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Structural Integrity and NDE Reliability I

ENIQ International Activities on Risk Informed In-Service-Inspection

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ABSTRACT/SUMMARY

The European Network for Inspection and Qualification (ENIQ) is a utility driven network that works towards a harmonized European approach on reliable and effective in-service inspection (ISI). In particular, ENIQ task groups work on issues related to the qualification of ISI systems (task group on qualification, TGQ) and to risk-informed in-service inspection (RI-ISI) (task groups on risk, TGR).

After achieving a major milestone with the publication of the European Framework Document on RI-ISI in 2005, ENIQ TGR has been recently working at producing more detailed recommended practices and discussion documents on several RI-ISI related issues, such as defence-in-depth, guidance for expert panels, verification and validation of structural reliability models and RI-ISI application to pressure vessels and internals.

Another important activity initiated within ENIQ TGR and currently under development is a project aimed at linking Inspection qualification and RI-ISI, to investigate and demonstrate an approach able to provide some quantitative measure of the confidence derived from inspection qualification, and to allow risk reduction associated with a qualified inspection to be calculated.

Finally, TGR initiated in January 2006 a project together with the European Commission's Joint Research Centre and Nuclear Energy Agency of the OECD aimed at benchmarking RI-ISI methodologies (RISMET project). Several international organisations, utilities and regulators are participating in this project, which should reach a conclusion towards the end of 2007.

The aim of this paper is to review and explain these activities of ENIQ TGR.

INTRODUCTION

The purpose of Risk-informed in-service inspections (RI-ISI) is to achieve a coherent in-service inspection management by taking into account the results of plant-specific risk analyses in the definition of the inspection program. The key idea is to identify risk-significant locations where the inspection efforts should be focused.

RI-ISI methods are widely applied in US, where the US Nuclear Regulatory Commission has approved different methodologies as a valid alternative to ASME Section XI. In Europe the situation is traditionally different, as there are as many regulatory environments as there are countries with nuclear power plants in operation, thus implying a variety of ISI codes and standards and national guidelines.

The last few years have witnessed in several European countries a growing interest to move towards risk-informed approaches. Usually, the US methodologies cannot be adopted as such, since they have been originally developed to the American regulatory environment. Thus, activities are ongoing both to develop own methodologies and to adapt the US methodologies to comply with national requirements. In this framework, European regulators and utilities have established working groups to discuss RI-ISI related issues, to identify common views, and to agree on recommendations and good practices.

The European Network for Inspection and Qualification, ENIQ, is a utility driven network working towards a harmonized European approach on reliable and effective in-service inspection (ISI). Its Task Group on Risk (TGR) addresses questions related to RI-ISI. This paper summarizes the main activities of the ENIQ TGR.

ENIQ TASK GROUP ON RISK (TGR)

ENIQ was set up in 1992 as the importance of qualification of NDE inspection systems used in ISI programs for nuclear power plants was identified. Driven by European nuclear utilities and managed by the European Commission's Joint Research Centre (JRC) in Petten, the ENIQ network was set up so that the available resources and expertise could be pooled at European level. ENIQ has a Steering Committee (SC) with one voting member for each EU member country with nuclear plants, and for Switzerland.

In 1996, ENIQ recognized the importance of addressing at European level the issue of optimizing inspection strategies on the basis of risk. For this reason, ENIQ set up a sub-group (originally called Task Group 4, or TG4) in order to harmonize the different activities on RI-ISI for nuclear reactor safety and to develop a common European approach to RI-ISI. In 1999, the ENIQ TG4 produced a discussion document [1] which represented a first attempt at defining a European framework on 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, TG4 became the Task Group on Risk (TGR). At the kick-off meeting of TGR, it was decided that the task group would aim at establishing a common European framework on RI-ISI. Currently, TGR has about 20 members representing European nuclear utilities, research organizations and consultants.

As a result of the work of the TGR, the European Framework Document for Risk Informed In-Service Inspection [2] was published in 2005. It 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. This is described in the next section.

The activities of TGR have been complementary to the Task Force of RI-ISI set up by Nuclear Regulators Working Group (NRWG). The NRWG was an advisory expert group to the European Commission, composed of representatives from nuclear safety authorities and technical support organizations from EU member and candidate countries, with Switzerland participating as observer. The NRWG has published (2004) a document summarizing the common views of the European Regulators on RI-ISI [3].

More 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/.

CURRENT ACTIVITIES OF THE ENIQ TASK GROUP RISK

As the Framework Document [2] provides general principles without going in details in RI-ISI implementation, the TGR recognized the need to produce more detailed recommended practices and discussion documents on several RI-ISI related issues. The TGR identified a list of issues that would need further consideration within the group, and preliminary work plans for more than ten tasks were developed.

The benchmarking of various RI-ISI methodologies was identified as one of the top priorities. A project (RISMET) was successfully launched in co-operation with JRC and the OECD Nuclear Energy Agency (NEA). Under this item of work, four of the original work areas tasks were also integrated: (1) sensitivity and uncertainty analyses (both structural reliability models and PSA); (2) risk acceptance criteria and risk importance measures; (3) justification of partial scope RI-ISI application; and (4) the applicability of Code Case N716 in EU.

Work also significantly progressed under the following areas:

- Link between RI-ISI and inspection qualification
- Guidelines for expert panels
- Defence in depth issues
- Guidelines for the validation and verification structural reliability models

In the following we describe each of these activities in greater detail.

RISMET project: benchmarking of RI-ISI methodologies

Through the benchmarking of different RI-ISI methodologies it should be possible to identify how they impact reactor safety and whether they lead to significantly different results. Also, a benchmarking should result in the identification of critical paths, i.e. those phases in a methodology with the greatest potential to affect the outcome, and might suggest areas for further improvement.

Never so far there had been a direct comparison of different RI-ISI methodologies applied to an identical scope of components (system, class, etc.) and several international groups and committees gave recommendations and support for performing such a benchmarking of various RI-ISI approaches, among which for instance the US-NRC advisory committee on reactor safeguards (letter, May 16 2003); the Nuclear Regulators Working Group – Task Force on RI-ISI [3]; the ENIQ TG Risk (meeting in Petten, February 9-10 2005). Also, the OECD/NEA CSNI supported a proposal from the working group on Integrity and Ageing of Components to undertake a Benchmark study (meeting in Paris, December 2004).

A project for benchmarking RI-ISI methodologies, called RISMET, was initiated by TGR together with the JRC and NEA. A preliminary meeting of the RISMET project took place at JRC, Petten, in September 2005. The meeting confirmed the interest of several organizations, including nuclear utilities, regulators, consultants and international bodies, in carrying out the benchmark exercise. The kick-off meeting of the project was held on January 30-31 2006 in Leibstadt, Switzerland. The second meeting was held in Miami (US) on 7-8 November 2006 and the third meeting took place in Paris on 16-17 April 2007. The project funding is based on in-kind contributions. The project has more than twenty participating organizations from Europe, U.S., Canada and Japan, including also the IAEA. More than half of the participants are also members of the TGR. More information regarding the RISMET project can be found at http://safelife.jrc.nl/eniq/projects/RISMET.

RISMET project: Objectives and Scope

As stated above, the overall objective of the project is to apply various RI-ISI methodologies to the same case, i.e. selected piping systems in one nuclear power plant. The comparative study aims at identifying the impact of the differences in methodologies on the final results, i.e. the definition of the risk-informed inspection program. In addition, one objective is to identify how the various approaches fulfil requirements and recommendations put forward in the ENIQ Framework Document for RI-ISI [2], in the NRWG document [3] and the NURBIM project [4]. The benchmark should also provide a basis for further development of existing or new methodologies.

The Swedish Nuclear Power plant Ringhals (PWR) was considered as the preferred choice as the host plant, since a full scope WOG RI-ISI application has already been carried out at the plant.

Based on selected criteria, the selection of systems consisted of the Reactor Coolant System, the Residual Heat Removal System, the Main Steam System and the Condensate System. Three other systems were selected as optional, their analysis depending on the securing of additional funding.

RISMET project: Organization

The technical work of the project is organized in so-called Application and Evaluation groups. The Application groups are composed of participating organizations having knowledge and experience in one or more RI-ISI methodologies. These organizations should organize the application of methodologies on the selected scope. The Evaluation groups are composed of generalists and experts in specific areas will assess the safety impact and compare various aspects of the applications.

Analyses to be considered by the evaluation groups may include, but are not limited to the identification of differences in the analysis in all phases including results; the analysis of the importance of identified differences; and the comparison with more “traditional” inspection programmes, as well as the principles and recommendations of NRWG, ENIQ and NURBIM. The following four main evaluation groups were identified:

(1) Scope of application;
(2) Failure Probability Analyses;
(3) Consequence analyses; and
(4) Risk ranking, classification and selection of segments/sites; definition of inspection programs.

The JRC is acting as the technical coordinator of the project, and the NEA is providing secretarial support.

Link between RI-ISI and inspection qualification

The link between inspection qualification complying with the European Qualification Methodology [5] and a RI-ISI program has been identified by the TGR as an issue needing research efforts. Such a need was also expressed in the recommendations of the Nuclear Regulators Working Group (NRWG), [3].

The probability of failure is influenced by the inspection, and therefore the effectiveness of inspection is an important input for risk informed in-service inspection (RI-ISI) analysis. If a quantitative RI-ISI analysis is to be performed, then a quantitative measure of inspection effectiveness is needed in order to calculate the reduction in risk associated with inspection. A Probability of Detection (POD) curve would provide ideal data.

POD data is normally generated by performing practical trials on a large number of defects in test pieces. The probability of detection is then plotted against an appropriate defect parameter (usually, the defect's through-wall extent). From classical statistics it can be derived that, for instance, a minimum of 29 defects with the same parameter all need to be detected in order to establish a 90% probability of detection at a lower bound confidence of 95%. This provides just one point on the POD curve. Further, whilst it can be relatively simple to establish POD curves for NDT methods such as magnetic particle or dye penetrant testing (where the main parameter influencing detection is generally defect length), there are cases (i.e. for ultrasonic inspection, which is the main NDT method for ISI of nuclear plant) in which there are many variables affecting detectability, such as defect depth, length, location, tilt, skew, shape, and roughness.

In recognition of these limitations, the ENIQ approach to inspection qualification is based on a combination of technical justification and test piece trials. A technical justification involves assembling supporting evidence for inspection capability (results of capability evaluation exercises, feedback from site experience, theoretical models, physical reasoning, etc.). The balance between the various elements and the level of detail involved in qualification are judged separately for each case. The output from the ENIQ 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, the ENIQ methodology is not designed to provide a quantitative measure of inspection capability of the type that can be used by quantitative RI-ISI. It also means it is difficult to "benchmark" the confidence associated with any given inspection qualification.

A program of work was therefore 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 objectives of the project are to:

(1) investigate approaches to quantifying the confidence associated with inspection qualification;
(2) produce guidelines on how to relate inspection qualification results, risk reduction and inspection intervals;
(3) apply the guidelines in practice via a pilot study, and modify them as required based on the experiences from the pilot study; and
(4) provide a forum for focused discussion and agreement on the approaches and guidelines

The work done on the quantification of the ENIQ inspection qualification process by developing a Bayesian approach to combine the expert judgment of the qualification process with evidence from test piece trials is described in detail in another paper presented at this conference [6].

Guidelines for the validation and verification structural reliability models

Based on the outcome of NURBIM project, this ENIQ Recommended Practice (RP) was recently published as ENIQ report N. 30, EUR report 22228 EN, [7].

A Structural Reliability Model (SRM) is an engineering tool based in probabilistic fracture mechanics and used for calculating components and piping failure probabilities. Generally, these probabilistic analyses involve deterministic fracture mechanics procedures with random input variables, and require numerical techniques that are implemented in computer programs.

Any engineering model that attempts to describe a process or mechanism should be accompanied by suitable documentation and evidence of its ability to accurately perform the task. Verification is about demonstrating that the SRM/software does exactly what it was intended to do. Validation is about demonstrating that the SRM/software output is representative of the reality the program is trying to represent.

Guidance is given regarding for instance scope and basic modelling assumptions, experimental validation, comparison with industrial data (world data), benchmarking with other SRMs, and the role of expert judgement.

A summary of recommendations is also given:

1. The basic programming is shown to have suitable quality assurance documentation
2. The scope, analytical assumptions and limitations of the modelling capability are well defined
3. The analytical assumptions are well grounded and based on theory that is accepted as representative of the situations considered by the given SRM
4. 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
5. Attempts have been made to show how the model compares with the world or field data
6. The model has been benchmark against other SRM models within the same field or scope and possible differences are adequately explained

This RP can be downloaded from the ENIQ website: http://safelife.jrc.nl/eniq/.

Guidelines for expert panels

The European Framework Document for Risk Informed In-Service Inspection [2] recommends the use of Expert Panels to review the selection of safety-significant sites before the inspection programme is finalised. However, more detailed guidance is not provided.

ENIQ TGR has been recently working on a Recommended Practice (RP) which is intended to assist a user involved in a RI-ISI application on how to form, 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.

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 [3].

An expert panel can have a different role and composition, depending on the organisation and resources of the RI-ISI project. It could for instance be an independent review body, as described in the Framework Document, largely consisting of members external to the RI-ISI project. Alternatively, it could be a body intended for an internal review of the failure probability and consequence analyses, without large external involvement, with the aim of ensuring a systematic review of the analyses and a balanced utilisation of information and expertise from several disciplines in the decision-making process. Finally, it could be a body for a review of the risk ranking. The guidance offered in this RP is mainly targeted to the latter.

In this RP it is argued that an expert panel should verify that the estimated failure rates are consistent with plant operating history, that the classification among segments within a system and between systems is consistent and that uncertainties have been properly considered and treated. Further, it should review the selected piping segments in order to identify any proposed relaxations in inspection requirements from prior practices and assess their effect on the plant safety, giving at the same time due consideration to strategies other than inspection.

Different roles are identified, among which those of (1) the Decision maker; (2) the RI-ISI Project Leader; (3) the Panel Leader; (4) the Technical experts and (5) the Technical secretary. For each role, the RP identifies the main responsibilities.

Guidance is also given regarding the planning and preparation of the expert panel, for instance regarding the training for the participants, and the conduction of the expert panel sessions.

The RP argues that the decisions taken by the expert panel should be reached by consensus, i.e. unanimous acceptance or agreement. If a unanimous decision cannot be reached, the panel should identify the reasons behind the differing opinions, and whenever possible, the panel should take appropriate measures (for instance, obtain additional information, request additional analyses, etc.) to facilitate a convergence of the differing views.

A thorough record of the proceedings and of the final decisions should be kept, documenting in particular those instances when a consensus was not reached and the reasons why. Any member of the panel should have the right to have an opinion officially recorded.

This Recommended Practice is nearly ready for publication as EUR report N. 22234 EN.

Discussion document on Defence in depth

Another achievement of the ENIQ TGR was the publication of ENIQ report N. 29: the "ENIQ TGR discussion document on the role of in-service inspection within the philosophy of defence in depth", [8].

Developing a RI-ISI programme should involve evaluating the risk-informed inspection programme generated at the end of the analysis against the DID principle to see if more inspections are needed with a view to creating a more robust inspection programme. Unfortunately, DID concepts are used incorrectly in many applications, for instance by only looking at the effect on one single barrier. The document discusses how to apply DID concepts by looking at several DID levels.

Further, the report looks at the role of the in-service inspection 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 role of ISI within the defence-in-depth concept; the tools and the processes used to determine pipe break frequencies; and a perspective on pipe break frequency's contribution to core damage frequency.

The report concludes that the goals of defence-in-depth for ISI should be to:

- Ensure the validity of pipe break frequencies in the FSAR (Final Safety Analysis Report) studies;
- Focus on the risk-dominant piping and welds, by making extensive use of PSA studies;
- Optimise the ISI programme, on economic terms and in terms of doses to workers, for welds with high failure probabilities and low core damage frequencies;
- Establish an operating experience programme to find new failure mechanisms in piping with extremely low failure frequencies.

CONCLUSIONS

In this paper, we have summarized the current main activities of the Task Group Risk of the European Network for Inspection and Qualification. ENIQ TGR has recently published a set of supporting documents for the European Framework Document for RI-ISI, giving more detailed guidance on some issues related to the RI-ISI process.

An important TGR field of activity currently under way is also the benchmarking of different RI-ISI methodologies. Such benchmarking is organized in project called RISMET, coordinated by the European Commission's JRC and the OECD/NEA.

Finally, an area of significant work is the study of the interaction between RI-ISI and inspection qualification.

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