI reports on specific scientific issues. In 2006 US NRC together with PNNL launched a process of reviewing all the available material & data on AM/LTO with emphasis on US publications, which they called "Pro-active Management of Materials Degradation (PMMD)". Since a lot of work has been done on AM/LTO not only in the USA, but also in Asia and Europe and since two organisations alone cannot review all the work alone PMMD should eventually evolve into IFRAM. The first step to establish IFRAM was the Asian Engagement Workshop followed by the next step, the European Engagement Workshop. To US NRC and PNNL the objectives and benefits of IFRAM are:

- Consolidate the present knowledge on AM/LTO,
- Keep this knowledge available for the next generations of nuclear staff,
- Share information and knowledge on AM/LTO between countries, especially on R&D
- Identify open gaps and prioritise resulting work, and

- Avoid duplication of work since human and financial resources for AM/LTO are limited (in 2008 research activities were estimated by US NRC to be at the level of approximately $ 100 Mio (US) worldwide).

There was consensus among the participants on the above objectives and benefits, but the issue of sharing information and knowledge on AM/LTO was subjective to intensive debate. Some participants stated that utilities in their countries are most probably not willing to share results of their research work on AM/LTO, because working on specific technical issues might indicate to the public in their countries that there are technical problems in their NPPs. The participants agreed that results of fundamental research projects, i.e. ageing mechanisms and their root causes, can be shared without any problems, where as the exchange of plant specific data, i.e. on their safety, is extremely difficult. At this stage the question about the motivation for utilities to join IFRAM was raised. Since IFRAM is dealing with LTO of NPPs input of utilities is badly needed. One participant mentioned that as long IFRAM performs studies and activities on real field problems rather than performing basic review exercises on major degradation mechanisms IFRAM will gain the needed “attractiveness” among utilities.

Another point that was mentioned in connection with exchange of data was that there are different approaches to conduct research on AM/LTO in various countries. In the USA the nuclear industry has strong links with the regulator and thus information on AM/LTO is relatively free floating. Similarly in Germany research on AM/LTO is usually performed in cooperation between the utilities and the German Ministry for Environment and Reactor Safety and so the results are open to a wider public. In France a huge proportion of the research work on AM/LTO is performed by one utility. Thus the scientific output of those projects is not publically available. But here one workshop participant stated that comparing and understanding the different ways research work on AM/LTO is conducted in the various countries with commercial nuclear reactors is a benefit of IFRAM on its own already.

A number of participants pointed out that there is a need to qualify data before exchanging. The underlying question is to what extend all the available data in such a forum like IFRAM is relevant for every member. E.g. is data on AM/LTO of BWRs in Spain interesting for a country that relies entirely on PWRs? A nuclear organisation is only willing to join IFRAM if they recognize it as a forum that offers solutions to their specific problems. Here one should keep in mind that the motivation for AM/LTO can be quite different depending upon the organisation behind it. The motivation for a utility to perform AM/LTO programs are economic driven, where as regulatory authorities are more interested in the safety aspect of AM/LTO.

When information is stored and exchanged via databases there is a need to define common requirements for the data with regards to type, format, quality, etc. Also databases need to be updated regularly and their content should be regularly controlled by experts according to validity of the data. Also there needs to be an agreement on how long data should be kept.

At the end there was consensus among the participants that an international platform or umbrella is needed for exchanging information and data on AM/LTO of NPPs. One of the first steps in establishing IFRAM should be the development of a matrix of known issues and open gaps, which is the extension or outcome of the above mentioned PMMD initiative jointly started by PNNL and US NRC to review all the activities on AM/LTO conducted so far. Such a matrix would also provide indication about the major concerns of a country with a nuclear program. One of the participants remarked the identification of open gaps could be crucial, because some issues (degradation mechanisms) were not relevant for LTO to 40 years, but might become relevant for LTO to 60 years and beyond and that even unknown degradation mechanisms might even occur. The participant stated that IFRAM should primarily focus on such issues and the audience agreed that this should be an important objective of IFRAM.

Some participants also stated the need of IFRAM to have strong links with the International Generic Ageing Lessons Learned (IGALL) Project currently established by IAEA. The result of the IGALL project should be the publication of the IGALL report/database, which lists in table format for all the passive components of the common nuclear reactor types around the world (BWR, PWR, VVER, CANDU) all possible degradation mechanisms and suitable ageing management programs for their mitigation. The idea for the IGALL report/database originates from the US GALL report issued by US NRC for the first time in 2001. As envisaged for the IGALL project also for IFRAM the output should be some sort of common guidelines, state-of-the-art reports and databases including one on shared aged material samples.

Concerning the link between national existing programs to IFRAM some participants raised the question what gaps IFRAM will fill, which are not covered by national (existing) programs and what are the extra benefits of IFRAM compared to existing programs. At this stage it was pointed out that quite a number of international programs/platforms for AM/LTO already exist, e.g. the IAGE subgroups of OECD-NEA. The reply given by PNNL/US NRC was that IAGE is focussed on materials and their degradation and that NDE and on-line monitoring, which is an integral part for LTO of NPPs, are not so intensively treated within IAGE. So NDE should be one of the scopes of IFRAM. Due to the short time window to find solutions (due to the advanced age of NPPs in the USA) IFRAM should focus on the components of NPP that cannot be replaced. Once again it was pointed out that financial and human resources for AM/LTO around the world are limited, which requires coordination of programs, leverage of results and data, diversity and allocation of activities.

IFRAM should consolidate existing knowledge and perform state-of-the-art reporting and identify best-practice methods. On one occasion it was mentioned by some parties that IFRAM could also be a useful platform for participating organisations to receive feedback on their own research activities. IFRAM could also be a suitable environment for round-robin tests in order to identify best practice methods, especially for in-service inspection (ISI) and

NDE. Round-robin tests on the same NDE subject could even be performed on a regular basis (e.g. every 5 years) to quantify progress in evolving technology.

Topics C & D: Next Steps for Cooperation and Matrix on past & on-going scientific & technical Programs

All the participants agreed that the next step in establishing IFRAM should be the fast establishment of a Global Steering Committee (GSC). The GSC should have not more than 15 members and the three continents involved in the two engagement workshops, thus America, Asia and Europe, should be evenly represented plus the international organisations having nuclear power related activities, i.e. IAEA, OECD-NEA and JRC – EURATOM Program. All the common nuclear power reactors in the world, which are BWR, PWR, VVER, CANDU, should be present in the GSC. The GSC should draft terms of reference for IFRAM and think about the structure of IFRAM. Most probably there will be topic areas / working groups dealing with specific NPP components or materials.

There was consensus among the workshop participants that the issuing of a matrix on past and on-going research projects on AM/LTO at national, European or international level should be the first concrete action of IFRAM. Every participant should provide info and send it to US NRC and PNNL for compilation. PNNL agreed to draft a questionnaire for this purpose. The outcome of this questionnaire is a matrix/report on existing research programs on AM/LTO. It should be a living document so should be updated regularly. From this document open gaps could be identified enabling the creation of joint research projects on specific scientific issues. These research projects could be common research projects (CRPs) under IAEA supervision performed under the above mentioned working groups. One of the workshop participants remarked here that it would be beneficial to issue a list of NPP components that should be in focus. Here the participants agreed earlier that the focus of IFRAM should be on passive components that cannot be replaced during the lifetime of a NPP.

Other practical steps which were agreed on are the implementation of an IFRAM web page and the issuing and distribution of an IFRAM newsletter every quarter. US NRC and PNNL agreed to takeover the responsibility for this task. Then it was agreed to have a huge kick-off meeting with all parties interested in IFRAM in the first half of 2011. Wide variety in participating organisations, i.e. research institutes, utilities, regulators should be envisaged.

4 Discussion 2: Scientific / Technical Issues for AM / LTO 60 Years+

The discussion on the establishment of IFRAM was followed by a discussion on scientific issues for AM/LTO 60 years and beyond. Mr Oliver Martin (JRC) initiated the discussion by giving a presentation on possible issues that could be relevant for AM/LTO to 60 years. Afterwards the workshop participants came forward with their ideas for scientific issues relevant for AM / LTO 60 years and beyond. The ideas are summarized by topical areas in the following paragraphs.

Instrumentation and Cables (I&C) and Safety of Digital Systems

Some participants came up with the idea to investigate ageing of I&C. Ageing of I&C is a "hot" issue at the moment in the nuclear community. Several programs have been launched dedicated to this issue (see presentation of Tecnatom and of NULIFE). Also as part of the renewal programs some NPP utilities around the world have replaced the original analogous control systems with digital ones. The immediate question coming up in connection with digital systems is their security against cyber attacks. Some participants shared the opinion that research on this issue should be conducted and it would be useful to look at other industries, e.g. the oil and gas industry, how they secure their plants against cyber attacks. Another topic related to digital systems and I&C, which needs further investigation with regards to LTO of NPPs according to some workshop participants, is the interface between mechanical and electronic systems in NPPs and their reliability with growing age. Here again a closer view to other industries especially the aerospace industry could be beneficial. Another issue that was raised is the behaviour of digital systems after complete blackouts.

Corrosion Issues and their Detection

A point of discussion was the ageing and degradation of Alloy 690. Alloy 690 is a nickel based alloy used for steam generator tubes in PWRs. Within the last 15 years quite a number of PWRs around the world underwent renewal programs in which the initial steam generators with tubes made of Alloy 600 were replaced with new ones whose tubes are made of Alloy 690. So far no incidents occurred with the Alloy 690 steam generators, but the question is are there any (water) conditions that foster SCC of Alloy 690. One participant pointed out that lead in cooling water could be a driver for intergranular SCC (IGSCC) of Alloy 690 and this mechanism should be investigated more deeply. Beside Alloy 690 other nickel based alloys are utilised in steam generators and primary circuit components of NPPs as well, e.g. the alloys of the 800 series. Also for these alloys the question about water conditions fostering SCC can be raised.

Another proposal related to SCC was to summarize the state-of-the art on acoustic emission (AE) measurement technology. AE is used to measure and monitor the progress of SCC. It is well established in laboratory environments and there are considerations to use it for SCC monitoring in NPPs.

Flow Accelerated Corrosion (FAC)

Another point of discussion was FAC. Although the mechanism is well understood failures and accidents resulting from FAC continue to occur. One of the participants stated that the reason for these failures and accidents is the lack of information distribution and the lack of implementation of adequate follow-up on-site measures after FAC induced failures and accidents. Software codes for predicting the effects of FAC are available and should be used more widely[2]. Nevertheless a number of participants would like a research project on FAC being performed. This research project should involve adequate specimens from real NPP components degraded from FAC.

RPV and Embrittlement

Issues related to RPVs involved mainly mitigation methods for embrittlement and restoring its structural integrity. A number of VVER RPVs underwent annealing in order to restore fracture toughness. Some participants raised the question if there are other appropriate mitigations methods that could be performed instead of annealing. Warm pre-stresses were mentioned as an alternative. Another proposal was to investigate possible modifications in the operation process of the reactor with the aim of reducing the overall flux level and thus slow down the embrittlement process.

Another issue that was raised during the discussion was to what extent the complete replacement of RPVs is an alternative to annealing since annealing might have negative side effects (sensitization for IGSCC). The participants agreed that this is more an economic issue rather than a technical/scientific issue, and the question is if economic issues should be in the focus of IFRAM.

Another raised issue related to RPVs was the extent of embrittlement in a RPV when it is subject to higher neutron fluxes and different neutron spectra than originally anticipated and what are the resulting long term changes in material properties in a time frame of 60-80 years or even 80-100 years. Answering this requires extensive studies involving the irradiation of samples in operating reactors and brings back the idea of a database with irradiated material samples mentioned during the discussion on the establishment of IFRAM. At this point a number of workshop participants stated that samples made from real irradiated parts of decommissioned NPPs should be used wherever they are available. The major problem here is to turn irradiated reactor components into handy specimens.

In conjunction with a database on irradiated material samples some participants proposed the development of “embrittlement trend curves” for LTO. These curves should be updated frequently and data of research reactors should also be included. This requires a discussion on the transferability of such data to power reactors.

Another issue that was raised during the discussion was RPV cladding. More specific

[2] There is currently an IAEA CRP on FAC codes underway.

questions that were discussed on this topic were the ageing of RPV cladding in general, how can the toughness of RPV cladding be controlled and assessed during service and, more generally, is the present knowledge on the topic enough or is further research needed on this. In the on-going discussion the latter was answered with a “yes” since some participants came up with a proposal for a research project on residual stresses in RPV cladding. Possible subtopics could be the prediction of residual stresses, how are they affected by hydro tests and is the stress free temperature equal to the operation temperature.

Concrete and Concrete – Steel Interaction

Proposals for concrete involved the review of research projects on the ageing of buried piping systems in concrete. It is an example for the interaction between concrete and metallic materials. A number of cases of leaking pipes in concrete have been reported recently, e.g. in the high flux reactor in Petten. Another example for concrete – metal interaction that was raised during the discussion, is the interaction between tendons and concrete in containment buildings of NPPs.

Another proposal for research that was made was on the concrete itself. The concrete used for the construction of civil structures of NPPs is not unique around the world. Here it would be interesting to have an overview on the exact composition of the concrete used for containment structures of NPPs. Another issue that was raised was the issue of irradiation effects on concrete. This issue is in particular relevant for the storage and disposal of nuclear waste.

Another point of discussion on concrete was the issue of NDE of concrete structures. NDE of concrete is a challenge and is gaining more attention in the nuclear community. Some participants proposed to define inspection and monitoring needs for concrete and emphasized the usefulness to summarize the state-of-the-art of NDE on concrete. When research on concrete is conducted within IFRAM non-nuclear civil structures should be looked at, as well, because the amount of available data is by far larger than for nuclear civil structures alone.

ISI and NDE

A number of participants shared the view that IFRAM should have a working group on risk informed ISI and NDE. Once again it was emphasised that round robin studies on NDE should be performed within this group even on a regular basis to assess the technological progress. Other ISI / NDE issues raised were leak detection methods, on-line monitoring techniques and NDE for neutron irradiation embrittlement. Another large NDE issue that was discussed was the issue the early detection of flaws and the monitoring of their growth. One participant stated that tests have been performed in Russian and US NPPs on the use of AE for early damage detection and that this issue could be a possible topic for research within IFRAM.

Welding and Leak-before-Break

Other topics of discussion were welding and dissimilar metal welds (DMW). NDE of DMW, welding procedures in older Gen II reactors and welds in steam generators were identified as potential topics for further studies. Another smaller topic of discussion was Leak-before-break (LBB). One participant suggested a study on LBB in conjunction with active degradation mechanisms like PWSCC.

Human Factors and the Nuclear Workforce

With regards to the ageing workforce in the nuclear industry there should be an initiative within IFRAM to identify best practice methods on LTO related to human factors. Related to this is the development of the nuclear workforce management, not only in view of the expected retirements in the near future, but also in view of the on-going trend in the nuclear industry to outsourcing of activities. IFRAM could also be used as a platform to exchange trainees on a short term basis between participating organisations in order to share and compare different LTO strategies.

Misc

Some participants raised a couple of other important issues and questions, which do not fall under the above fields. These were:

- Priorities in scientific/technical issues can be quite different for the individual reactor types. A comparative study on VVERs vs. western type PWRs should be performed with regards to differences in design and operation (What can the nuclear community learn from that?).
- “Yellow Pages” on nuclear reactors foreseen for LTO to 60 years and beyond whose data can be shared within IFRAM should be issued.
- Documentation of materials used in NPPs is not unique. Documentation of materials for older reactors is sometimes even not complete.
- Interaction between known degradation mechanisms.
- IFRAM should have a working group on risk assessment. One task for this group could be a feasibility study to find out to what extent the safety level of a Gen II reactor can be raised to the one of a Gen III reactor.
- The impact of maintenance on the improvement of safety levels (for LTO) should be assessed.
- Issues related to nuclear waste and its disposal should also be covered by IFRAM.

5 Agreed next Steps and Outcome of the Planning Group Meeting

At the end of the workshop the participants agreed on the following symptomatic concrete steps for the further establishment of IFRAM.

1. A matrix/report on past and on-going projects related to AM/LTO will be issued. It should be a living document and updated regularly (Responsible: US NRC/PNNL with help of workshop participants).
2. JRC will issue, with the support of PNNL/US NRC, the proceedings of the European Engagement Workshop.
3. A global steering committee (GSC) will be established. It should have members from the three continents Asia, America and Europe plus IAEA, OECD-NEA and JRC - Euratom and all common reactor types around the world should be represented. Main responsibilities of the GSC is to draft terms of reference (ToR), draft a charter and to issue a working plan based on the information document of IFRAM originally issued by US NRC/PNNL.
4. PNNL will create a web page for IFRAM. Eventually there will also be a web page for the European section of IFRAM (possible responsible: JRC). The website of IFRAM should have a link to the web site of NULIFE.
5. The participants of the European Engagement workshop should think about setting up focus / work groups.

The above next steps were further discussed in the planning group meeting immediately following the workshop (see workshop agenda below). The planning group encompasses a smaller group of the workshop participants, who "paved the way" to the European Engagement Workshop through discussions in joint telephone conferences in the 9 months preceding the workshop. The planning group members attending the European Engagement Workshop had a smaller meeting immediately after the workshop to summarize its outcome and specify the details of the next steps. The planning group meeting was attended by US NRC, PNNL, EC-JRC, IAEA, NRI Rez and Slovenske Elektrarne. Based on the two discussions during the workshop itself the planning group approved the following:

Structure and Scope of IFRAM

IFRAM should be a network with unlimited duration, not a project with a fixed closure date. It should serve as a communication platform where participating organisations can exchange ideas and knowledge on materials degradation, AM and LTO of NPPs. Contributions to IFRAM are done in-kind. For the establishment and smooth running of IFRAM the experience from previous European Networks, e.g. AMES, ENIQ, NESC, etc., should be used. M. Bièth (JRC) offered to provide some documents of "European Network for Inspection Qualification (ENIQ)" (collaboration agreement, Terms of Reference) that can help to elaborate the IFRAM charter. Strong links with IAEA and NULIFE should be established.

Projects within IFRAM

Member organisations of IFRAM can form individual working groups for collaboration on specific (scientific) issues. These projects should have a limited duration with fixed dates for deliverables (decided by the Steering Committee). The output of these projects will only be distributed to the participating organizations in the project.

Global Steering Committee (GSC) of IFRAM

A GSC will be established for IFRAM. The following persons/organisations should be represented in the GSC:

- Ki-Sig Kang (IAEA)
- Alejandro Huerta (OECD-NEA)
- Prof. Tetsuo Shoji (Tohoku University, Japan)
- Prof. Il Soon Hwang (Seoul National University, Republic of Korea)
- Prof. Han En-Hou (Institute of Metal Research, Bejing, Peoples Republic of China)
- Vivekanand Kain (Homi Bhabha National Institute, India)
- Michel Bièth (EC - JRC)
- Rauno Rintamaa (NULIFE)
- Jan van der Lee (Materials Ageing Institute (MAI))
- Milan Brumovsky (NRI Rez, Czech Republic, representing VVER community)
- Andrei Blahoianu (Canadian Nuclear Safety Commission)
- Gene Carpenter (US NRC)
- Richard Reister (US Department of Energy (DOE))
- John Gaertner (Electric Power Research Institute (EPRI)
- Leonard Bond (PNNL, GSC Secretariat)

The first task of the GSC is the development of ToR, draft charter and a detailed working plan for IFRAM. Secretarial tasks within the GSC, e.g. updating web page of IFRAM, updating of matrix on projects on AM/LTO, etc…, are performed by PNNL.

Next Steps

Based on the above the planning group decided the following:

1. US NRC/PNNL will provide a draft template for the matrix on all on-going projects related to AM/LTO before the summer holidays, by 1st September 2010, at the latest. Feedback on the draft template should be provided within 30 days after its submission. A first draft of the matrix should be available by December 2010.
2. JRC will issue the 1st draft of the workshop proceedings by the 30th June 2010.

3. The GSC should be established within one month after the European Engagement Workshop and should have a first telephone conference on the 8th July 2010 and a side meeting during the PVP2010 conference. ToR, charter and work plan of IFRAM should be available by December 2010.
4. PNNL will create a web page for IFRAM. A link to NULIFE will be inserted. PNNL will also distribute a News Letter to all IFRAM members once per quarter.
5. The GSC should start soon after its establishment with arrangements for the start-up event of IFRAM. Envisaged date for start-up event is first half 2011.

Appendix 1: Workshop Agenda & Presentations of Participants

Tuesday 25th May 2010

Until 12:00 Arrival and registration of participants

12:00 Lunch

13:00 Welcome & Opening of Workshop: Joint Research Centre – Institute for Energy 2010 (M. Bièth, EC-JRC)

13:15 NRC Research to Support Regulatory Decisions related to subsequent License Renewal Periods inc. Concept of IFRAM (C.E. Carpenter, US NRC)

14:00 Presentation 1: International Forum on Reactor Ageing Management (IFRAM) – Views & Ideas of IAEA (K.-S. Kang, IAEA)

14:30 Presentation 2: AM/LTO activities of Tractebel (M. de Smet, Tractabel, Belgium)

14:50 Presentation 3: LTO in the Czech Republic (M. Brumovsky, NRI Rez, Czech Republic)

15:10 Presentation 4: AM / LTO Activities at VTT (Ms. P. Karjalainen-Roikonen, VTT, Finland)

15:30 Coffee Break

15:50 Presentation 5: The Materials Ageing Institute (J. van der Lee, MAI, France)

16:10 Presentation 6: Non-destructive characterization of the neutron embrittlement in reactor pressure vessel steel with electromagnetic testing (Ms I. Altpeter / G. Dobmann, IFZP, Germany)

16:30 Presentation 7: Ageing Management for Mechanical Systems, Structures and Components (SCC) in Nuclear Power Plants – Activities of MPA Stuttgart (M. Hoffmann, MPA, University of Stuttgart, Germany)

16:50 Presentation 8: Overview of LTO Experience in Hungary (F. Gillemot / Ms M. Horváth, AEKI, Hungary)

17:10 Presentation 9: Ageing Management and Long Term Operation of Spanish NPPs (I. Marcelles Ramirez, Tecnatom, Spain)

17:30 Presentation 10: The Modernisation and Power Upgrade Program of the NPP V2 Jaslovske Bohunice, Slovak Republic (I. Krajmer, Slovenske Elektrarne, Slovakia)

17:50 End day 1

Wednesday 26th May 2010

9:00 Presentation 11: LTO Activities at CIEMAT (Ms M. Serrano, CIEMAT, Spain)

9:20 Presentation 12: Long Term Operation Activities at the Institute for Nuclear Research, Romania (Ms M. Nitoi on behalf of V. Radu, INR, Romania)

9:40 Presentation 13: AM and LTO activities of SSM (B. Brickstad, SSM, Sweden)

10:00 Presentation 14: Ageing activities at Studsvik (J. Stjärnsäter, Studvik Nuclear AB, Sweden)

10:20 Presentation 15: AM / LTO activities of ENSI (K. Germerdonk, ENSI, Switzerland)

10:40 Coffee break

11:00 Presentation 16: Overview of IPS activities on mechanical testing, stress state and lifetime of RPVs, steam generators and piping of Ukrainian NPP units (V. Kharchenko, Institute for Problems of Strength, Ukraine)

11:20 Presentation 17: ASME-EPRI Long Term Operation (LTO) Workshop – Extending the life of current nuclear plants to 60 years and beyond (C.E. Carpenter on behalf of B. Nickell, ex-ASME, USA)

11:40 Presentation 18: Long Term Operation in Europe and associated Programs at JRC-IE (Ms C. Bruynooghe, JRC)

12:00 Presentation 19: The European NULIFE research network for plant life management (R. Rintamaa, VTT, Finland)

12:30 Lunch

14:00 Panel discussion on establishment of IFRAM (Need for int. forum, benefits, structure, organization, relationship with national and international organizations, intellectual property issues, etc…)

Topic A: Define the Benefits of the International Forum—what are the likely returns for those who participate?

Topic B: Describe ways national programs could be linked to the International Forum—how to leverage so that benefits are greater?

Topic C: Describe the best ways for International Forum to share and exchange information—Recommended “next steps” for cooperation.

Topic D: Develop matrix of individuals/organizations technical programs—who is doing what?

15:45 Coffee break

16:00 Resume of panel discussion on establishment of IFRAM

18:00 End day 2

19:30 Workshop dinner at Restaurant Zegels in Alkmaar

Thursday 27th May 2010

9:00 Panel discussion: Technical & scientific issues

- Ensure safe and secure plant life extension
- Establish technical basis for lifetime extension – Assessment of the state of the art
- Identify open questions and issues that require research and other activities
- Establishment of database for naturally and laboratory aged materials, particularly focused on beyond 40+ and 60+ years.
- …

10:30 Coffee break

10:45 Continuation of panel discussion on technical & scientific issues

12:00 Discussion, Next Steps, Closure of Workshop

13:00 Lunch

15:00 Departure of workshop participants to hotel/airport

15:30 Meeting of planning group to review results of workshop

17:45 Closure of planning group meeting

Appendix 2: List of Participants

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Abstract
In 2009 the US Nuclear Regulatory Commission (US NRC) together with the Pacific Northwest National Laboratory (PNNL) initiated the "International Forum on Reactor Ageing Management (IFRAM)". The aim of the forum is to consolidate the present knowledge on ageing management (AM) and long term operation (LTO) of commercial NPPs, identify open gaps and prioritize and even conduct the necessary R&D work to fill these gaps. IFRAM is seeking to share knowledge and data and to avoid duplication of work since human and financial resources for AM/LTO are limited. IFRAM should be an international forum with members from Asia, America and Europe and all common commercial nuclear reactor types around the world should be represented. An Asian Engagement workshop was held successfully in Seoul from 11th – 13th October 2009 to bring together Asian nuclear organisations & research institutes and US NRC & PNNL to further discuss the idea of IFRAM. The Asian Engagement workshop was followed by the European Engagement workshop held in Petten, the Netherlands from 25th – 27th May 2010 and hosted by JRC-IE. Similar to the Asian Engagement workshop the aim of the European Engagement workshop was to bring together European nuclear organisations & research institutes and US NRC & PNNL to further discuss the idea of IFRAM and open scientific / technical issues on AM/LTO. The European Engagement workshop was held successfully and this EUR report summarizes the presentations given by the workshop participants and the outcome of the two discussion sessions, i.e. establishment & benefits of IFRAM and scientific / technical issues on AM/LTO 60 years+ of NPPs.

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