6th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components
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Plenary Session
The Current International Position on Major Inspection Concerns

Developments in the USA: Looking to the Future

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ABSTRACT

This is an exciting time for the nuclear power industry. At the 5th International Conference in San Diego, May 2006, Dave Modeen (EPRI Vice President for the Nuclear Power Sector) made a keynote presentation about the "nuclear renaissance" that is gaining momentum worldwide. This renaissance includes two central features: plans for construction of new nuclear power plants, and renewal of the licenses of existing plants. EPRI's NDE Program is striving to perform the necessary research, development, and technology transfer to address the NDE needs of the nuclear renaissance, while continuing to support the traditional, ongoing NDE needs of the existing fleet.

The construction of new nuclear power plants presents the industry with an opportunity to plan, design, and build more intelligently than was done in the 1960s through 1980s. By designing components with inspection in mind, the inservice inspections can be accomplished with complete coverage and with high effectiveness, with a minimum of cost and radiation exposure. The use of materials with low susceptibility to inservice degradation and the application of preservice mitigations will serve to reduce the probability of degradation, and perhaps will justify longer intervals between inspections. Construction Code changes with a fitness-for-purpose philosophy may reduce the number of weld repairs during construction, which will save cost and improve resistance to cracking. Such a Code change will increase the importance of accurate location and sizing of fabrication and welding defects, which may lead to a necessity for a new performance demonstration program.

Utilities in the US are applying for renewal of their operating licenses from the original 40-year duration to 60 years. Some utilities are already working to identify the issues that must be addressed to extend the licenses further, to 80 years. Many of these issues involve NDE. Some of the NDE issues are familiar ones, for example examination of cast stainless steel piping; other issues concern plant components that have never before been part of the utilities' inspection plans. These emerging NDE needs include examination of small-diameter piping; examination of components to detect and characterize selective leaching of specific alloying elements; and examination of components to help the implementation of groundwater protection initiatives.

All of these emergent NDE needs will place even greater strain on an NDE workforce that is barely adequate to meet the needs of today's fleet. Over half of the highly-qualified NDE personnel in the USA are expected to leave the field within the next decade. Initiatives are being prepared to increase the coordination between the industry and educational institutions. The objective is to build a perception of NDE as a desirable, high-paying career: to make high-school students aware of the NDE profession; to support new and existing NDE programs at two-year vocational schools and four-year colleges; and to influence the curricula of these institutions such that they produce graduates who already have most of the qualifications that are necessary to perform nuclear NDE.

TODAY'S CLIMATE FOR NUCLEAR POWER IN THE USA

At the 5th International Conference in San Diego, May 2006, Dave Modeen (EPRI Vice President for the Nuclear Power Sector) made a keynote presentation about the "nuclear renaissance" that is gaining momentum worldwide. This renaissance includes two central features: plans for construction of new nuclear power plants, and renewal of the licenses of existing plants. Several factors are driving the resurgence of nuclear power in the USA.

Economic incentives instituted by the US government are helping utilities to make the decision to build new nuclear units. The Energy Bill of 2005 provides production tax credits and guaranteed debt financing for the first few units to be built. Risk insurance is available for the first few units, covering 100% of the cost of plant start-up delays due to regulatory action, up to a maximum of

USD500.000.000 per unit. Finally, the Energy Bill extends the Price-Anderson Act, a long-standing law in the US that guarantees the availability of insurance for reactor operators and limits their liability.

Utilities are very conscious of global climate change and the effects of greenhouse gas emissions. At present there is no “tax” on CO_2 emissions, but the utilities fully expect that one will be instituted in the near future. This will increase the cost of electricity generation for several generating technologies. Figure 1 shows the estimated cost of electricity for several generating options as a function of the cost of CO_2. The competitiveness of all coal-fired options is highly sensitive to this cost, but wind, biomass, and nuclear power are unaffected.

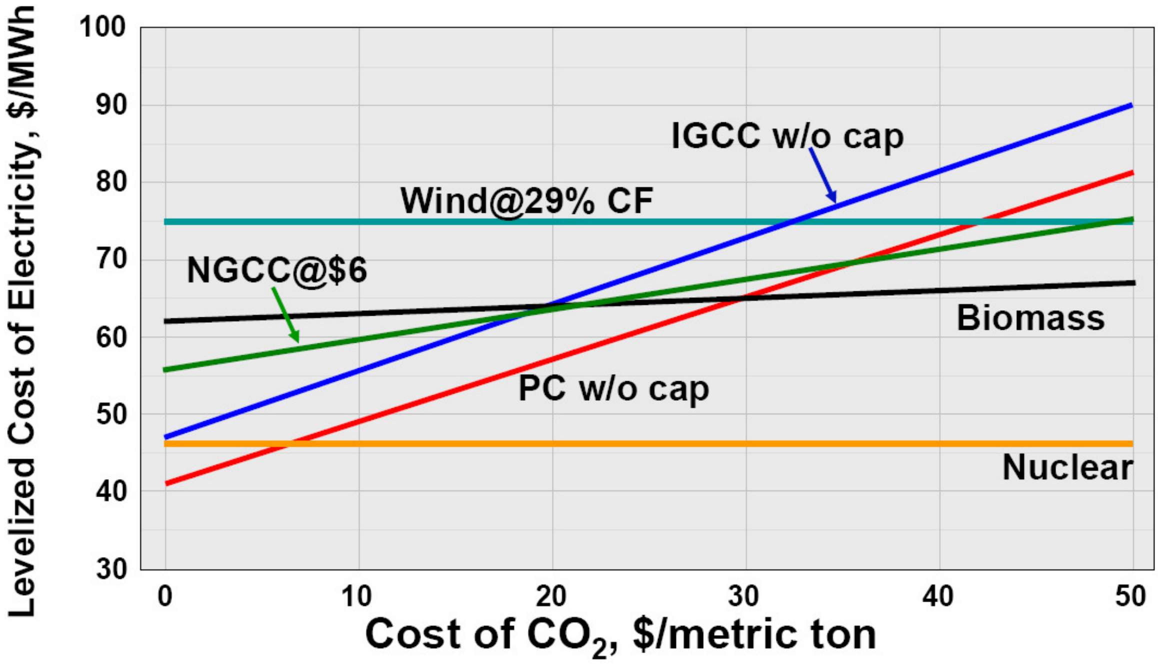
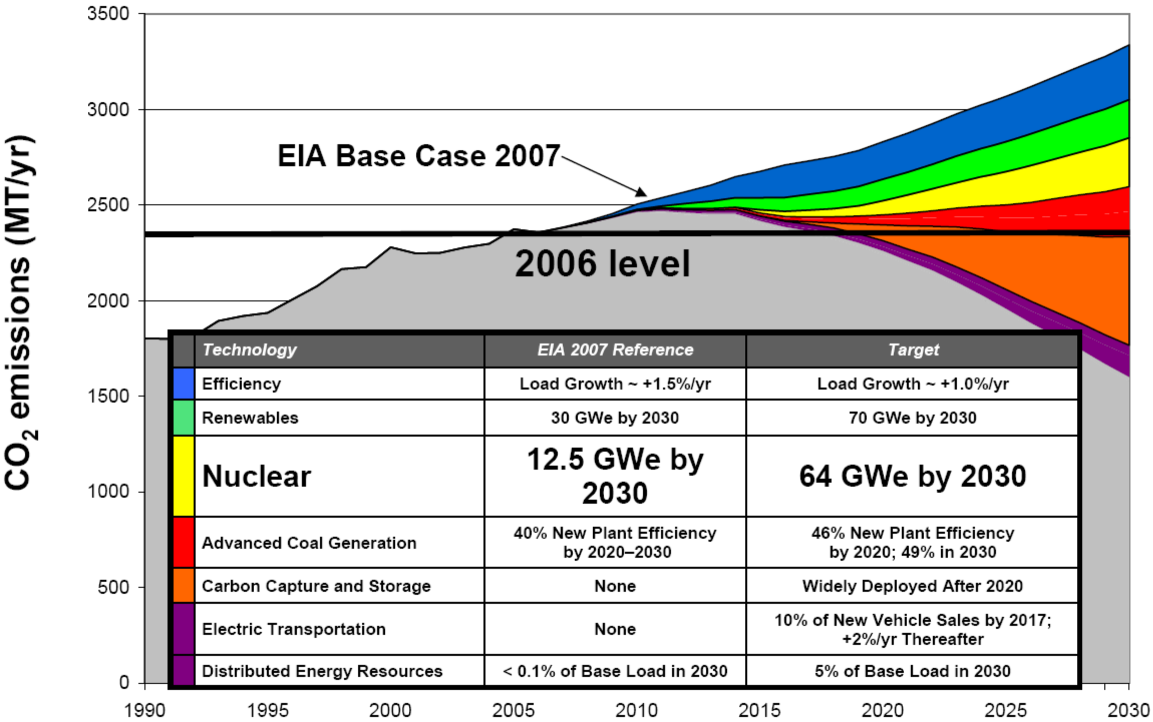


Figure 1 – Cost of electricity generation as a function of the cost of CO_2 emissions

EPRI has performed a detailed study of the technology deployments that would be necessary for the US to reduce its annual CO_2 emissions to the 1990 level, with a target date of 2030. Figure 2 shows the EPRI target emissions profile versus time, compared to the recent projection by the US Department of Energy’s Energy Information Agency, which predicts 2030 emissions to be double those of 1990. It is clear that aggressive deployments of all advanced energy technologies are necessary. In addition to nuclear energy, this includes end-use efficiency, renewables, advanced coal-fired generation, CO_2 capture and storage, plug-in hybrid electric cars, and distributed energy resources. The EPRI target for nuclear generation includes renewal of the operating licenses of all units to 60 years, plus deployment of 64MWe of new nuclear generation. This would be about 45 new units, considering the capacity of Generation III and IIIa designs.

In addition to the economic and environmental incentives, the public must be willing to accept new nuclear generation. The public view of nuclear energy has maintained a gradual increase in recent years, coupled with a decrease in the number of people who are adamantly opposed (Figure 3). One reason for the improvement is the increasing public concern about global climate change. Most of US electricity is generated by burning coal; the public is acutely aware of the high CO_2 emissions from coal and the zero-emissions generation provided by nuclear plants. The powerful environmental community is gradually moving toward acceptance – occasionally, enthusiastic acceptance – of nuclear energy as a necessary part of the CO_2 solution. Coupled with the public’s awareness of the need for clean energy is their understanding of the industry’s excellent safety record and reliable performance (Figure 4).

Extension of the licenses of all operating US reactors to 60 years is in progress. These license renewals are necessary to bridge the gap between the existing fleet and the new fleet. Figure 5 shows that the existing fleet's 40-year licenses are beginning to expire. By the time a substantial number of new units are on the grid, perhaps in 2020, half of the existing fleet would have exhausted their original licenses.



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.0%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	40% New Plant Efficiency by 2020–2030	46% New Plant Efficiency by 2020; 49% in 2030
Carbon Capture and Storage	None	Widely Deployed After 2020
Electric Transportation	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
Distributed Energy Resources	< 0.1% of Base Load in 2030	5% of Base Load in 2030

Figure 2 – EPRI target emissions profile to achieve reduction of CO_2 emissions to 1990 levels

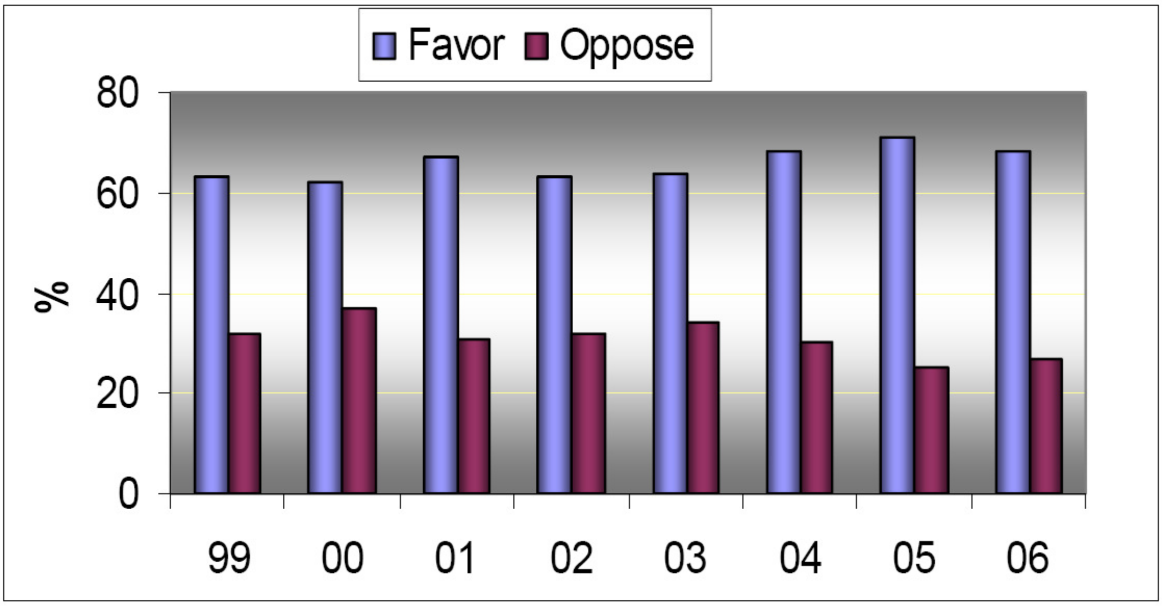


Figure 3 – US public views on nuclear power generation

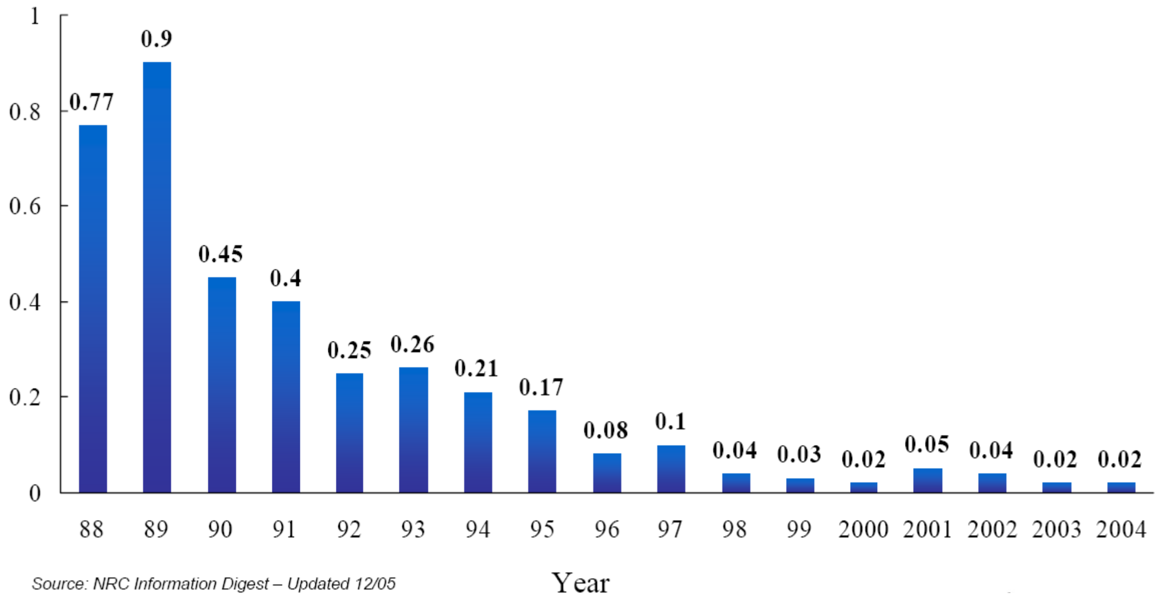


Figure 4 – NRC Significant Events

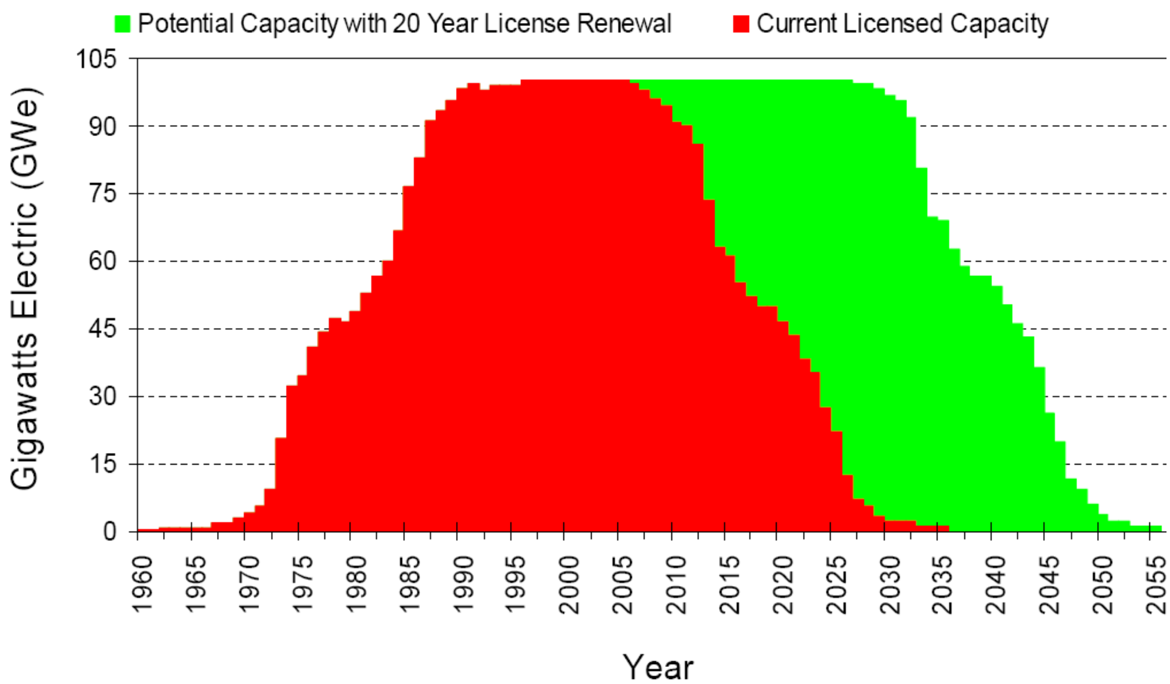


Figure 5 – License renewal to 60 years can bridge the gap between the current nuclear capacity and the contribution from new nuclear plants

NDE DEVELOPMENTS NEEDED TO SUPPORT LICENSE RENEWAL FOR THE EXISTING FLEET

License renewal applications are processed by the US Nuclear Regulatory Commission (NRC). Each application includes many commitments by the reactor operator to ensure the integrity of the plant systems and the plant's fitness to operate another 20 years. EPRI has compiled a database of over 2000 individual commitments based on the applications submitted to date. Many of these commitments are related to NDE and will require some degree of development.

Several commitments have been made with regard to effective volumetric examination of cast stainless steel components. Several studies performed during the past 30 years have concluded that ultrasonic examination of this material is exceedingly difficult. All of those studies have considered defect sizes of 10% to 50% of the wall thickness, and aspect ratios of 2:1 to 4:1. The material is actually quite flaw-tolerant, and EPRI is now developing guidance to determine the flaw size of interest, including the effects of thermal aging embrittlement. It is expected that the flaw size of interest will be much deeper than 50% through the thickness, and much longer than the flaws that have been used in prior studies. Such large target flaws suggest that ultrasonic solutions may yet provide adequate reliability. The cost of developing the flawed specimens necessary for technique development and for qualification programs will be high. Radiographic examination is a possible alternative, though development and qualification costs may also be high, and acceptance of radiography by plant radiation protection personnel can be a problem.

Selective leaching, or dealloying, of metals is a growing concern. This mode of degradation can take several forms: leaching of carbon from cast iron, or graphitic corrosion; leaching of zinc from brasses, or dezincification; leaching of nickel from copper-nickel alloys, or denickelification. Both ultrasonic and electromagnetic methods are appropriate for detection and characterization of these conditions.

Groundwater protection has become a highly visible issue for reactor operators in the US. Tritium leakage events at a few units, though well below the regulatory emissions limits, have garnered negative attention from the public, government, and environmentalists. EPRI has developed a guideline for utilities to use in developing their plant-specific groundwater protection programs. NDE developments may be needed for examination of buried piping, tanks, spent fuel pool liners, and other components that to date have not been the subject of NDE programs.

Utilities are beginning to consider license renewal beyond 60 years, probably to 80 years. The existing fleet, as it approached the expiration of its initial 40-year license period, is operating more reliably and more profitably than at any point in the past. If the fleet's condition and profitability is still robust at age 60, further renewal would be desirable. The US utilities and regulator are already beginning to consider the issues that must be addressed for operation beyond 60 years.

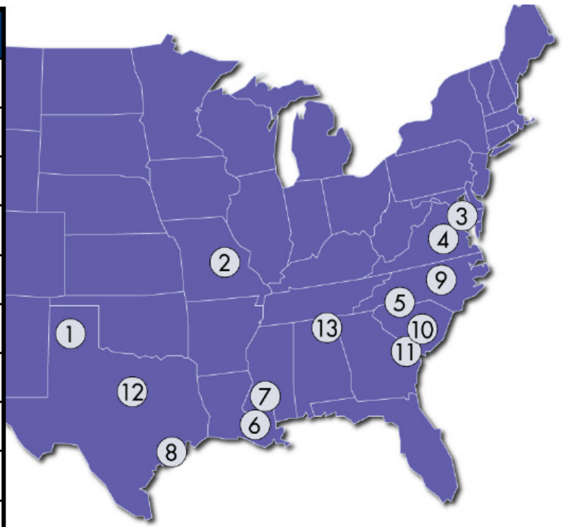
The familiar subjects of nuclear NDE programs, such as the pressure boundary and other passive metallic components, can have indefinite lifetimes, with an effective program of inspection, repair, and replacement. Even the reactor pressure vessel can be annealed or replaced; such action, while expensive, might be economically justifiable in order to achieve 20 more years of generation.

Life extension beyond 60 years will require assessment of safety-related concrete, including PWR containment buildings and BWR drywell support structures. The integrity of safety-related cabling will also be an issue of concern.

NDE DEVELOPMENTS NEEDED TO SUPPORT NEW NUCLEAR POWER PLANTS

Over 20 new nuclear units are in various stages of planning in the US. The licensing process begins with an early site permit, which is granted by the NRC to the individual utility, and with certification of the reactor design, which is granted by the NRC to the reactor vendor. Once a utility has its early site permit and has selected a reactor design, the utility applies to the NRC for a combined construction and operating license (COL). The first COL application was submitted to the NRC in September 2007 by NRG Energy. The application is for construction and operation of two General Electric ABWR units at the existing South Texas Project site. Many new reactors are expected, as shown in Figure 6. The utilities' plans evolve rapidly, so this Figure should not be taken as representing firm intentions.

	Design	Number of Units
1	EPR	1
2	EPR	1
3	EPR	3
4	ESBWR	1
5	AP1000	2
6	ESBWR	1
7	ESBWR	1
8	ABWR	2
9	AP1000	2
10	AP1000	2
11	AP1000	2
12	US-APWR	2
13	AP1000	2



Source: NEI

Figure 6 – Planned new reactors in the USA

Five different designs are expected to be built in the US. They include the General Electric ABWR and ESBWR; the AREVA EPR; the Westinghouse AP-1000; and the Mitsubishi US-APWR. Several NDE development needs have been identified for the new plants. In some cases, separate solutions may be necessary for the different plant designs.

The definition of inspection requirements must be developed. Some of the components of the new designs are of unfamiliar configuration, and their safety significance may be different from that of similar components in the existing designs. If possible, the reactor developers should be influenced to consider inspectability in component and weld design. This task is not as straightforward as one might think; the developers' driving motivation is often to minimize the fabrication and construction cost of the plant, and they might not be swayed by opportunities to reduce operation and maintenance costs (such as inspection) during plant operation. When unique and difficult configurations result, NDE technology development will be required.

Construction Codes should be modified to permit operation with structurally insignificant defects. During construction of the existing fleet, flaw-intolerant Codes required frequent and repeated repairs to many piping welds. These repair locations have been shown to be the most likely locations for degradation by stress corrosion cracking during plant operation. Regulatory acceptance of a flaw-tolerant construction Code will require support by reliable, qualified flaw detection, characterization, and sizing techniques. Current NDE qualification programs are focused on inservice materials degradation mechanisms. No qualifications are in place for detection and sizing of embedded fabrication defects.

Finally, the NDE workforce in the US is limited and is decreasing (Figure 7). The construction of new nuclear plants will increase the pressure on the NDE workforce. Additional workers will be required because of the high volume of construction examinations; also, many of today's experienced NDE workers will be attracted to the new construction NDE opportunities because of the limited requirement for travel. This will create even more pressure on an already strained workforce serving the needs for inservice inspection of the existing fleet.

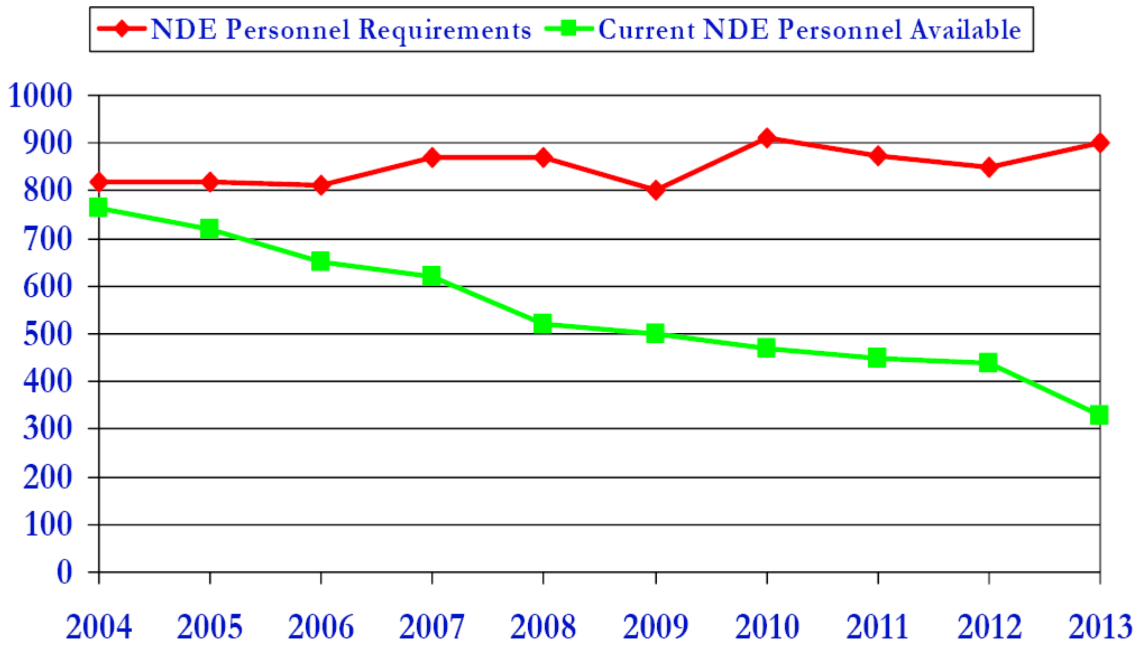


Figure 7 – Projected nuclear NDE workforce gap in the USA

EPRI has started an NDE Workforce Initiative to develop more new NDE workers. Part of this effort includes development of a streamlined process for meeting training and experience requirements, minimizing the time needed to produce a qualified nuclear NDE examiner. The initiative also includes collaboration with local community colleges to include nuclear NDE applications and topics in their NDE curricula.

CONCLUSION

This is an exciting time in the nuclear power industry. Many of us have worked with the understanding that the nuclear power industry would sustain us for the duration of our careers, but would disappear shortly thereafter. Now, in a very short period the global nuclear industry has been revitalized, due to economic and environmental factors. Existing nuclear power plants will operate for 60 years instead of the originally licensed 40, and likely will be operated beyond 60 to at least 80 years. Utilities' plans for construction of new nuclear units are growing and accelerating rapidly.

Many new NDE needs will come with operation of the existing fleet to twice its design lifetime, and with construction of a fleet comprising five new reactor designs. The NDE needs will include technical solutions, regulatory and Code changes to incorporate the lessons learned through operation of the existing fleet, and an increased workforce ready to address the diverse techniques and technologies that will be required to address those needs.

Plenary Session
The Current International Position on Major Inspection Concerns

Recent Development of Condition Monitoring Technique in Japanese Nuclear Industry

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ABSTRACT

Maintenance of SSC (System, Structure and Component) in nuclear power stations is closely associated with regulation by the nuclear safety authority. In the case of the Japanese nuclear industry, regulation is prescriptive where application of appropriate condition monitoring techniques for SSC has been very limited. On the other hand, those techniques have been used for many SCC in the US and Europe. In the last year and a half, the Japanese nuclear safety authority has organized the deliberation through several committees to replace the present inspection system with a new system that is a little bit performance based, while keeping most of the present prescriptive regulation. Reflecting on the current situation, condition based maintenance is ready to be used for SSC by adopting and applying condition monitoring techniques.

In this paper, the progress of condition monitoring techniques achieved by industries including chemical and steel making plants is reviewed. Some topics on new approaches based on the electromagnetic diagnostic method is then introduced as a mean to locate a portion of abnormal events and discriminate the type of events that occur. A principle of the electromagnetic method is the utilization of u x B motive force leading to the occurrence of an induced current. The induced current makes a magnetic field which can be detected by a coil sensor at a location outside of a machine case; signals reflect structural irregularity of rotating elements. It is difficult to specify a location of the irregular position whereas the electromagnetic method is able to do this. Application and details of the method will be explained in the presentation.

Plenary Session
The Current International Position on Major Inspection Concerns

Some European Trends in NDE for the Nuclear Industry

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ABSTRACT

In-service inspection by non-destructive testing continues to be an issue high on the agenda, not least shown by the interest in this conference. With ageing plants, life-extensions and opening of the electricity market it is as important as ever to maintain high safety and reliability of plants. This paper will review some of the trends and resent developments that can be observed in Europe.

Although "NDT qualification" is reaching maturity in Europe it is still seeing some significant developments. Within the European Network for Inspection and Qualification – ENIQ – developments continue on both areas of inspection qualification and risk-informed in-service inspection (RI-ISI).

In addition, a large international benchmark study of various RI-ISI methodologies, under the auspice of JRC and OECD, with more than 20 participating organisations, is well underway.

As Qualification Bodies in Europe has been established in most countries, significant experience has been gained over the years and the wish for stronger cooperation has been expressed. The "2nd International Workshop of Qualification Bodies", jointly organised by JRC and IAEA will be held in October 2008.

Finally, a recent FP6 study have highlighted critical needs for R&D in the fields of in-service inspection and continuous monitoring, which underpin the safe and economic operation of nuclear plant. The 33 organizations who defined their RTD needs through a questionnaire survey are key stakeholders from across Europe (utilities and safety authorities).

OVERVIEW OF ENIQ AND PROGRESS

History

ENIQ was set up in 1992 as the importance of the issue of qualification of NDE inspection systems (procedures, equipment and personnel) used in ISI programmes for nuclear power plants was identified. Driven by European Nuclear utilities and managed by the European Commission Joint Research Centre (JRC) in Petten, ENIQ was meant to be a network in which the available resources and expertise could be pooled at European level. The parties involved in ENIQ also recognized that harmonization in the field of codes and standards for inspection qualification would represent important advantages for all, with the ultimate goal of increasing the safety of European nuclear power plants.

A significant milestone was reached with the publication in 1995 of the first issue of the European Methodology for Qualification of non-destructive tests. The European Qualification Methodology Document (EQMD) contained guidelines for the qualification of non-destructive tests. Qualification as defined in that document is a combination of technical justification, which involves assembling mainly the following supporting evidence for test capability

- results of capability evaluation exercises
- feedback from site experience
- applicable and validated theoretical models
- physical reasoning) and test piece trials using deliberately defective test pieces.

This document was the first to be published in Europe on this issue and contained a number of innovative proposals such as the use of technical justification, the separation between procedure/equipment and personnel qualification and the use of non-blind trials for procedure and equipment qualification.

In April 1996 the European Regulators issued a common position document on qualification of NDT systems for pre- and in-service inspection of light water reactor components [1]. This official report of the Nuclear Regulator Working Group (NRWG), considered also the essential elements of the European Methodology and is, in general, in good agreement with the European Methodology. There were two major differences: firstly the European regulators discussed the issue of inspection qualification in a wide context of safety and secondly they placed different emphasis on the different elements constituting inspection qualification.

Since the first issue of the EQMD the issue of inspection qualification was discussed widely both at national and international level and some evolution in thinking occurred. The Steering Committee of ENIQ thus decided to conduct a first pilot study to explore ways of applying the European methodology for inspection qualification to a specific component. A number of important lessons were learned from this pilot study. All this led the Steering Committee of ENIQ to issue a second version of the EQMD, which was approved by the Steering Committee of ENIQ in February 1997.

In 1999, the final report of first pilot study was published. Between 1999 and now, ENIQ produced a series of eight Recommended Practices, i.e. documents supporting the high-level EQMD with more specific guidance, see Table 1.

Based on the results of the second ENIQ pilot study and based on experience feedback from applying the ENIQ methodology in Europe the Steering Committee decided to revise the European Methodology Document. This third issue of the EQMD [2] has been produced by ENIQ TGQ, and was approved for issue by the ENIQ Steering Committee. The main changes from Issue 2 are as follows:

- Updating of the foreword to reflect the much more mature status of qualification in Europe prevailing today
- Adding references to the text citing existing supporting Recommended Practices wherever possible
- Rewriting of Appendix 3 to summarise the content of Recommended Practices which have actually been issued
- Editorial changes and changes to clarify the text.

No changes to the actual principles of the European methodology have been made.

In 1999, ENIQ also recognized the importance of addressing at European level the issue of optimising inspection strategies on the basis of risk. Traditionally, strict regulations and codes specify the locations, frequency and methods of inspection based primarily on the type and safety class of the component. However, it has been recognized that many resources have often been spent inspecting sites of negligible risk for plant safety. On the other hand, practical experience and the use of probabilistic safety assessments have demonstrated that failures with high risk significance can occur at locations not covered by the traditional inspection programme. As the costs of qualifying and performing such effective inspections are very high, the effort must be targeted at the most risk-significant locations. For this reason, in 1996 ENIQ set up a sub-group in order to homogenize the different activities on RI-ISI for nuclear reactor safety and to develop a harmonized European approach to RI-ISI.

At the end of 2001, ENIQ members emphasized the need to strengthen the risk-related activities and to promote the full integration of RI-ISI into ENIQ. In connection with the reorganization of ENIQ working groups, this became Task Group on Risk (TGR). At the kick-off meeting of TGR, it was decided that the task group aims at establishing a common European framework on RI-ISI.

The European Framework Document for Risk Informed In-Service Inspection [3] is intended to serve as guidelines for both developing own RI-ISI approaches and using or adapting already established approaches to European environment taking into account utility-specific characteristics and national regulatory requirements.

Recent inspection qualification activities

A key achievement of ENIQ has been the issue of the European Qualification Methodology Document [2], which has been widely adopted across Europe. This document defines an approach to the qualification of inspection procedures, equipment and personnel based on a combination of technical justification (TJ) and test piece trials (open or blind). The TJ is a crucial element in the ENIQ approach, containing evidence justifying that the proposed inspection will meet its objectives in terms of defect detection and sizing capability. A Qualification Body reviews the TJ and the result of any test piece trials and issues the qualification certificates.

In order to test the European qualification methodology, two pilot studies have been conducted in which qualifications have been performed for inspections of mock-ups simulating specific plant components. The First Pilot Study, on an austenitic pipework weld, is complete and has been reported elsewhere (see e.g. [4]). A Second Pilot Study has been completed, for an automated ultrasonic inspection of a clad ferritic BWR-type nozzle-to-shell weld [5]. The aim of this study was to explore the potential of a TJ to reduce or remove the need for full-scale practical trials on mock-ups.

In this Second Pilot Study, a full-scale test piece containing artificially inserted defects was made to simulate the real component. A specification was drawn up of the defects which the inspection was required to find, and an automated ultrasonic inspection was designed to detect them. A TJ [6] was written which predicted whether the designated inspection would be successful in detecting the specified defects. The evidence in the TJ came mainly from physical reasoning, theoretical modelling and results from previous work. The effect of the cladding was quantified partly using new experimental measurements on a clad “parametric studies” block, and partly from existing evidence in the literature. The predictions of the TJ were then compared with experimental measurements taken on the defects in the test piece – these measurements simulated the actual inspection of the component.

This exercise was largely successful in demonstrating that TJs have the potential to predict the outcome of specific inspections and thus to reduce or remove the need for large-scale test pieces in qualification. However, the extent to which this can be done in practice will vary from case to case, depending on the difficulty of the inspection, the availability of relevant existing data and the ability and resources to generate new data which can be used in the TJ. The exercise also showed the value of theoretical modelling, but emphasised the importance of only using models which have been experimentally validated and using them within their regimes of validity, as reported in the 2nd Pilot Study final report [7].

Both the first and second pilot study, as well as the experience feedback from field-qualifications, led to a number of recommended practices and their revision.

RP number	Title	Issue no	Issue date	Report number
RP1	Influential/essential parameters	2	Jun 05	EUR 21751 EN
RP2	Recommended contents for a technical justification	1	Jul 98	EUR 18099 EN
RP3	Strategy document for a technical justification	1	Jul 98	EUR 18100 EN
RP4	Recommended contents for the qualification dossier	1	Feb 99	EUR 18685 EN
RP5	Guidelines for the design of test pieces and conduct of test piece trials	1	Feb 99	EUR 18686 EN
RP6	The use of modelling in inspection qualification	1	Dec 99	EUR 19017 EN
RP7	Recommended general requirements for a body operating qualification of non-destructive tests	1	Jun 02	EUR 20395 EN
RP8	Qualification levels and approaches	1	Jun 05	EUR 21761 EN
RP9	Verification and validation of structural reliability models and associated software to be used in risk-informed in-service inspection programmes		May 07	EUR 22228 EN
-	ENIQ Glossary	2	Dec 99	EUR 18102 EN

Table 1 - List of ENIQ Recommended Practices
(available on the ENIQ website http://safelife.jrc.nl/eniq/)

Meanwhile, the European Qualification Methodology Document is supported by nine issued Recommended Practices (Table 1), covering various aspects of qualification in more detail. All these documents provide guidance on conducting qualification, while retaining the flexibility to allow detailed variations in implementation between different countries.

Recent developments on Recommended Practices include a new issue of RP1 on influential and essential parameters, and the first issue of RP8 on qualification levels and approaches. A brief overview of these developments is given here.

RP1 was revised to simplify and clarify the recommended approach to the treatment of influential and essential parameters, following feedback from users on applying Issue 1. This is a good example of how the Recommended Practices are regarded as "living documents", to be reviewed periodically in the light of feedback from users.

The influential parameters are those parameters (for example defect orientation or probe beam angle) which can potentially affect the outcome of an inspection, while the essential parameters are those which could actually affect the outcome of a specific inspection in such a way that the inspection would no longer meet its objectives.

The main changes from Issue 1 of RP1 are:

- Combining the Procedure and Equipment Parameter Groups into a single Inspection System Group.
- Clarification that the non-inclusion of parameters which are clearly non-essential need not be justified in the TJ.
- Removal of the distinction between essential Inspection System parameters which are "fixed within a tolerance" and those "covering a range". Instead these parameters are categorised into so-called "Set 1" parameters (those which particularly affect the outcome of the inspection) and "Set 2" parameters (those which only affect the outcome if they differ substantially from their chosen values).

- Confirmation that the essential parameters should be listed in a table in the TJ, but with clarification of how each type of parameter (Input, Inspection System Set 1, and Inspection System Set 2) should be addressed.

RP8 is a new Recommended Practice on qualification levels and approaches. It recognises that some countries or organisations might wish to introduce the concept of different qualification levels, depending on the assurance required that the inspection would attain its objectives in demonstrating structural integrity. One method of setting the qualification level is using a risk-informed methodology, and the RP provides some guidance in doing this.

The qualification level in turn acts as one of the inputs in determining the qualification approach, that is, the range of qualification activities needed to achieve the desired qualification level. This qualification approach will depend on the difficulty or novelty of the proposed inspection as well as the qualification level itself. The chosen qualification approach will affect various aspects of qualification such as the realism of the test pieces used (full-scale, simplified, or flat plates), the requirements for the Qualification Body and the QA arrangements.

In a recent survey on harmonisation of nuclear safety among EU member states, the Working Party on Nuclear Safety" (working under the European Council) concluded that the ENIQ documentation is widely used throughout Europe. Further, the usefulness of the documentation was recognized by WENRA in their recent report on reactor safety reference levels 13].

Examples of recent developments in qualification in European countries

The ENIQ approach to qualification has now been widely adopted across Europe, including the new EU members, and many successful qualifications have been completed. Several countries have set up their own qualification bodies. ENIQ members regularly report to ENIQ Steering Committee meetings on developments in their individual countries under a standing item on the agenda. Recent reports include:

- An update on qualification work in Belgium on RPV and primary circuit welds, including Inconel safe-end welds.
- An update on the extensive qualification programme for VVER components underway in the Czech Republic.
- 10-15 qualifications underway in Finland, together with preparation of qualification of pre-service inspections at Olkiluoto 3, the new European Pressurised Reactor power station now under construction.
- Contacts initialised between Sweden and Finland to promote the mutual recognition of inspection qualification and intensify bilateral collaboration.
- A pilot study to investigate the feasibility of introducing the ENIQ qualification methodology in Germany has been successfully completed.
- A review of its activities by the Swedish Qualification Centre, which has now been in existence for 10 years.
- A 10-year timescale introduced in Switzerland in 2003 for the implementation of qualification.
- A qualification of the ultrasonic inspection of studbolts in boiler closure units at AGR power stations in the UK; also the qualified inspections of the Sizewell B RPV at the end of the first 10 years of operation.
- There are several papers at this conference, from the Czech Republic, France, Germany, Sweden and the UK, describing recent developments in individual countries in more detail.

Recent risk-informed in-service inspection activities

As mentioned above, ENIQ Task Group on Risk (TGR) has published the European Framework Document for Risk Informed In-Service Inspection [3], which forms a basis for its current activities. It might be worth mentioning that this document is one of the basic requirements when RI-ISI was developed in Finland for TVO3 (EPR under construction). Following the publication of the

Framework Document TGR is currently working on several RI-ISI related issues to develop Recommended Practices and discussion documents in support of a more detailed harmonisation in Europe:

- Defence in depth issues
- Verification and validation of structural reliability models (SRM) & codes
- Guidelines for expert panels
- Interaction between RI-ISI and inspection qualification
- Guidelines for use of PSA in RI-ISI
- Expert elicitation for degradation mechanisms
- RI-ISI application for internals, RPV
- Sensitivity and uncertainty analyses (both structural reliability models and PSA)
- Criteria, risk importance measures / risk acceptance criteria
- Justification of partial scope RI-ISI application
- The applicability of Code Case N716 in EU

A basic regulatory requirement when introducing RI-ISI is to maintain defence-in-depth. In order to elaborate its view on this issue, TGR has published "ENIQ TGR Discussion document on the role of ISI within the philosophy of defence in depth" [9]. The report discusses the role of the ISI programme (and connected activities) within the entire reactor safety programme, with special focus on the defence-in-depth philosophy for reactor safety. More specifically, the report deals with such issues as the tools and the processes used to determine pipe break frequencies, and gives a perspective on pipe break frequency's contribution to core damage frequency.

Following up on the FP5 project NURBIM, TGR members have elaborated and published ENIQ Recommended Practice 9: Verification and Validation of Structural Reliability Models and Associated Software to Be Used in Risk-Informed In-Service Inspection Programmes, see Table 1. Structural Reliability Models are commonly used to evaluate failure probabilities in the development of RI-ISI programmes. RP9 summarises the Verification and Validation requirements that should be met in order to be suitable for such purposes:

- The basic programming can be shown to have suitable quality assurance documentation.
- The scope, analytical assumptions and limitations of the modelling capability are well defined.
- The analytical assumptions are well grounded and based on theory that is accepted as representative of the situations considered by the given SRM.
- The model is capable of reproducing the data on which its analytical assumptions are based and examples are provided that can demonstrate its general agreement with the available experimental data.
- Attempts have been made to show how the model compares with the world or field data.
- The model has been benchmarked against other SRM models within the same field or scope and possible differences are adequately explained.

The Framework Document [3] recommends the use of Expert Panels (EP) to review the selection of safety-significant sites before the inspection programme is finalised. However, more detailed guidance was not provided and to this end, TGR is developing a soon to be published ENIQ Recommended Practice on the subject. This ENIQ recommended practice is supposed to assist a user involved in a RI-ISI application on how to form, plan and prepare, conduct, and document an expert panel whose final goal is making decisions concerning the inclusion or exclusion of sites from the risk-informed inspection programme. It also covers the role, responsibilities and composition of an EP. The development of guidelines for the expert panel process in this area has also been recommended by the Nuclear Regulatory Working Group, who explicitly advocates the use of Expert Panels in its report on the regulatory experience of RI-ISI [10].

In a joint project between TGR, JRC and the OECDs Nuclear Energy Agency (NEA), some 20 partners (utilities, regulators, R&D, vendors….) are performing a unique benchmark of various RI-ISI methodologies, applied to the same set of four piping systems of a Swedish PWR. The general objective is identifying the impact of such methodologies on reactor safety and how the main differences influence the final result, i.e. the definition of the RI-ISI programme. This project is also covering the 4 last bullets at the beginning of this section.

The project is divided into five application groups and four evaluation groups. The application groups are using the following methodologies on the defined set of four piping systems:

- Westinghouse Owners Group, both in original version, and with amendments/changes required by the Swedish regulatory body;
- SKIFS 1994 (a previous qualitative methods previously required in Sweden);
- EPRI methodology;
- Code Case N-716;
- And, as a comparison, the ASME Section XI approach, including augmented programme.

The four Evaluation Groups are each studying the following aspects:

- Scope of application
- Failure Probability Analyses
- Consequence analyses
- Risk ranking, classification and selection of segments/sites, definition of inspection programmes

A more detailed description of TGR work may be found in [8], these proceedings.

QUANTIFICATION OF NDE RELIABILITY

The output from the European inspection qualification process is generally a statement concluding whether or not there is high confidence that the required inspection capability will be achieved in practice, for the specified inspection system, component and defect range.

However, this process does not provide a quantitative measure of inspection capability of the type that could be used for instance in the connection of the risk-informed in-service inspection (RI-ISI) process. In a quantitative RI-ISI, a quantitative measure of inspection effectiveness is needed in determining the risk reduction associated with inspection. The issue of linking the European qualification process and a quantitative measure of inspection capability has been discusses within the ENIQ over several years. In 2005 the ENIQ Task Group on Risk decided to initiate an activity to address this question. A program of work was proposed to investigate and demonstrate an approach to providing some objective measure of the confidence which comes from inspection qualification, and allowing risk reduction associated with a qualified inspection to be calculated. The work plan focuses on following issues:

- Investigating sensitivity of risk reduction to POD level and detail;
- Investigating the use of user-defined POD curve as target for qualification;
- Testing a Bayesian approach to quantifying output from qualification;
- Linking qualification outcome, risk reduction and inspection interval;
- Pilot study of overall process, including a pilot qualification board.

The work is organised in a project "Link Between Risk-Informed In-Service Inspection and Inspection Qualification". The project is partly funded by a group of nuclear utilities. The project is presented in detail in a separate peper in these proceedings [11].

INSPECTION QUALIFICATION BODIES COOPERATION

Both in Europe and internationally there is now a wide implementation and in several countries long experience with Inspection Qualification. At several meetings and in reports over the last years qualification body members have asked for better ways to exchange experiences and cooperate. Ideas to form a "Qualification Bodies network" have also been aired. Thus, JRC took the initiative to a 1st International Workshop for ISI Qualification Bodies, which was organised in cooperation with IAEA in Petten, NL, November 2006. The objectives for the meeting were for QBs to exchange information and experience and to identify areas for cooperation. In total 33 persons from 18 countries around the world participated: ARM, BE, BU, CAN, PRC, CZ, FIN, FR, HU, RO, RU, SL, ES, SE, CH, UKR, US, IAEA, EC. In this 1st meeting it was shown that most countries have developed a qualification system and that the most widely applied methodology is ENIQ (in combination with IAEA in some countries) [12]. The workshop concluded with:

- a list of issues that arose from the workshop for future consideration,
- several recommendations/actions, and
- a strong desire to continue with the series of workshops.

The most important issues arising from the meeting were:

- Test piece fabrication
- Derivation of inspection objectives/technical specification
- IQ/PD in relation to plant life management
- Qualification levels/tiers
- Exchange of qualifications between countries
- Personnel qualification
- Relationship between IQ/PD and RI-ISI
- Improved harmonisation of qualification approaches

A 2nd Workshop for ISI Qualification Bodies was held in Budapest on 10-11 October 2007, hosted by the Hungarian Qualification Body and Paks NPP (and a 3rd one is planned in Vienna for 2008).

GAIN – ANALYSIS OF FUTURE R&D NEEDS FOR NUCLEAR PLANTS

The project GAIN - Gap Analysis for Long Term Inspection Needs of Nuclear Plant – was a so called Specific Support Action under FP6, aimed at identify needs for future Community RTD work.

Specifically, the purpose of GAIN was to establish an "END USERS wish list" of medium and long term R&D, by means of questionnaire. In this context "end users" were defined as utilities and regulators

The responses to the questionnaire gave a very good representation of the European situation base on replies from 23 utilities and 11 regulators in Europe, with a good distribution between various reactor types (AGR, BWR, PVR, VVER) and age. The questionnaire covered areas like:

- Inspection Qualification
- Development of NDT and monitoring techniques
- Inspection Strategies/RI-ISI for NPPs (e.g. RI-ISI)

The results show that there is strong consensus, with up to 95% agreement on the need for R&D in certain areas. For Inspection qualifications the most highlighted areas were:

- Defect simulation/manufacturing in test pieces (realistic, complex and simple defects)
- Recognition of qualifications between countries
- Computer simulations/modelling of NDT (ultrasonics, eddy current etc.)
- Influence of human and organisational factors (expressed by regulators)

For NDT and monitoring techniques, the most highlighted areas were:

- Penetrations and nozzles, dissimilar metal welds (IGSCC, PWSCC)
- Piping with Ni-alloy welds
- Piping, Stainless to Stainless welds

For Inspection Strategies/RI-ISI, the most highlighted areas were:

- RI-ISI for improved ISI effectiveness
- Benchmark of RI-ISI methodologies (strongest by regulators)
- Validation and Verification of probabilistic fracture mechanics / structural reliability models and codes used for probability of failure analysis
- Procedures for expert judgement/elicitation for degradation mechanisms

The GAIN results and conclusions have highlighted critical needs for R&D in the fields of in-service inspection and continuous monitoring, which underpin the safe and economic operation of nuclear plant. Several of the issues highlighted in the study are already being treated in various fora (as seen elsewhere in this paper).

CONCLUSIONS

In-service inspection continues to be an important issue, and attracts a lot of attention, shown by this conference and several reported activities in Europe.

Within the European Network for Inspection and Qualification – ENIQ – utilities, vendors, R&D etc continues to develop harmonised approaches for Inspection Qualification and for Risk-informed ISI. Inspection Qualification has been introduced broadly in Europe and the experience is used to continuously update the ENIQ methodologies and Recommended Practices. The widespread use of the ENIQ documents have been confirmed by an official survey on Nuclear Safety, performed under the European Council, and its usefulness has been confirmed by WENRA – Western Nuclear Regulators Association.

Specifically, a novel approach on how to perform ENIQ qualifications resulting in quantitative results, through a Bayesian approach, has been developed and tested, in a project that aims at developing the link between NDT qualification and RI-ISI.

RISMET

As inspection qualification bodies have been established in Europe and internationally, they have started a formal cooperation through a series of international Workshops.

A recent FP6 project – GAIN - highlighted critical needs for R&D in the fields of in-service inspection and continuous monitoring, which underpin the safe and economic operation of nuclear plant.

Additional information concerning ENIQ and its task groups and activities, as well as publications, can be obtained from the ENIQ website: http://safelife.jrc.nl/eniq/.

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