NUGENIA
Nuclear Generation II&III Alliance

ENIQ Position on

Review of the current ENIQ Suite of Documents on Risk-Informed In-Service Inspection (RI-ISI) and Proposal of a Roadmap for RI-ISI Development

ENIQ Report No. 69

August 2023

ENIQ
European Network for Inspection & Qualification
NUGENIA Technical Area 8

SNETP Association

c/o EDF

Avenue des Arts 53B, 1000 Brussels, Belgium

Email: secretariat@snetp.eu

Website: www.snetp.eu

This document was prepared by the SNETP Association.

Brussels: The SNETP Association

ISBN 978-2-919313-36-5 (pdf)

ISBN 978-2-919313-36-5 (print)

Executive Summary

This position paper / discussion document has been developed as a consensus document amongst the members of NUGENIA Technical Area 8 (TA8) – European Network for Inspection and Qualification (ENIQ), and specifically the Sub-Area for Inspection Effectiveness (SAE). The main objective of this discussion document is to review the current suite of Risk-Informed In-Service Inspection (RI-ISI) documents and provide a roadmap of future activities of the SAE group. The first priority of the group is to support the extension of RI-ISI principles from piping systems to pressure boundary components (e.g. vessels and valves) such that methods would be applicable to a significantly wider scope of components. Other near-future activities include the production of guidance material on the safety benefits achievable via risk-informed approaches for ISI planning, and risk-informed optimisation of Pre-Service Inspections (PSI) and ISI for modular reactors in the longer term. ENIQ SAE will also maintain the European Framework Document for RI-ISI as required.

Index

1. Introduction

The current objective of the European Network for Inspection and Qualification (ENIQ) Sub-Area for Inspection Effectiveness (SAE) is the development of Risk-Informed (RI) methods for the non-destructive inspection (e.g. In-Service Inspection (ISI), Pre-service Inspection (PSI)) of nuclear plants, and the production of guidance material and discussion documents to facilitate the application of such methods.

Since 2001 SAE has produced 13 ENIQ reports [1] which discuss and provide guidance on RI-ISI approaches both holistically and focusing on several more specific aspects. The methods and guidance material published by SAE is mature and has been applied by several nuclear utilities across Europe during the development and implementation of RI-ISI schemes. Although the European Framework Document for Risk-Informed In-Service Inspection (RI-ISI) (ENIQ report no. 51) [1] provides a general framework for the development of RI-ISI approaches or the adaptation of established approaches, the focus of the framework has been the application of RI-ISI methods to piping systems. Whilst the Framework Document acknowledges that the RI-ISI approach is not limited to piping systems, piping systems remain the main area for the application of RI-ISI, in particular the inspection of piping welds. Nevertheless, it is also recognised that it is possible to apply the principles of RI-ISI to any pressure boundary component. There is therefore considerable scope to expand the work of SAE.

The objectives of this discussion document are to:

- Present and justify the work priorities of SAE.
- Review the current suite of ENIQ documents relating to RI-ISI to identify areas that require further development or formulation to facilitate the extension of RI-ISI to pressure boundary components or close any gaps in guidance material. A more detailed analysis is also reported which identifies where the current philosophy, tools and methods need further development to extend RI-ISI beyond piping systems, i.e. to non-piping pressure boundary components (e.g. vessels and valves).
- Review the recent NUGENIA Vision document [2] for work priorities relevant to SAE and incorporate relevant items into the future work priorities for SAE.

2. Overview of the ENIQ Suite of RI-ISI Documents

ENIQ report no. 21 (Discussion Document on Risk-Informed In-Service Inspection of NPPs in Europe) [3] was published in December 2000[2]. The report represented the consensus view of SAE on RI-ISI and was a precursor to the development of the first issue of the RI-ISI Framework Document (ENIQ report no. 51) in 2005 [1].

Since the issue of these documents, SAE has produced a suite of documents that support the Framework Document. These documents are listed below and the content of each report is summarised in Appendix 1. The Framework Document was revised in 2019.

[1] Formerly ENIQ Task Group for Risk (TGR) (2002-2011) and ENIQ Task Group 4 for RI-ISI (1996-2001), For simplicity, in this Discussion Document the reports produced by ENIQ TGR and other predecessors of SAE are referred to as ENIQ SAE documents.

[2] This report was produced under the framework of the EURIS Concerted Action (European Network for Risk-Informed In-Service Inspection), funded by the European Commission, Directorate General Research. The document was produced by Task Group 4 on Risk-Informed In-service Inspection of the ENIQ, a predecessor of SAE.

Framework Document

- ENIQ report no. 51. European framework document for risk-informed In-service inspection. Issue 2 [1]

Recommended Practices (RPs)

- ENIQ report no. 53. ENIQ Recommended Practice 11 (RP11): Guidance on Expert Panels in Risk-Informed In-Service Inspection. Issue 2 [4];
- ENIQ report no. 52. ENIQ Recommended Practice 9 (RP9): Verification and Validation of Structural Reliability Models and associated Software to be used in Risk-Informed In-Service Inspection Programmes. Issue 2 [5].

Position Papers/Discussion Documents

- ENIQ report no. 21. Discussion Document: On Risk-Informed In-Service Inspection of Nuclear Power Plants [3];
- ENIQ report no. 29. Discussion Document on the Role of in service inspection within the philosophy of defence in depth [6];
- ENIQ report no. 35. Discussion Document: On the Role of In-Service Inspection of the Reactor Pressure Vessel [7];
- ENIQ report no. 37. Discussion Document on Updating of risk-informed inspection programmes [8];
- ENIQ report no. 46. Discussion Document on Risk Informed In-Service Inspection: An overview for the non-specialists [9].

Technical Reports

- ENIQ report no. 36. Link between risk-informed In-service inspection and inspection qualification [10];
- ENIQ report no. 41. Probability of detection curves: statistical best practices [11];
- ENIQ report no. 47. Influence of sample size and other factors on hit/miss probability of detection curves [12];
- ENIQ report no. 48. Lessons Learned from the Application of Risk-Informed In-Service Inspection to European Nuclear Power Plants [13];
- ENIQ report no. 67. Extending Risk-Informed In-Service to General Mechanical Components – Benefits and Challenges [15].

Other

- NEA/CSNI/R(2010)13. EC-JRC/OECD-NEA Benchmark Study on Risk Informed In Service Inspection Methodologies (RISMET) [3] [15]

[3] Project initiated by ENIQ TGR together with OECD-NEA, with substantial participation of ENIQ TGR members.

3. Priorities for Future SAE Work

The topics for the future activities of the SAE group arise from the experiences and needs of practitioners of RI-ISI and relevant regulators. However, these suggested topics must also reflect the work done so far, any gaps in existing guidance, and the R&D challenges reported in the recent NUGENIA Vision document [2].

A review of the following topics is reported to consider these issue and provide a basis for recommending the future work of SAE:

- Coverage of the existing SAE Suite of RI-ISI documents to capture any gaps in coverage that are recommended as the subject of future work;
- Consider the extension of the scope of SAE Suite of RI-ISI documents and methods;
- Review of RI-ISI related NUGENIA R&D challenges and to capture SAE's view on the relative priority of these topics.

3.1. Coverage of the ENIQ Suite of RI-ISI Documents

The suite of RI-ISI documents consists basically of two types of documents: 1) holistic / generic documents to discuss the RI-ISI process and its applications, 2) more specific documents addressing certain technical issues in the RI-ISI process.

In the following the SAE suite of documents is reviewed from three perspectives:

- Coverage of SAE guidance material for the various steps in a RI-ISI process;
- The need to extend the scope from the "core business", i.e. RI-ISI for piping of operating nuclear power plants (NPPs);
- The need to widen the target audience of SAE documents.

3.1.1. Coverage of ENIQ Guidance Material for the RI-ISI process

Figure 1 illustrates how the more technical SAE documents cover the various phases of a RI-ISI process.

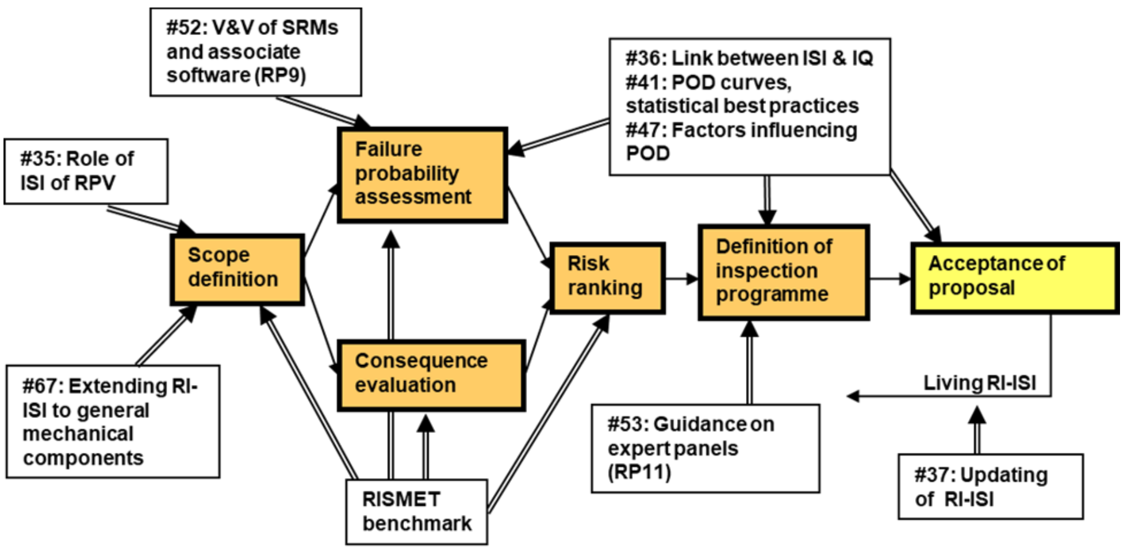

Figure 1. SAE documents supporting various steps of a RI-ISI process

It can be seen that all steps are addressed in at least one supporting document, or in the RISMET benchmark. This is in line with the SAE group's view that there is no urgent need to produce a new supporting document on a specific topic. However, the need to update or complement existing documents could be identified with more detailed analysis. Below we briefly elaborate on two specific topics, namely:

- Development of Links between the European Framework Document for RI-ISI and the European Methodology for Inspection Qualification;
- Probability of Detection (POD) Methods.

Development of Links between the European Framework Document for RI-ISI and the European Methodology for Inspection Qualification

The Framework Document [1] discusses Inspection Qualification (IQ) and notes that *'An essential input to the ENIQ qualification process is the identification of appropriate inspection qualification requirements defining the defects of concern for which the capability of detection and sizing is to be demonstrated'*. The requirement for inspection qualification are discussed further in the European Methodology for Inspection Qualification [16].

A very important aspect of ensuring that any RI-ISI programme is effective in reducing the likelihood of failure at a particular location is ensuring that the IQ requirements focus on the identified dominant damage mechanism (e.g. thermal fatigue cracking, stress corrosion cracking, flow accelerated corrosion) at a particular location and the level and rigour of IQ is appropriately selected. ENIQ Sub-Area for Qualification (SAQ) has produced RP8 Qualification Levels and Approaches [17] and this facilitates a qualification approach based upon risk. It is recommended that further work is carried out to consider the benefits of the application of the principles described in RP8 [17] within RI-ISI programmes.

Investigation of how the principles described in RP8 [17] could be implemented during any RI-ISI programme and the factors that should be considered when selecting the qualification level and approach for RI-ISI are therefore recommended for further work.

Probability of Detection (POD) Methods

There has also been previous work within SAE on POD methodologies to quantify the benefits of an inspection based upon the assessed Probability of Failure (POF). Successful development of an accepted POD methodology would be beneficial for quantification of risk reduction. Further work in this area is recommended to provide a better understanding of the potential benefits of using POD values within RI-ISI programmes, the challenges associated with producing robust values for POD, and the potential impact on RI-ISI programmes using those values as inputs.

Consideration should therefore be given to developing further the previous work within SAE on POD methodologies to quantify the benefits of an inspection upon the assessed POF. Successful development of an accepted POD methodology would be beneficial and facilitate the application of qualification levels and the targeting of RI-ISI.

3.1.2. Extension of the Scope of RI-ISI

SAE completed initial work on the extension of RI methods to mechanical components in 2021, and published ENIQ report no. 67 on the benefits and challenges. This work was an initial first step on efforts to extend the scope of SAE guidance material from the traditional assumption of "risk-informed ISI of piping for operating NPPs".

SAE sees in principle three possible dimensions to expand from this original scope:

- extending inspections to cover also pre-service inspections;
- extending the scope of inspections to non-piping components;
- extending the application to future reactor types.

The extension of the RI-ISI scope to pressure retaining non-piping components is considered as the first priority for SAE. Section 4 reports a detailed review of the areas where SAE would need to focus to achieve this goal. Pre-service inspections and inspections of new reactor types, including SMRs, are potential topics for the SAE group in the future.

3.1.3. The need to widen the target audience of ENIQ RI-ISI documents

The generic documents (on RI-ISI philosophy) are listed in Table 1. These generic documents are mainly targeted at nuclear utilities and are intended to aid the development of RI-ISI approaches, or the adaptation of established approaches for existing plant. The overview for non-specialist is targeted at a wide audience of engineers and technical staff who may not be routinely involved with RI-ISI. This raises the question of whether SAE should target other audiences.

Table 1. SAE documents on RI-ISI methodology.

Doc#	Title
51	European framework document for risk-informed In-service inspection
21	Discussion Document: On Risk-Informed In-Service Inspection of Nuclear Power Plants
29	Discussion Document on the Role of in service inspection within the philosophy of defence in depth
46	Discussion Document on Risk Informed In-Service Inspection: An overview for the non-specialists
48	Lessons Learned from the Application of Risk-Informed In-Service Inspection to European Nuclear Power Plants
67	Extending Risk-Informed In-Service to General Mechanical Components – Benefits and Challenges
NEA/CSNI/ R(2010)13	EC-JRC/OECD-NEA Benchmark Study on Risk Informed In Service Inspection Methodologies (RISMET)

SAE has made efforts to promote the use of RI-ISI approaches, but what is common to these documents is that they are targeted at industrial end-users. Although RI-ISI methodologies have been applied in many countries, their acceptance is not worldwide, and an effort should be made to approach those nuclear regulators who still may have some doubts concerning the RI-ISI. Further work is therefore recommended to promote the safety benefits of applying RI-ISI methods.

3.2. Review of RI-ISI related NUGENIA R&D challenges

Recently SNETP has published the NUGENIA Vision document [2] including a summary of R&D challenges in the area of ENIQ. The challenges relevant to SAE are as follows:

- Review of risk-informed pre-service inspection (PSI) for new build and modifications of existing plants;
- Extension of RI-ISI to all mechanical components, i.e. beyond piping. SAE completed initial work on this topic in 2021, and published ENIQ report no. 67 on the benefits and challenges of applying RI methods to mechanical components;
- Benchmarking of RI-ISI approaches worldwide to harmonize them and improve credibility.

When reviewing these recent R&D challenges, SAE concludes the following:

- The topic on PSI for new build, especially for modular reactors, is a topic of interest, but at the time of writing is not considered the highest priority, since it will still take several years before the challenges of applying RI methods to such plants become clear (i.e. SMRs are at an early stage of deployment).

- Further investigations of the extension of RI-ISI to mechanical components is considered as a high priority and this topic is relevant for PSI of new build. This would require deeper studies of the related challenges identified in the report published in 2021 [14]. This is considered further in Section 4.
- Benchmarking of RI-ISI approaches is not considered as topical, as an extensive benchmark was carried out earlier within the RISMET project [15]. Although the study was done more than 10 years ago, its conclusions can be judged still to be valid. ENIQ report no. 48 published in 2017 summarises the use of RI-ISI in 19 units in seven European countries and shows that there are several RI-ISI approaches that can be used to cost-effectively improve plant safety, reduce worker exposure, and allows limited resources to be focused on the areas that yield the greatest benefit. SAE does not see an urgent need to harmonise existing approaches. However, the group agrees that an effort should be made to improve the credibility of RI-ISI. This is one topic considered for the future work, especially focusing on the safety improvements achievable with the optimisation of inspections.

3.3. Conclusion on SAE Priorities

Based on the analyses of the topics of previous SAE reports, and R&D challenges pointed out in the NUGENIA Vision, SAE concludes the following roadmap for its activities:

- The extension of RI-ISI to pressure retaining mechanical components is the first priority.
- A document to promote RI-ISI safety benefits is the second priority, and will be developed in parallel with the work on the first priority.
- PSI and RI-ISI for modification of operating plants as a third priority.
- Potential future topics include:
  - PSI and RI-ISI for new build (including SMRs);
  - Investigation of how the principles described in RP8 [17] could be implemented during any RI-ISI programme and the factors that should be considered when selecting the qualification level and approach for RI-ISI;
  - Development of POD methodologies to quantify the benefits of an inspection upon the assessed POF and effect on RI-ISI site selection.

As the European framework document for RI-ISI is the core methodology document, the group will regularly evaluate the need to update it.

In order to start working on the extension of RI-ISI to vessels and other mechanical components beyond piping systems components, a more thorough review of the SAE documentation is made in the following section. This helps to identify further revision needs of SAE technical documents, and to develop a more detailed work plan.

4. Review of ENIQ documentation for extension of RI-ISI to non-piping components

The following review of the NUGENIA SAE suite of RI-ISI documents focuses on those of most relevance to extending the scope of RI-ISI to non-piping systems. These are ENIQ reports no. 51 [1] and 21 [3].

The review will highlight where the current RI philosophy, tools and methods need further development to adequately extend RI-ISI to additional pressure boundary components. It considers those pressure boundary components, such as vessels and valve bodies, that have traditionally been treated deterministically in much the same way as piping components were treated prior to the introduction of RI methods as an alternative philosophy. The RI principles are equally applicable to any system regardless of the Safety Class.

It is recognised that specific components (e.g. the reactor pressure vessel (RPV)) may present challenges for the application of RI-ISI methods that must be considered by licensees and regulatory bodies during the development of individual RI-ISI programmes.

4.1. Probability of Failure

The current RI-ISI approach relies upon many very similar systems, structures and components (SSCs) and the potential for segmentation where a length of piping contains many physically similar locations with a largely comparable consequence of failure (typically welds) but each having a slightly different loading conditions. Within such a system calculating a probability of failure of individual components, and therefore constructing a risk ranking is accepted and straightforward. As noted in [1] it is desirable to utilise quantitative data estimated through a Structural Reliability Model (SRM) based upon probabilistic fracture mechanics methods. Operating experience, failure statistics and expert judgement support the SRM evaluations.

For non-piping pressure boundary components the ability of SRMs to provide quantitative probability of failure data is more difficult due, in part, to the wide variation in geometry. This is likely to place greater reliance upon operating experience, failure statistics and expert judgement.

The capability of SRMs and models for calculating Probability of Failure (POF) at different locations on non-piping pressure boundary components (for example valves and pressure vessels) requires review to ensure the output is appropriately reliable and robust.

4.2. Consequence Analysis

Probabilistic Safety Assessments (PSAs) provide a robust technical basis and method to estimate appropriate values of the Consequence of Failure (COF) for piping components. The COF analysis considers, in accordance with the Framework Document [1], the Conditional Core Damage Probability (CCDP) or Conditional Core Damage Frequency (CCDF), based upon postulated break sizes ranging from small to large.

While this approach is also applicable to other pressure boundary components, an additional level of detail may be needed for some components. Examples are provided as follows:

1. The consequences of a postulated failure of a valve body may be identical to postulated failure of the connected piping.
2. The postulated failure of a tank nozzle located at the bottom of a tank may result in draining the tank.
3. The postulated failure of a tank nozzle located at the top of a tank may have a negligible impact.

4.3. Qualitative or Semi-Quantitative Risk Assessment

As noted in the previous Sub-sections there are likely to be significant challenges to establishing robust quantitative values for POF for non-piping systems. In recognition of these challenges, consideration should be given to the development of RI schemes primarily based upon operating experience, failure statistics and expert judgement [4].

4.4. Balance of ISI Programme

The extension of RI-ISI across all pressure boundary components requires the interface of risk assessment across component boundaries and the avoidance of risk dominance between components or systems.

To an extent this issue is addressed in the framework document [1] but its treatment is largely limited to piping components. Extending RI-ISI to additional pressure boundary components will see the issue of risk outliers become more problematic and challenging (different components are likely to be very different in terms of CCDF).

4.5. Risk Distribution

Sub-section 4.9.3 of the Framework Document [1] notes that *'It is recognised that locations characterised by high consequence and low POF can be of concern for reasons of uncertainties, even if the risk at the location is moderate in absolute or relative terms.'* Such sites are likely to correspond to some tanks and vessels, and can be seen to lie at the bottom right of the risk plot shown in Figure 2. Most of the Class 1 piping components also fall into this category.

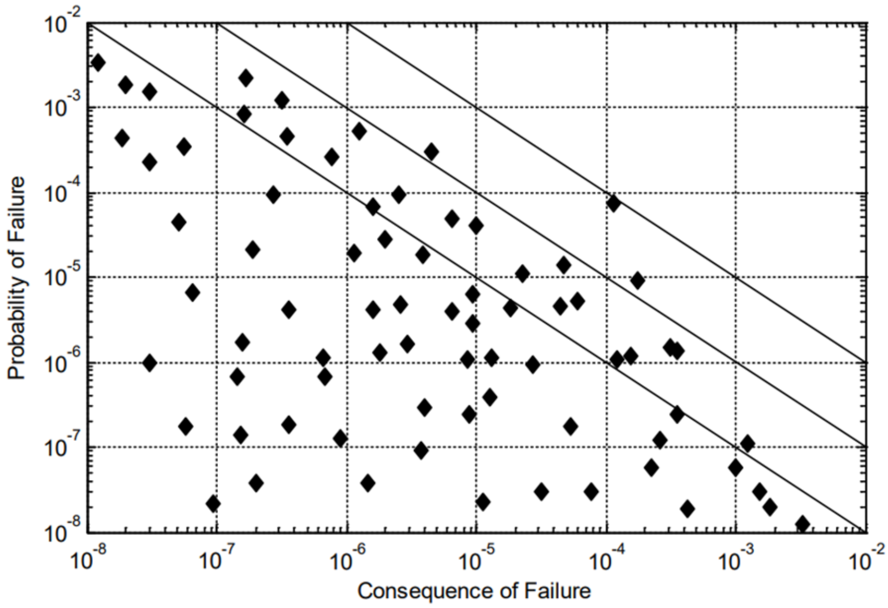

Figure 2. Illustration of a Risk Plot (from [1])

It is noted in 4.9.3 [1], that *'No specific relative risk level is given here since different factors may need to be considered for different utilities and different regulatory bodies.'*

Both the sensitivity of the assessed risk value due to small variations in POF and also the regulatory sensitivity to assigning ISI based upon risk for high COF for SSCs needs careful consideration to reach a consensus position.

4.6. Review of Existing Documentation and Industry Practice

The Framework Document [1] requires revision to ensure that it is consistent with any developments arising from findings in the planned work on RI-ISI extension. In undertaking these reviews consideration will also be given to broader industry practice (Westinghouse, ASME XI, ASME code case).

4.7. Summary

Based on the review it is recommended to aim at proposing solutions to apply RI-ISI to pressure boundary components focusing in the following topics:

a. Consideration of how to ensure a balanced RI-ISI programme can be achieved and the use of a risk cut-off (Section 4.4);

b. Development of a consensus position on assigning ISI based upon risk for high COF SSCs (Section 4.5);

c. Review of RI schemes primarily based upon operating experience, failure statistics and expert judgement (Sections 4.1 to 4.3, Qualitative or Semi-Quantitative Risk Assessment).

Further, a review of external approaches to extend RI-ISI to non-piping components should be made to identify best practices.

5. Conclusions

The ENIQ SAE suite of documents and NUGENIA Vision document [2] have been reviewed and a number of potential actions are recommended to meet the objectives of the SAE group. The main 'roadmap' activities are as follows:

- The extension of RI-ISI to pressure retaining mechanical components is the first priority.
- A document to promote RI-ISI safety benefits is the second priority, and will be developed in parallel with the work on the first priority.
- PSI and RI-ISI for modification of operating plants as a third priority.
- Potential future topics include:
    - PSI and RI-ISI for new build (including SMRs);
    - Investigation of how the principles described in RP8 [17] could be implemented during any RI-ISI programme and the factors that should be considered when selecting the qualification level and approach for RI-ISI;
    - Development of POD methodologies to quantify the benefits of an inspection upon the assessed POF and effect on RI-ISI site selection.

As the European framework document for risk-informed In-service inspection [1] is the core methodology document, the group will regularly evaluate the need to update it.

For the work on the extension of RI-ISI to pressure retaining mechanical non-piping components, the first step is to define and initiate a pilot study to further investigate the challenges identified in ENIQ report no. 67 [14]. On the basis of a review of two ENIQ documents (no. 21 & 51), the following actions are recommended:

a. Consideration of how to ensure a balanced RI-ISI programme can be achieved and the use of a risk cut-off;

b. Development of a consensus position on assigning ISI based upon risk for high COF SSCs;

c. Review of RI schemes primarily based upon operating experience, failure statistics and expert judgement.

In addition, external approaches and experiences to extend RI-ISI beyond piping should be reviewed to identify best practices.

References

[1] ENIQ report no. 51. *European framework document for risk-informed In-service inspection. Issue 2*. 2019.

[2] *NUGENIA Vision*, SNETP, 2021 https://snetp.eu/wp-content/uploads/2021/06/NUGENIA-Vision-June-2021.pdf .

[3] ENIQ report no. 21. *Discussion Document: On Risk-Informed In-Service Inspection of Nuclear Power Plants*. 2000.

[4] ENIQ report no. 53. *ENIQ Recommended Practice 11 (RP11): Guidance on Expert Panels in Risk-Informed In-Service Inspection. Issue 2*. 2017.

[5] ENIQ report no. 52. *ENIQ Recommended Practice 9 (RP9): Verification and Validation of Structural Reliability Models and associated Software to be used in Risk-Informed In-Service Inspection Programmes. Issue 2*. 2017.

[6] ENIQ report no. 29. *Discussion Document on the Role of in service inspection within the philosophy of defence in depth*. 2007.

[7] ENIQ report no. 35. *Discussion Document: On the Role of In-Service Inspection of the Reactor Pressure Vessel*. 2008.

[8] ENIQ report no. 37. *Discussion Document on Updating of risk-informed inspection programmes*. 2009.

[9] ENIQ report no. 46. *Discussion Document on Risk Informed In-Service Inspection: An overview for the non-specialists*. 2012.

[10] ENIQ report no. 36. *Link between risk-informed In-service inspection and inspection qualification*. 2009.

[11] ENIQ report no. 41. *Probability of detection curves: statistical best practices*. 2010.

[12] ENIQ report no. 47. *Influence of sample size and other factors on hit/miss probability of detection curves*. 2012.

[13] ENIQ report no. 48. *Lessons Learned from the Application of Risk-Informed In-Service Inspection to European Nuclear Power Plants*. 2017.

[14] ENIQ report no. 67. *Extending Risk-Informed In-Service to General Mechanical Components – Benefits and Challenges*. 2021.

[15] *EC-JRC/OECD-NEA Benchmark Study on Risk Informed In Service Inspection Methodologies (RISMET)*, NEA/CSNI/R(2010)13. 2011.

[16] ENIQ report no. 61. *European Methodology for Qualification of Non-Destructive Testing. Issue 4*. 2019.

[17] ENIQ report no. 59. *ENIQ Recommended Practice 8 (RP8): Qualification Levels and Approaches. Issue 2*. 2018.

Appendix 1 – Summaries of the ENIQ Suite of RI-ISI Documentation

ENIQ report no. 51. European framework document for risk-informed In-service inspection.

RI-ISI approaches are used to define inspection programmes based on analysis of consequences and probability for leakage in pressure bearing components important to reactor safety. By using plant specific consequence analysis and detailed review of degradation susceptibility and analysis of failure probability, the risk-informed approaches have the capability to identify the items presenting the highest risks of failure, including important locations that might otherwise be overlooked. This document is intended to provide general guidelines to utilities for developing their RI-ISI approaches or adapting already established approaches, taking into account utility-specific characteristics and national regulatory requirements. This ENIQ document is Issue 2 of the European Framework Document for RI-ISI.

ENIQ report no. 53 (RP11). Guidance on Expert Panels in Risk-Informed In-Service Inspection.

This Recommended Practice (RP) has been developed as a consensus document amongst the members of NUGENIA Technical Area 8 (TA8) - ENIQ. This recommended practice is meant to assist users of RI-ISI applications in how to form, prepare, conduct and facilitate an expert panel as a part of a RI-ISI process. It will give guidance on responsibilities, composition, planning, conduct and documentation of the expert panel. Users are free to use this RP at national level, as they see fit.

ENIQ report no. 52 (RP9). Verification and Validation of Structural Reliability Models and associated Software to be used in Risk-Informed In-Service Inspection Programmes.

This Recommended Practice (RP) has been developed as a consensus document amongst the members of NUGENIA Technical Area 8 (TA8) - ENIQ. Structural Reliability Models (SRMs) are commonly used to evaluate failure probabilities in the development of RI-ISI programmes. The main objective of this RP is to summarise the Verification and Validation requirements that a SRM and associated software should satisfy in order to be suitable for such programmes.

ENIQ report no. 21. Discussion Document: On Risk-Informed In-Service Inspection of Nuclear Power Plants.

The objective of this work is to continue the work presented by EURIS (European Network for Risk Informed In-Service Inspection) and to develop a methodology for risk based assessment relevant to the needs of plant operators. The methodology could then be used to identify safety-significant categories for power plant components, and to optimise the targeting of inspections whilst maintaining or even increasing the safety. The present document represents a first attempt in this direction and should be seen as a discussion document that represents the thoughts of Task Group 4 (TG4) of ENIQ.

ENIQ report no. 29. Discussion Document on the Role of in service inspection within the philosophy of defence in depth

Developing a RI-ISI programme involves evaluating the first version of a new inspection programme against the defence-in-depth principle. The risk-informed inspection programme generated at the end of the analysis should be evaluated against the Defence-in-Depth (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, by only looking at the effect on one single barrier. This report discusses how to apply DiD concepts by looking at several DiD levels. Further, this 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 DiD philosophy for reactor safety.

ENIQ report no. 35. Discussion Document: On the Role of In-Service Inspection of the Reactor Pressure Vessel

The RI-ISI Framework Document focuses on piping but its application to the Reactor Pressure Vessel (RPV) is not excluded. This report discusses the application of an RI-ISI strategy to the RPV.

ENIQ report no. 37. Discussion Document on Updating of risk-informed inspection programmes.

The European Framework Document for RI-ISI is intended to provide general guidelines to utilities both for developing RI-ISI approaches and for using pre-established approaches or adapting them to the European nuclear environment, taking into account national regulatory requirements and utility-specific characteristics. The Framework Document emphasises the process of keeping RI-ISI living, i.e. updated, and briefly discusses the concept of living RI-ISI. An effective risk-informed inspection strategy requires a feedback procedure to update the risk ranking after changes are made to the plant or other relevant information is acquired. Furthermore, the document published by the Nuclear Regulatory Working Group highlights performance monitoring and updating of RI-ISI programmes. A US document on RI-ISI updating gives several examples of plants which have completed updates of their RI-ISI programmes. This European Network for Inspection and Qualification (ENIQ) discussion document is intended to help users involved in a RI-ISI application to maintain and update a RI-ISI programme. It also provides an overview of current ISI updating practices in most EU Member States with nuclear power plants in operation.

ENIQ report no. 46. Discussion Document on Risk Informed In-Service Inspection: An overview for the non-specialists

An introduction to a non-specialist of the principle features and elements of the RI-ISI Framework Document.

ENIQ report no. 36. Link between risk-informed In-service inspection and inspection qualification

There is a growing need for a quantitative measure of inspection effectiveness as an input to quantitative RI-ISI. A Probability of Detection (POD) curve could provide a suitable metric. However there can be significant problems associated with generating realistic POD curves by practical trials. The ENIQ inspection qualification methodology can provide high assurance that an inspection system will achieve its objectives, but is not designed to provide a quantitative measure of the type that can be used in RI-ISI analysis.

The report discusses how a simplified POD curve, such as a step curve, could be used as the target for inspection qualification, or as an output from it. Work to investigate the sensitivity of relative risk reduction to the details of the POD curve is described, from which it is concluded that use of a simplified POD curve could be justified.

ENIQ report no. 41. Probability of detection curves: statistical best practices

A review of the 'state of the art' with regard to statistical best practice in relation to the development of POD curves.

ENIQ report no. 47. Influence of sample size and other factors on hit/miss probability of detection curves

The purpose of this report was: (1) to extend the conclusions of an earlier report (ENIQ report No 41: "Probability of Detection Curves: Statistical Best-Practices"), (2) to justify the Rule-of-Thumb that a valid POD vs. size curve requires a minimum of 60 targets for binary response (hit/miss) data, (3) to provide guidelines for the non-destructive examination (NDE) practitioner in designing a study to assess the effectiveness of a binary response inspection system using POD vs. size curves.

ENIQ report no. 48. Lessons Learned from the Application of Risk-Informed In-Service Inspection to European Nuclear Power Plants

The purpose of this report is to summarize the experience from RI-ISI programmes and pilot studies of nuclear power plants (NPPs) in Europe, in particular the experienced changes compared to previous deterministic ISI programmes. The report covers the experience from countries, where RI-ISI is fully recognised by the nuclear regulator, but also countries that still follow a deterministic ISI approach, but which have performed RI-ISI pilot studies to get an idea of possible benefits or extra burdens when moving to RI-ISI. The report covers the experience from Finland, Slovenia, Spain, Sweden, Bulgaria, Lithuania and Romania and thus covers different reactor types, i.e. BWR, PWR, VVER, RBMK and CANDU reactor.

ENIQ report no. 67. Extending Risk-Informed In-Service to General Mechanical Components – Benefits and Challenges

This technical report discusses the extension of RI-ISI approaches for piping welds to cover other general mechanical components at a nuclear power plant. The term “general mechanical components” as used in this report includes pressure boundary components (e.g. tees, elbows, piping welds, vessels, tanks, heat exchangers) as well as the pressure boundary function of a number of active components (e.g. valve body, pump body) as well as their supports (e.g. spring can, rigid restraint, snubber, anchor). The intent of this document is to identify benefits and challenges for extending risk-informed approaches for inspection planning to general mechanical components. The main steps of RI-ISI procedures are reviewed to identify how these are affected when the scope is expanded.

Contributors to Drafting and Editing

Robertas Alzbutas	Lithuanian Energy Institute (LEI)	Lithuania
Otso Cronvall	Technical Research Centre of Finland (VTT)	Finland
David Duxbury	Rolls Royce	Great Britain
Anders Lejon	Ringhals NPP / Vattenfall	Sweden
Patrick O’Regan	Electric Power Research Institute (EPRI)	United States
Andrey Shipsha	Kiwa Inspecta	Sweden
Karen Stone	Jacobs	Great Britain
Tony Walker	Jacobs	Great Britain
Kaisa Simola	European Commission – Joint Research Centre	European Commission
Oliver Martin	European Commission – Joint Research Centre	European Commission

ENIQ

European Network for
Inspection & Qualification
NUGENIA Technical Area 8

ABOUT ENIQ AND NUGENIA

The **European Network for Inspection and Qualification (ENIQ)** is a utility driven network working mainly in the areas of qualification of non-destructive testing (NDT) systems and risk-informed in-service inspection (RI-ISI) for nuclear power plants (NPPs). Since its establishment in 1992 ENIQ has issued over 60 documents. Among them are the "European Methodology for the Qualification of Non-Destructive Testing" and the "European Framework Document for Risk-Informed In-Service Inspection". ENIQ is recognised as one of the main contributors to today's global qualification guidelines for in-service inspection.

ENIQ is the technical area 8 of NUGENIA, one of the three pillars of the Sustainable Nuclear Energy Technology Platform (SNETP) that was established in September 2007 as a R&D&I platform **to support technological development for enhancing safe and competitive nuclear fission in a climate-neutral and sustainable energy mix.** Since May 2019, SNETP has been operating as an international non-profit association (INPA) under the Belgian law pursuing a networking and scientific goals. It is recognised as a European Technology and Innovation Platform (ETIP) by the European Commission.

The international membership base of the platform includes industrial actors, research and development organisations, academia, technical and safety organisations, SMEs as well as non-governmental bodies.

secretariat@snetp.eu

www.snetp.eu

SNETP

SNE_TP

9 782919 313365