Nuclear Generation II&III Alliance

ENIQ RECOMMENDED PRACTICE

ENIQ Recommended Practice 8

Qualification Levels and Approaches

Issue 3

ENIQ Report No. 74

August 2025

European Network for Inspection & Qualification

NUGENIA Technical Area 8

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This document was prepared by the SNETP Association.

Brussels: The SNETP Association

ISBN xxx-xx-xx-xxxxx-x (pdf)

ISBN xxx-xx-xx-xxxxx-x (print)

ISSN xxxx-xxxx (print)

ISSN xxxx-xxxx (online)

doi: xx.xxxx/xxxxx

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Foreword – Brief Revision History of RP8

The first issue of ENIQ Recommended Practice 8 (RP8) on Qualification Levels and Approaches was produced by the former ENIQ Task Group for Qualification (TGQ) and approved by the ENIQ Steering Committee for publication in 2005. For Issue 2 of RP8, a number of changes were made: The relationship between qualification levels and approaches and the factors, which may be considered in determining qualification levels, are clarified. Practical examples for qualification levels and approaches (one from Hungary, one from UK) were added. For Issue 3 of RP8, the relationship between Qualification Level and Qualification Approach and the factors influencing Qualification Levels are clarified.

Executive Summary

The main objective of this Recommended Practice is to provide licensees, Qualification Bodies and inspection vendors with guidance on the setting of Qualification Levels and defining appropriate Qualification Approaches.

The Qualification Level is typically based upon safety/risk significance and the role of the inspection in structural integrity. Once the Qualification Level is defined then an appropriate Qualification Approach can be selected, and consequent Qualification Plan produced with consideration to the Qualification Approach and the novelty, complexity, and difficulty of the inspection.

1. Introduction

The European Methodology for Qualification [1] is intended to provide a general framework for the development of qualifications for the inspection of specific components to ensure they are developed in a coherent and consistent way while still allowing qualification to be tailored in detail to meet different national requirements.

The European Methodology for Qualification [1] supports the principle that the Qualification Level and Qualification Approach are beneficial concepts that may be used to vary the qualification process to suit a particular situation. It should also be noted that Performance Demonstration requirements within Appendix VIII of ASME Section XI vary with the needs of different components.

This ENIQ Recommended Practice (RP) will assist those involved in inspection qualifications and in how to set Qualification Level and to determine the Qualification Approach. This Recommended Practice (RP) is relevant to any Non-Destructive Testing (NDT) method.

The general definitions in the ENIQ Glossary [2] apply to this RP.

2. Objectives

The main reason for introducing the concept of Qualification Level and Qualification Approach is to provide those involved in the qualification process the flexibility to decide and agree how much work or evidence is required to qualify a particular inspection. This is in recognition of the fact that some inspections may require more extensive work and evidence to qualify than others depending on the complexity of the Non-destructive Testing (NDT) system, the novelty and difficulty of the inspection and/or the role of the inspection in demonstrating structural integrity.

The quality standard to which the qualification is implemented should always be appropriately high and it is not the intention in varying the Qualification Approach to undermine this principle.

3. Definitions

There are two terms used throughout this RP that require definition at the outset.

Qualification Level: A numeric value that reflects the assurance required that the inspection would attain its objectives in demonstrating structural integrity.

Qualification Approach: The elements of qualification required to achieve the desired Qualification Level. Determination of the approach involves considering the difficulty or novelty of the inspection as well as the Qualification Level that is required.

Typically, the specification of the Qualification Level is the responsibility of the client or licensee and is an input to the qualification process. Determination of the Qualification Approach needed to achieve the desired Qualification Level is the responsibility of the Qualification Body (QB).

4. Considerations when varying the Qualification Level and Approach

This section discusses some of the potential advantages, and some of the difficulties, of matching the Qualification Level and Approach to the needs of each inspection.

The main advantage of applying different Qualification Levels is that it can facilitate a wider application of inspection qualification principles to a broader range of risk and/or safety significant components rather than focusing all the effort on the highest ranked components.

For example, the inspection of a Reactor Pressure Vessel (RPV) circumferential seam weld would likely be qualified to the highest Qualification Level by a robust and very detailed programme (extensive Qualification Approach) whereas an inspection of lower safety significance or failure impact would be qualified to a lower Qualification Level and Approach.

This ensures that the amount of qualification effort and resource is concentrated on those components where the inspection plays the greatest role in reducing risk and/or where the consequences of component failure are greatest but also allows the inspection of lower risk and safety significant components to be qualified in an appropriate way. This principle aims to use the limited resources that are available in the most effective manner.

The main practical difficulty of applying different Qualification Levels for different inspections is that careful consideration needs to be given to establishing an appropriate framework and clear guidance material such that the appropriate Qualification Approach can be identified and applied in a consistent manner.

It should be emphasised that the inspection personnel applying the qualified inspection are required to apply the same due diligence in application regardless of Qualification Level.

5. Qualification Level

5.1. Specification

The Qualification Level is specified by the licensee - in some cases in agreement with the regulator. The specification of the Qualification Level does not involve the QB as it relates only to issues concerned with the safety and structural integrity of the plant. These matters only concern the regulator and licensee and do not directly concern the QB.

Once the Qualification Level has been identified, the QB specifies the Qualification Approach considering both the Qualification Level and, where considered appropriate, the difficulty or novelty of the inspection.

5.2. Qualification Level Selection

The number of different Qualification Levels is typically selected by the licensee but is a matter to be agreed between all the parties involved. However, experience indicates that a three-tier classification is a pragmatic number of levels. It is recommended that a numeric notation is used to denote and differentiate the chosen qualification levels. If more than three qualification levels are to be used, this would be expected to result in more nuances of the medium qualification level.

There are two main factors to be considered in determining the qualification level.

1. Safety or Risk significance of the component.
2. Role of the inspection in assuring the structural integrity of the component: In some cases, the inspection may play the only or main role in assuring structural integrity. In other cases, the inspection will only provide one element, with other elements such as chemistry, maintenance or ongoing monitoring being considered.

Other factors that may influence the Qualification Level are uncertainties in the structural integrity analysis (for example uncertainties in fracture toughness or crack growth rates) and operational feedback (components with a recorded failure either in the concerned plant or in plant of similar design).

No attempt is made here to be more prescriptive about how these factors may be used to determine qualification level. This is mainly because every proposed inspection is different, and it would be impractical to provide a prescriptive approach which satisfactorily covers all cases. Rather, it is recommended that the qualification level is determined through informed judgment, taking account of the factors listed above and their relative importance in the application.

6. Determining the Qualification Approach

The specification of the Qualification Level significantly influences the QB in their selection of the Qualification Approach.

Figure 1 is provided as an illustration of how the complexity of the Qualification Approach increases with Qualification Level. The elements of qualification presented in Figure 1 are for illustration and the precise 'mix' of elements is a matter for the QB.

Overall, the Qualification Approach is a high-level specification of the major elements of the Qualification Plan which details the step-by-step instructions to implement the qualification.

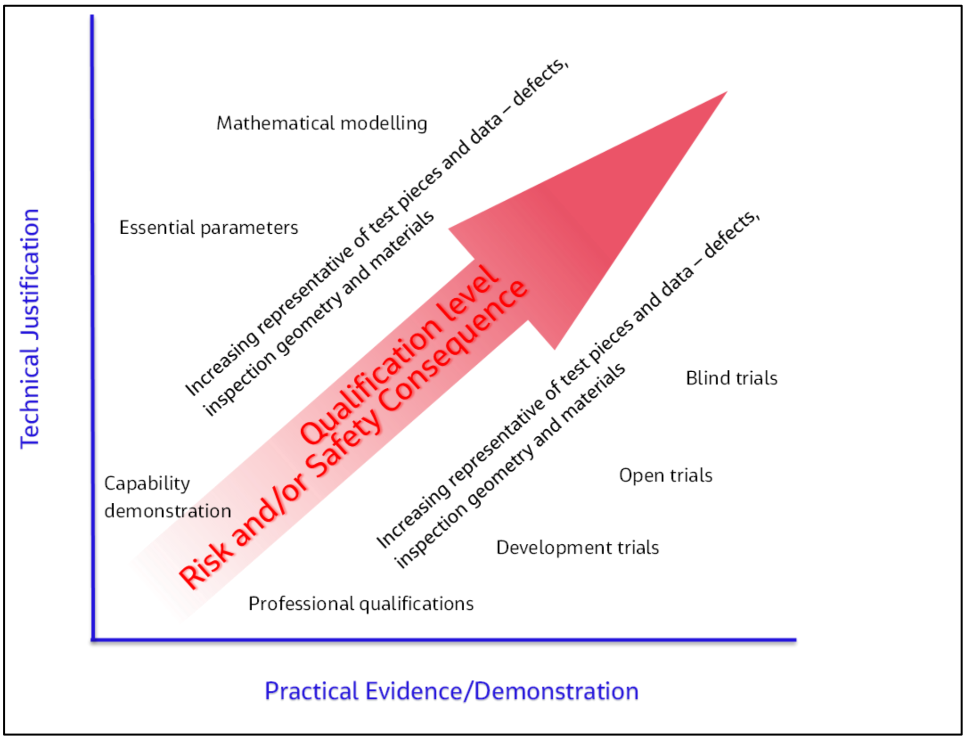

Figure 1: Illustrative Example of Qualification Level

It should be noted that although the Qualification Level determines the Qualification Approach, the details of the Qualification Plan will vary dependent upon the technical difficulty and complexity of the inspection. For instance, for a given Qualification Level/Qualification Approach the detailed steps to be taken for the qualification (the Qualification Plan) are unlikely to be the same for a complex austenitic weld inspection as for a simple ferritic butt weld inspection. These detailed differences will be reflected in the Qualification Plan. The relationship between the factors affecting the Qualification Level, Approach and Plan is shown in Figure 1.

An example of how the principle of Qualification Level within a generic Risk-Informed In-Service Inspection Programme is provided in the Appendix to this report.

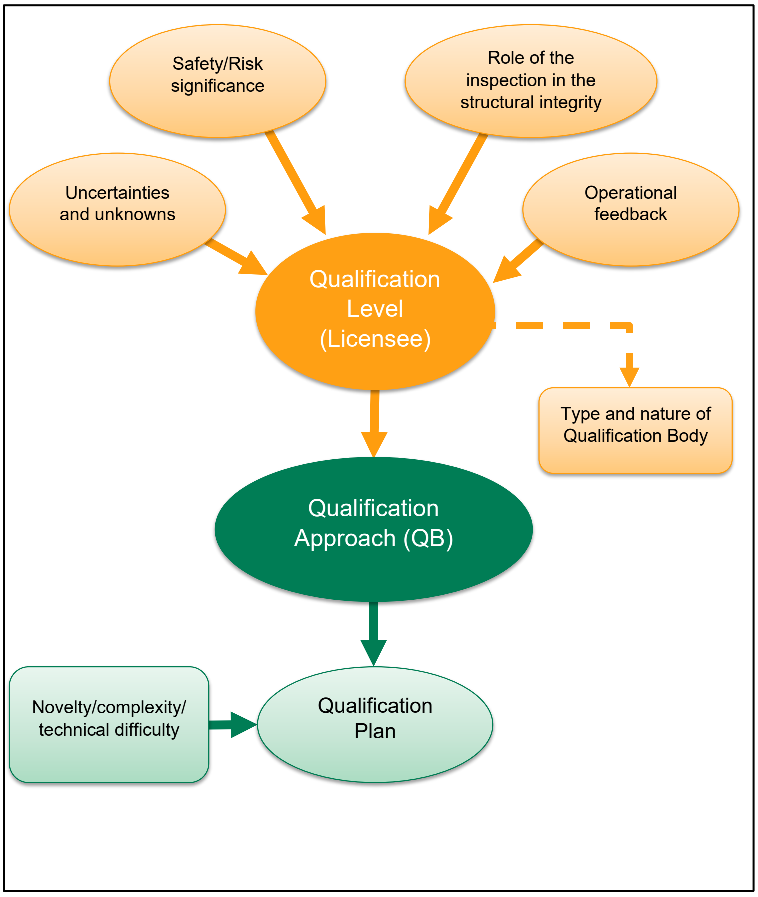

Figure 2: Factors affecting Qualification Level, Approach and Plan

6.1. Qualification Plan

The Qualification Plan is the document that specifies in detail how a particular qualification exercise is performed. The Qualification Plan defines:

1. The role of the Technical Justification (TJ)
2. The need for and role of Open Trials
3. The need for and role of Blind Trials
4. How each element of the qualification process, namely procedure, equipment, and personnel, are to be qualified

The Qualification Level largely determines the overall Qualification Approach, and hence the major elements of the Qualification Plan, and the extent to which the activities listed above are required for a particular qualification and how each will be performed.

For example, a high Qualification Level will require an appropriately robust Qualification Approach and, most likely, a TJ that has a large amount of evidence specific to the inspection being qualified. The evidence provided in the TJ is likely to be a combination of both experimental and modelling evidence. The precise mix of experimental and modelling evidence will be dependent upon the specifics of the inspection being qualified (novelty, complexity, and technical difficulty).

In contrast, a smaller amount of general evidence from similar inspections could be used for a lower Qualification Level. At its simplest, the Qualification Approach and Qualification Plan could involve no more than the production of a simple capability statement based on existing evidence.

The Qualification Level influences the extent to which all Influential Parameters of the inspection are analysed:

- For a high Qualification Level, there should be a rigorous justification of the impact of all the parameters to provide the most robust assurance that the inspection will attain its objective.
- For a lower Qualification Level (providing lower assurance), some parameters may be addressed using relevant available evidence (feedback, engineering reasoning etc.). Where parameters are disregarded or treated less rigorously an appropriate justification may be provided.

As shown in Figure 2, the other input in determining the appropriate Qualification Plan relates to the difficulty, complexity, or novelty of the inspection. At a given Qualification Level, a difficult ultrasonic inspection of, say, a geometrically complex austenitic weld will require more extensive qualification activities than that of a simple ferritic pipe weld, which in many cases could be qualified through TJ alone. Likewise, qualification of a new method of inspection for which there is little previous experience will require more extensive qualification activities than a method that is well established.

Another aspect of the Qualification Approach relates to the way experimental results from test-pieces are generated and used. For the most rigorous Qualification Approach, appropriate to the highest Qualification Level, test-pieces are likely to be complex, geometrical replicas of the real component, representative in metallurgical structure (in situations where the structure is considered important) and containing defects that are as realistic as possible. For a lower Qualification Approach, flat plates containing simple targets, such as Electrical Discharge Machining (EDM) notches and flat-bottomed holes, may suffice, particularly if the TJ is able to demonstrate how the results obtained can be related to the real component.

6.2. Type of Qualification Body

The Qualification Level may be considered when defining the amount of independence that is required for the QB and the technical expertise its members must have. In general, the higher Qualification Levels require more independence from QB members.

ENIQ RP7 [3] defines the requirements for different types of QB.

References

[1] *The European Methodology for Qualification of Non-Destructive Testing – Issue 4*, ENIQ report no. 61, The NUGENIA Association, 2019.

[2] *ENIQ Glossary of Terms – Issue 3*, ENIQ report no. 62, The NUGENIA Association, 2019.

[3] *ENIQ Recommended Practice 7: Recommended General Requirements for a Body Operating Qualification of Non-Destructive Tests – Issue 2*, ENIQ report no. 58, The NUGENIA Association, 2018.

[4] *European Framework Document for Risk-Informed In-Service Inspection – Issue 2*, ENIQ report no. 51, The NUGENIA Association, 2019.

Appendix: Qualification Level and Risk-Informed In-Service Inspection

This Appendix is based on the ENIQ Report no. 51 [4].

Risk-informed ranking of safety significance

Historically, the assessment of safety significance of systems, structures and components in nuclear power plants (NPP) has been based on general safety criteria and on deterministic safety analyses. This has resulted in established “traditional” safety classifications of systems, structures and components.

Nowadays, many utilities and nuclear safety authorities are increasingly using probabilistic safety assessment (PSA) results in decision-making related to the operation and maintenance of nuclear power plants. Due to such an increased use of PSA, nuclear operators have realized that the current safety classification does not always correctly reflect the risk associated with the various systems, structures and components.

Traditionally, inspection programmes have been mainly defined on the basis of the safety classification derived from deterministic analyses. A risk-informed in-service inspection (RI-ISI) approach aims at improving the inspection effectiveness by concentrating inspection resources on risk-significant locations, whilst reducing inspection requirements on locations with low-risk significance. Ideally, a RI-ISI application can result in improved safety, reduced cost, and reduced radiation exposure.

The RI-ISI analysis is based on evaluation of the likelihood of a structural component failure and its consequences. The consequences are evaluated with the plant risk model (PSA), and they can be measured, e.g. as conditional core damage probability given the failure of the structural element. In principle, the risk associated with each element can be determined as:

Risk = (Probability of Failure) x (Consequence of Failure)

The analysis yields a risk ranking of the structural elements. This risk (or safety significance) ranking serves then as an important decision criterion in defining the new inspection programme.

Figure A1 provides an illustrative example of how the assessed risks of individual elements can be plotted to provide a so-called ‘Log Risk Plot’. In such a plot, each structural element of interest is represented by a point whose coordinates are the logarithm of the probability of failure and the logarithm of the consequence of failure. Thus, straight lines representing constant risk can be plotted, which can be used to break the risk space into regions characterized by the same risk significance. Another commonly used graphical presentation of the risk ranking is a risk matrix (see example in Figure A2). In a risk matrix pipework elements or segments are classified in failure probability and consequence categories, using either qualitative categories (such as High, Medium and Low) or quantitative ranges (e.g. decades).

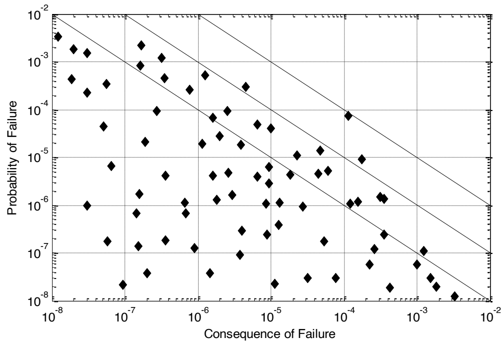

Figure A1: Illustrative Log Risk Plot

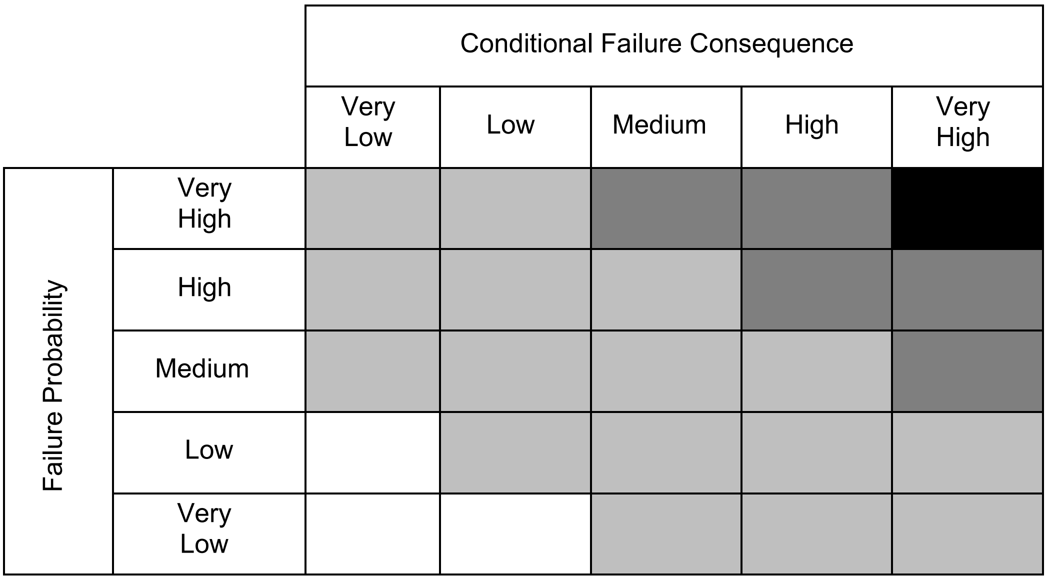

Figure A2: Risk matrix

Determination of qualification level for inspection of risk significant sites

If different inspection qualification levels are considered for application, it would be logical to link their definition to the risk significance. This implies that the highest qualification level would be required for inspections of elements for which the highest risk has been assessed. Inspections of elements of lower risk significance would require a lower qualification level.

It may also be considered appropriate to address directly the consequence of failure. This means that a high qualification level could also be required for elements whose risk is assessed to be low, due to a very low failure probability, but which are characterized by a very high failure consequence.

Usually the RI-ISI process uses the categorization of elements in several risk categories. This can be based on absolute or relative risks, depending on the approach used. These categories are used for the determination of the inspection intervals and the percentage of elements to be included in the inspection programme. The same categorization could be used as an input for the determination of the qualification levels.

To summarize, the risk ranking of the components in RI-ISI is an alternative safety classification of components. It can be considered to be the analogue of the "safety significance" defined in this document. Since during a RI-ISI process, the risk associated with each structural element or component is analysed in detail, it can be argued that such a risk classification is the most realistic and updated safety classification for the components included in the scope of the RI-ISI application. Further information can be found in the European Framework Document for RI-ISI [4].

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ABOUT ENIQ AND SNETP

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 70 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.

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