Structural Integrity and NDE Reliability I

Activities on RISK Informed In-Service Inspections within the ENIQ Network
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ABSTRACT

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). The ENIQ has two task groups: a Task Group on Qualification (TGQ), which works on issues related to the qualification of ISI systems, and a Task Group on Risk (TGR), which is focused on risk-informed in-service inspections (RI-ISI).

After publishing the European Framework Document on RI-ISI in 2005, ENIQ TGR has been working at producing more detailed recommended practices and discussion documents on several RI-ISI related issues. The following reports have been issued: Discussion document on the role of ISI within the philosophy of defence-in-depth; Recommended practice on verification and validation of structural reliability models (SRMs) and associated software to be used in RI-ISI programmes; Recommended practice on guidance on expert panels in RI-ISI; Discussion document on application of RI-ISI on reactor pressure vessel.

Work is ongoing to develop a discussion document on updating of RI-ISI programmes, and new initiatives were recently launched to study topics such as what magnitude of risk reduction is reasonable to achieve through ISI, how to set inspection targets following the selection of ISI sites, and how to produce detection probability estimates for ISI.

In addition, TGR has been active in initiating international projects linked closely to its work, such as the JRC-OECD/NEA co-ordinated RI-ISI benchmark exercise (RISMET), and the project on the relation between inspection qualification and RI-ISI.

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 two 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. During the last years there has been a growing interest to move towards risk-informed approaches in several European countries. 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. TGR has continued its work by developing support documents for the Framework Document. These recent activities are described in the next section.

More information about ENIQ, its task groups and activities, and publications, can be obtained from the ENIQ website: http://safelife.jrc.ec.europa.eu/eniq/

RECENT AND ONGOING ACTIVITIES OF THE ENIQ TASK GROUP RISK

The RI-ISI Framework Document [2] provides general principles on the RI-ISI process, but does not go in details in RI-ISI implementation. After the publication of the Framework Document, the TGR agreed upon the need to produce more detailed recommended practices and discussion documents on several RI-ISI related issues. Since 2005, the TGR has published reports on following topics:

- Guidelines for the validation and verification structural reliability models
- Defence in depth issues
- Guidelines for expert panels
- Role of ISI of the reactor pressure vessel

Work is ongoing to develop a discussion document on updating of RI-ISI programmes, and new initiatives were recently launched to study topics such as what magnitude of risk reduction is reasonable to achieve through ISI, how to set inspection targets following the selection of ISI sites, and how to produce detection probability estimates for ISI.

In addition to these activities, the TGR has initiated two separate projects that required larger resources and had participants also outside the TGR. As the benchmarking of various RI-ISI methodologies was identified as one of the top priorities of the TGR, a project was successfully launched in co-operation with JRC and the OECD Nuclear Energy Agency (NEA). A project on the relationship between RI-ISI and inspection qualification was also organised separately and funded by a group of European nuclear power utilities.

In the following, these activities and projects are described in more detail.
**Guidelines for the validation and verification structural reliability models**

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.

As SRMs are used to numerically assess the piping failure potential in quantitative RI-ISI approaches, the TGR decided to publish guidelines on the verification and validation of SRMs and associated software. This ENIQ Recommended Practice (RP) was published in 2007 as ENIQ report N. 30 [3], and it is largely based on the outcome of the NURBIM project [4].

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

**Discussion document on defence in depth**

Another achievement of the ENIQ TGR in 2007 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", [5].

Defence in Depth (DiD), which may be expressed in simple terms as the provision of several levels of protection against potentially significant faults or failures, is a well established concept in the European nuclear industry. The discussion document acknowledges that a RI-ISI programme should be evaluated to ensure that defence in depth is maintained. 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 discusses 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.
**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.

In 2008, ENIQ TGR published a Recommended Practice (ENIQ report 34, [6]) 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 [7].

The role and composition of an expert panel may vary, and may be an integral part of the RI-ISI team or an independent body. The role of the expert panel will generally be to conduct a systematic review of the risk analyses and to check that the multi-disciplinary information and expertise supporting the decision-making process is well balanced. Particular subjects for review may include failure probability and consequence analyses, or a review of the risk ranking. The guidance provided in the RP mainly concentrates on a review of the risk ranking, but notes that a similar approach can also be adopted for reviewing the final selection of inspection sites, periodic re-assessments and the impact of PSA updates on the RI-ISI programme.

The RP gives recommendations on the composition of an expert panel. 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 decisions taken by the expert panel should be reached by consensus, but 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. The report emphasizes the importance of a thorough record keeping of the panel discussions and the final decisions. In particular those instances when a consensus was not reached, and reasons why, should be well documented.

**Discussion document on the role of ISI of the reactor pressure vessel**

In terms of plant safety, the reactor pressure vessel (RPV) is the most critical pressure boundary component in light water reactors. The RPV represents a barrier against fission-product release, supports control rods and vessel internals, provides coolant around the reactor core and directs reactor coolant to the steam generator (PWR) or steam to the turbine (BWR).

The European Framework Document for RI-ISI [2] focuses on piping, but it does not exclude its application to the RPV. In 2008, ENIQ TGR published the ENIQ report 35: “Discussion document on the role of in-service inspection of the reactor pressure vessel” [8], which discusses the application of an RI-ISI strategy to the RPV.

There are few known damage mechanisms affecting the RPV, and for many locations there are no identified damage mechanisms. Thus, when considering a structural element of the RPV, such as a weld, it is typically concluded that the consequence of a structural failure are high and the probability of such a failure is low. If an inspection programme were to be specified solely on the basis of risk, this may suggest that the RPV should be excluded from an inspection programme. However, it is generally the case that stringent inspection requirements are maintained for the RPV due to the potentially high consequences of failure.
The Framework Document [2] acknowledges the special situation of inspection sites with a high consequence and a low probability of failure and recognizes that a problem of confidence can arise if the component’s probability of failure is well below the area for which there is any practical experience. It states that any inspection in this area is intended to provide additional confidence in the assessed probability of failure and provides an element of conceptual defence in depth.

Based on experience reported in the discussion document, the following conclusions are drawn:

• the consequences of failure of the RPV are high. As part of the second level of Defence in Depth, in-service inspection of the RPV should be used where it gives as large a benefit as possible to reduce the risk for rupture or leakage,
• RI-ISI as outlined in the ENIQ Framework Document [2] is applicable for planning and performing in-service inspection of the RPV,
• experience based on known damage mechanisms, the probability of failure and the capability of in-service inspection to reduce the probability of failure, clearly indicates that inspection effort should be aimed at relatively high-risk locations,
• the consequences of RPV failure are high and the probability of RPV failure is low. Accordingly, special consideration should be given when identifying inspection requirements for the RPV.

On-going TGR work

The TGR holds meetings regularly twice a year. At the meetings, the progress of on-going tasks is reported, and new initiatives discussed. At present, work in going on in following tasks:

• Discussion document on RI-ISI feedback and updating
• Discussion about what magnitude of risk reduction that is reasonable to achieve through ISI
• Guidance regarding how we set inspection targets, following the selection of ISI sites
• Guidance on different ways to produce POD for ISI

Of these tasks, the discussion document on RI-ISI feedback and updating is in the most advanced stage. A draft report has been written, and the work should be finalised during 2009. The document is meant to assist a user involved in a RI-ISI application on how to maintain and update a RI-ISI programme. The document provides also an overview of current ISI updating practices in the majority of EU member states having operating nuclear power plants.

RISMET project: benchmarking of RI-ISI methodologies

In 2005, a project for benchmarking RI-ISI methodologies, called RISMET, was proposed by TGR together with the JRC and NEA. Several organizations, including nuclear utilities, regulators, consultants and international bodies, showed interest and support in carrying out the benchmark exercise, and the project was carried out 2006-2008. The project funding was 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. The JRC acted as the technical coordinator of the project, and the NEA provided secretarial support.

The overall objective of the project was to apply various RI-ISI methodologies to the same case, i.e. selected piping systems in one nuclear power plant. The comparative study aimed at identifying the impact of the differences in methodologies on the final results, i.e. the definition of the risk-informed inspection program.

The scope of the benchmark included four piping systems of The Swedish Ringhals 4 PWR unit. Various RI-ISI approaches and the deterministic ASME XI ISI selection were applied to these systems. The results of the applications were analysed and compared by evaluation groups, who addressed following issues: (1) scope of the application; (2) failure probability analyses; (3) consequence analyses; (4) risk ranking, classification and selection of segments/sites, and definition of inspection programs; and (5) regulatory aspects.
The final report of the project should be finalised during 2009. The RISMET project and its main results are described in more detail in another paper presented at this conference [9].

Link between RI-ISI and inspection qualification

The link between inspection qualification complying with the European Qualification Methodology [10] 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. The ENIQ methodology for inspection qualification [10] can provide assurance that an inspection system will achieve its objectives. 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.

A project was established with the following objectives:

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

The project was completed in 2008, and its results are summarised in ref. [11]. The project is also described in another paper presented at this conference [12].

CONCLUSIONS

In this paper, we have summarized the recent main activities of the Task Group Risk of the European Network for Inspection and Qualification. After publishing the European Framework Document for RI-ISI in 2005, ENIQ TGR has published a number of supporting documents giving more detailed guidance on some issues related to the RI-ISI process. In addition TGR has been active in international RI-ISI projects, including a RI-ISI benchmarking exercise coordinated by the European Commission’s JRC and the OECD/NEA, and a project investigating the relation between inspection qualification and RI-ISI.

REFERENCES