ENIQ
RECOMMENDED PRACTICE

ENIQ Recommended Practice 8

Qualification Levels and Approaches

Issue 2

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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 are 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) are added.

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 on determining the qualification approach based on this choice of level. Examples for qualification levels and approaches of different nuclear power plants / licensees / qualification bodies in Europe are provided in the appendix.

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1. Introduction

The European Methodology Document [1] [2] 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.

This ENIQ Recommended Practice (RP) will assist those involved in inspection qualifications in how to set qualification level and to determine the qualification approach based on this choice of level if there is a wish to formalize different qualification levels. This 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 qualification approach determines to what extent the various aspects of a qualification (Technical Justification (TJ), open trials, blind trials) are included in a particular case. The European Methodology [1] supports the concept that the qualification approach is appropriate to the inspection situation. It is also worth noting that other qualification systems use the concept of varying the qualification requirements to the needs of different components. For example, Appendix VIII of ASME XI has different qualification requirements for different components.

The main reason for introducing the concept of varying the qualification approach is to give those involved in the qualification processes the flexibility to decide and agree how much work or evidence is required to qualify a particular inspection. The standard to which a qualification is carried out is always very high and it is not the intention in varying the qualification approach to undermine this principle. However, it is recognized that some inspections will require much more work and evidence to qualify than others depending on the particular situation.

3. Definitions

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

Qualification level: An alphanumeric value that reflects the assurance required that the inspection will attain its objectives as stated in the inspection specification.

Qualification approach: The range of qualification activities and the type and nature of the qualification body (QB) needed to achieve the desired qualification level.

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 particular 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 safety significant components rather than focusing all the effort on the highest risk components. It therefore complements a risk-informed approach to structural integrity demonstration.

For example, the inspection of a RPV 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 importance would be qualified to a lower qualification level and approach. This ensures that a proportionate amount of qualification effort and resource is concentrated on those components where the inspection plays the greatest role in reducing risk and 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 approach 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.

Furthermore, NDT personnel may incorrectly believe that an inspection that is qualified in a less extensive way does not have to be performed to the same standard as that for an inspection that is qualified in a more extensive way. It must be emphasized to all NDT personnel that the same quality (care and attention to detail) must be applied to all inspections.

5. How to decide and agree the Qualification Level

The qualification level is chosen and agreed early in the qualification process. Normally the nuclear utility will determine the qualification level - 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 plant owner 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.

Some utilities may wish to use a risk-informed inspection approach in order to determine the qualification level. Further guidance and examples on using a risk-informed approach are given in the Appendices. However, the selection of a qualification level is also possible without using a formal risk-informed approach.

The number of different qualification levels is a matter to be understood and agreed among the parties involved. It is recommended that an alphanumeric notation is used to denote and differentiate the chosen qualification levels.

As an example, in a three tier qualification level system, the following qualification approaches and levels could be specified:

- Lowest qualification level (qualification approach: not all influential parameters of the inspection are analysed in the TJ, possibly covering procedures of more generic application, with less rigorous demands on specific personnel qualification and independence of the QB);
- Medium qualification level (qualification approach: use of existing evidence and information, it may be possible to transfer some parts of the TJ between countries, potentially no requirements for blind trials);
- Highest qualification level (qualification approach: extensive and robust TJ supported by experimental and modelling evidence, open and blind trials).

If more than three qualification levels are to be used, this would be expected to result in more nuances of the medium qualification level. The factors listed below may be considered in determining the qualification level. The first two are generally the most important.

1. **Safety or risk significance of the component**: An assessment of the safety and risk significance of the component is made. In some cases, it may be appropriate to consider industrial safety as well as nuclear safety issues. The Appendices to this report provide illustrations of how risk can be used to determine qualification level.
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 being provided, for example, by leak detecting equipment, pressure testing, secondary restraints or by increasing redundancy

and/or diversity in the overall inspection programme.

3. **Uncertainties or unknowns associated with the inspection or with the use of the inspection results**: There may be cases where there are significant uncertainties in parameters affecting the structural integrity case for the component - for example uncertainties in fracture toughness or crack growth rates. In such circumstances, it may be appropriate to specify a higher qualification level to provide the necessary confidence in the absence of structurally significant defects than may otherwise have been the case.
4. **Operational feedback**: Components with a recorded failure either in the concerned plant or in plant of similar design could be considered to require a higher level of qualification. In this case, defects in the test pieces could reflect real defect types as identified from the failure.

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 particular application.

6. Determining the Qualification Approach

In general, once the qualification level has been determined it defines the corresponding qualification approach. Indeed, it desirable to have a predetermined qualification approach and set of generic requirements for the qualification procedure and the QB. In the case when a QB is an independent third-party organization the requirements for the qualification procedure can be determined by this QB in accordance with the already determined qualification level.

The activities that are affected directly by the qualification level are shown in Figure 1 and are discussed below. Although the qualification approach is largely determined by the qualification level there may be occasions where the novelty, complexity and technical difficulty of the inspection solution may influence the details of the qualification procedure. This situation could arise where the inspection solution corresponding to a lower qualification level is complex or novel

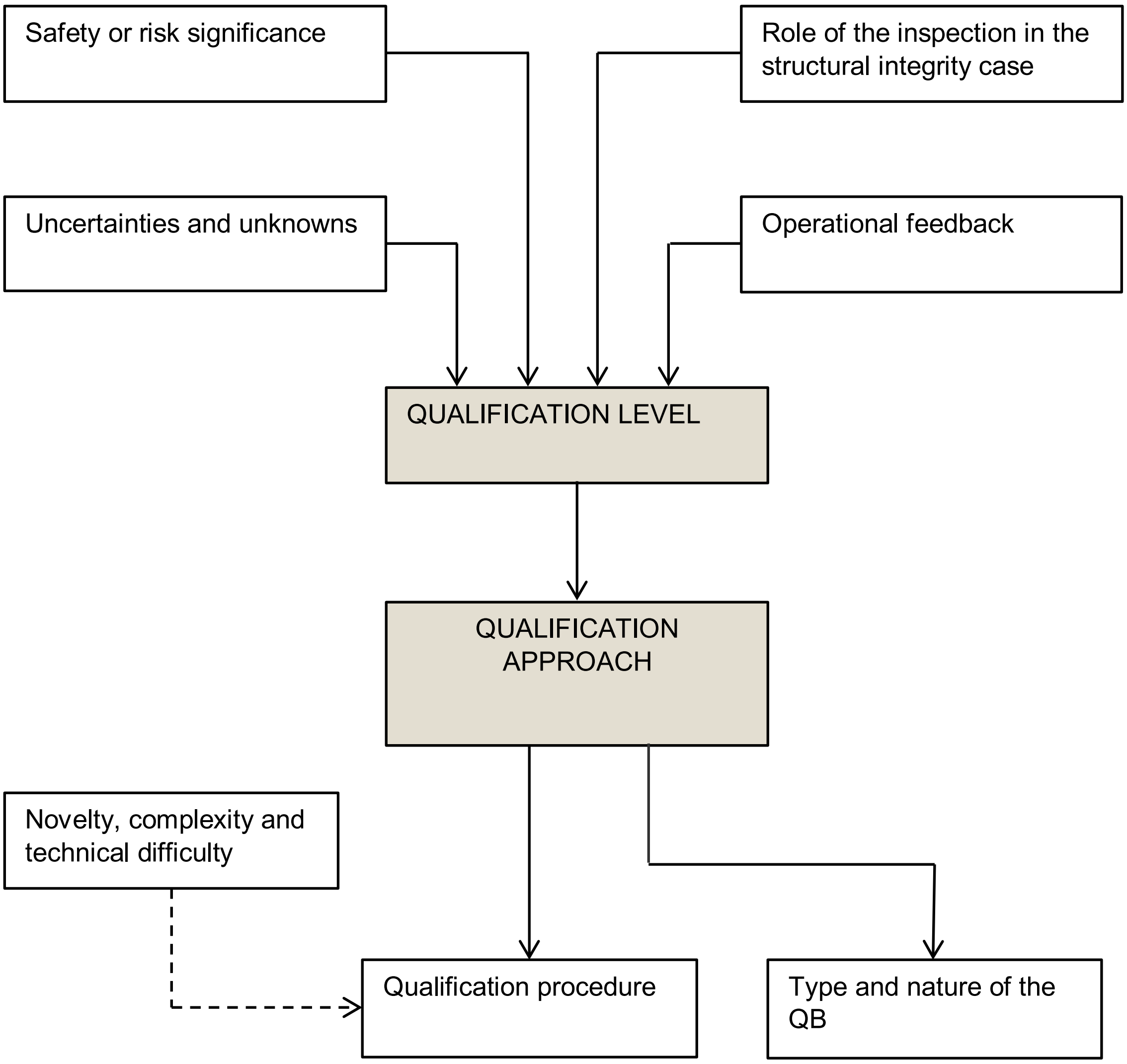


Figure 1: Inputs to qualification levels and outputs from qualification approach

6.1 Representation of Input Parameters

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

1. Role of the TJ;
2. Need for and role of open trials;
3. 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 primarily determines the overall qualification approach and hence the qualification procedure and the extent to which the activities 1 to 4 are required for a particular qualification and how each will be performed.

For example, a high qualification level will require a 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 procedure could involve no more than the production of a simple capability statement based on existing evidence.

The qualification level also determines the extent to which all influential parameters of the inspection are analysed:

- A rigorous justification of the impact of any parameter provides higher assurance that the inspection will attain its objective for on-site real conditions;
- Alternatively, for a lower level qualification (providing lower assurance), some parameters may be addressed through the use of relevant available evidence (feedback, engineering reasoning etc.). Where parameters are disregarded or treated less rigorously an appropriate justification may be provided.

As illustrated in Figure 1, the other input in determining the appropriate qualification procedure 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. One means of taking account of inspection novelty, complexity and technical difficulty when determining the qualification approach is to designate inspections as either complex or simple (i.e. one of two categories). The former might involve complex geometries and/or austenitic welds. The latter is exemplified by welds of simple butt geometry in ferritic or fine-grained material. Alternative categorizations, for example into 3 categories (low, medium and high novelty, complexity or technical difficulty) are possible.

Another aspect of the qualification approach relates to the manner in which experimental results from test-pieces are generated and used. For the most rigorous qualification approach, test-pieces are likely to be complex, geometrical replicas of the real component, identical in metallurgical structure if this is important and containing defects that are as realistic as possible. For a lower qualification approach, flat plates containing simple targets, such as electric 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 approach that is needed in any particular case can be used to determine the type of and requirements for expertise and experience of the QB. 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. 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, scheduled for publication in 2018.

[5] *ENIQ Recommended Practice 2: Strategy and Recommended Contents for Technical Justifications – Issue 3*, ENIQ Report no. 54, The NUGENIA Association, 2018.

APPENDICES

Appendix 1: Issues to Consider when Using Models Developed by Other Organisations or when Extending the Scope of the Model Application

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 2 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 3). 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).

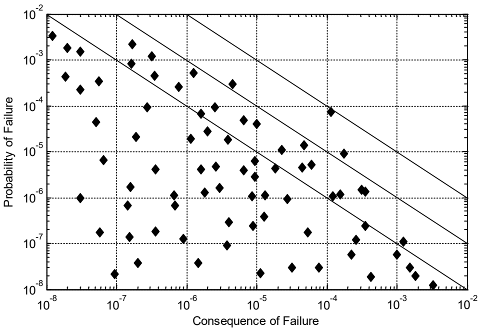
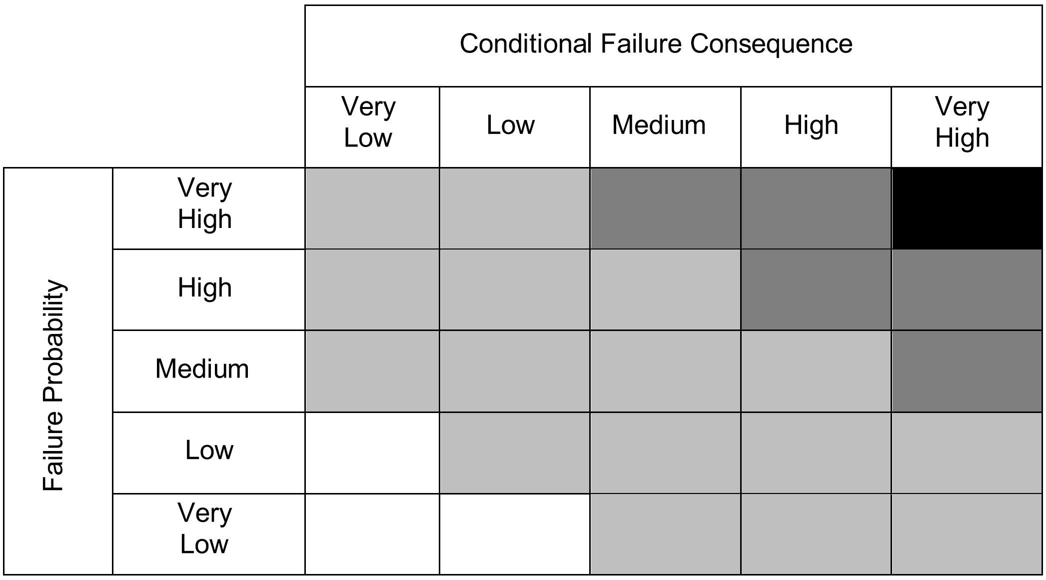


Figure 2: Illustrative Log Risk Plot



		Conditional Failure Consequence				
		Very Low	Low	Medium	High	Very High
Failure Probability	Very High	░	░	▓	▓	█
	High	░	░	░	▓	▓
	Medium	░	░	░	░	▓
	Low		░	░	░	░
	Very Low			░	░	░

Figure 3: 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].

Appendix 2: Example for Qualification Level and Approach of Paks Nuclear Power Plant / Hungarian Qualification Body

The procedure of determining qualification levels in Hungary considers the requirements of ENIQ RP8 and shares its main principles.

Description of Hungarian Qualification Levels and Approach

A2.1 Purpose of specifying Qualification Levels

With determining the qualification levels of non-destructive tests, the operator has the opportunity to assess the application of the possible elements of the qualification process (TJ, including physical rationale, application of the mathematical model, using previous qualifications, as well as open or blind practical trials) and the depth of the application of the selected elements. As a result, by specifying the qualification strategy to be applied in cases of different levels of inspections, the usage of the available resources can be optimised.

A2.2 Determining Qualification Levels

The qualification level of a specific inspection shall be specified and negotiated at the beginning of the qualification process. The qualification level is determined by PAKS NPP (Paks Nuclear Power Plant Ltd.) in certain cases after preliminary negotiations conducted with the authority. The QB is only involved after the determination of the qualification level. The QB specifies the appropriate qualification approach for the specific inspection qualification, knowing the determined qualification level. Upon determining the qualification approach, the QB considers the novelty, complexity of the inspections, as well as the technical difficulties and the objective thereof.

A2.2.1 Principles of specifying Qualification Levels

Safety risk is an important aspect regarding regular non-destructive tests and the qualifications of the inspections. The qualification level can also be defined as the level of the reliability of the inspection required to reach the target risk reduction. Therefore, the primary organising principle of determining qualification levels is risk.

Risk has two major components: 1) probability of the occurrence of the failure and 2) the severity of the consequences of failure. The determination of the qualification levels can be performed using parameters which are specified through engineering estimates, and are in close correlation with the components of risk.

The pieces of equipment and equipment parts in which the regular inspection programme has uncovered failures affecting the structural integrity of the specific equipment, obviously have a higher probability of failure than those that are only related to failures presumed (postulated) by the designer, and the likeliness of their failure is higher than in case of equipment where there are no apparent signs of damage or failure. Therefore, the failure probability categories “high”, “medium” and “low” of a so-called qualitative risk map can be replaced with the categories of “specific failure”, “postulated failure” and “undefined failure”.

The different categories can be defined as follows:

Specific failure: This group includes the inspection cases where a failure has already been found earlier in the equipment or component to be tested at the specific nuclear power plant or a power plant of equivalent type. Since the previous inspections and the discovery of the failure enable us to presume that the location, type and morphology of the failure can be known, an optimal non-destructive inspection method can be developed to detect these failures and to specify their magnitude. For such cases, the “high” or “elevated” level qualifications may be specified, if the component is categorised into the 1st or 2nd safety class.

Postulated failure: This group includes the inspection cases where the designer has presumed a failure in the equipment or their specific range, or if it is justified based on other strength calculations. In reality, the actual characteristics of the possibly being developed material discontinuity are not known, and therefore the presumption can mostly be based on engineering practice and failures occurring in power plants of the same type. This group also includes the inspection cases where the sensitivity of the equipment to a damage mechanism has proven to be high (as a result of other technical analyses). The “elevated” level qualification can be valid for this case. In case of postulated failures - since the characteristics of the failure are not accurately known - the optimal inspection technology can only be developed with certain limitations.

Undefined failure: This group includes all the equipment in which no failure was found and/or the designer presumed no failure, or in which no potential damaging mechanism was identified. For the qualification of these pieces of equipment, the “normal” qualification level is general appropriate.

If there was no other way, the consequences of the failure have already been incorporated as qualitative engineering estimates to the safety classification of equipment (see the relevant reference in Nuclear Safety Code Volume 3, Directive 3.1: Principles of the safety classification of nuclear power plant systems and components, version 1). Therefore, it is an acceptable approach to replace the “high”, “medium” and “low” consequence categories of the risk matrix with the “first”, “second” and “third” safety class (respectively).

A2.2.2 Methods of specifying Qualification Levels

Based on the above, a system of relationships (matrix) can be drawn up which shows similarities to a qualitative risk map, since it is based on similar principles. This is shown in Figure 4. Different fields of the diagram show the qualification levels. The levels are indicated with numbers, the lowest (normal) level is represented by 1, the elevated level is represented by 2 and the high level is represented by 3. The highest qualification level is only found in one of the nine fields. In case of two fields the elevated level qualification occurs, and in case of equipment assigned to the remaining elements of the matrix the normal qualification level is adequate. This is explained by the fact that the upper right elements of the matrix correlate with the highest risk. The content of this field and - generally - the requirements related to the qualification of equipment in the 1st safety class are individually analysed. This strictest qualification level is typically applied to selected equipment of the primary circuit (reactor pressure vessel, primary side of the steam generator, pressuriser tank).

The two elements horizontally adjacent to the upper right element of the matrix can be considered to have identical risks, therefore it is logical to apply the same - elevated level - qualification level for the equipment assigned to these elements. These include for example the inspections carried out in the main circulation pipeline and its armature. The diagonal line from the upper left element of the matrix to the bottom right element is an additional (so-called iso-risk) level that is lower than the previous ones. These elements belong to the normal qualification category, which can be justified with the explanation that - although only based on estimates or similarity to the qualitative risk map - these risks are significantly lower than the risk assigned to fields marked with the numbers 3 and 2.

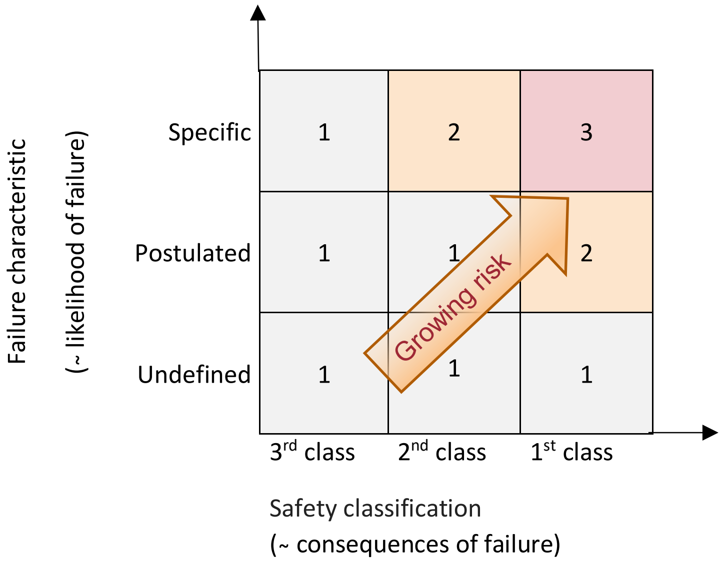


Figure 4: Qualification levels as a function of the failure characteristics and the safety classification of the tested equipment

Based on the above, the qualification levels can be the following:

1. Normal;
2. Elevated;
3. High.

A2.3 The impact of the Qualification Level on the Qualification Approach

The qualification level is an important initial data in determining which of the qualification activities are required for the specific qualification, and how to perform them. For example, a high (3) or elevated (2) qualification level requires a TJ which requires a large number of evidence available, appropriate for the qualified inspection. For the qualification of a normal (1) level inspection, the small number of general evidence collected during similar inspections can be used. In the simplest case, the qualification requires nothing else but a simple capability statement, based on existing evidence.

A2.3.1 Correlation between the Qualified Inspection and the Qualification Level

Based on the characteristics of the inspection, complex and simple inspections can be distinguished:

(a) Complex inspections:

  - Test equipment and procedure are complex (e.g. comprises multiple parts, requires significant computer background, the performance of calibration or the evaluation of test results are complicated, etc.).
  - Test equipment and procedure are new (or novel), their application is not widespread and the range of available experience is small.
  - Circumstances and conditions of the inspection are complex, hard to achieve (e.g. the tested volume is hard to access, the time frame available is limited, the geometry is complex or the structure of the tested material/substance makes it hard to perform the test, e.g. austenitic welds, metallurgies, etc.). The indicated faults have complex shapes, unfavourable orientations or a small size.
  - Specification of the size and/or orientation of failures expected from the inspection, with the required accuracy.

(b) Simple inspections:

- Test equipment and procedure are simple, well-known (e.g. mass-produced equipment, standardised methods, etc.).
- Test equipment and procedure are mature, and have been applied widely, for a long period.
- Circumstances and conditions of the inspection are simple (e.g. the tested volume can be accessed easily, without restrictions, the material has a ferritic/pearlite structure, the geometry is simple, etc.). The faults to be indicated have a favourable location (from the point of view of the test), their shape enables easy discovery, and have a large size.
- Objective of the inspection is to find and identify faults.

Table 1 provides guidelines to qualification elements appropriate for simple and complex inspections regarding the three different qualification levels.

Table 1: Qualification approach in the case of different qualification levels (OT - open trials, BT - blind trials, CS - capability statement).

Qualification level	**Inspection type**	**Qualification elements**
3.	Simple	TJ, OT
3.	Complex	TJ, OT or BT
2.	Simple	TJ
2.	Complex	TJ, OT
1.	Simple	CS
1.	Complex	TJ

A2.3.2 Correlation between the Applied Test Pieces and the Qualification Level

Test pieces applied during the execution of the open or blind practical trials play a major role in carrying out qualifications according to the qualification levels (if such trials are performed). The manufacturing of test pieces is one of the most expensive parts of the qualification, and therefore it is advisable to analyse the applicability of possible test pieces in the TJ and to confirm the reasons appropriately. It is often enough for example to apply test pieces made using electro spark machining or machining, if the TJ can present how the results can be applied to the real component. Table 2 includes guidance regarding the types of test pieces applicable to the different cases presented in Table 1.

Table 2: The impact of qualification levels and the complexity of the component on the test pieces

	Qualification level		
Inspection type	**1.**	**2.**	**3.**
Simple (ferritic structure, simple geometry, etc.)	● Flat surface geometry ● Electro-spark machining or machining notches	● Flat surface geometry ● Electro-spark machining or machining notches	● Real component geometry ● Realistic faults
Complex (austenitic, complex geometry, etc.)	● Flat surface geometry ● General grain structure ● EDM notch	● Simplified or real geometry ● Typical grain structure ● Electro-spark machining or machining notches, or likely faults	● Real component geometry ● Typical grain structure ● Realistic faults

A2.3.3 Staff number of the Qualification Body and the Qualification Level

As a general principle, it can be laid down that in case of lower qualification levels (e.g. 1) the number of members of the QB is smaller than in case of higher qualification levels (e.g. 3). The inspection type has a similar impact on the QB staff number. In case of simple inspections, the staff number is lower than in the case of complex inspections. Considering that the QB has two permanent members, the recommendation on the inspection qualification group (IQG) staff number is included in Table 3.

Table 3: Staff number of the IQG considering the qualification level and the inspection type

	Qualification level		
Inspection type	**1.**	**2.**	**3.**
Simple	1 person	2-3 persons	3 persons
Complex	1-2 persons	3 persons	3 persons

In reasonably justified cases, the QB can also involve external experts in its work. Within the QB, the criteria for the members of the IQG in undertaking operative professional tasks, changes according to the qualification levels and the inspection types. For example, in cases where the staff number of the IQG is 2-3 persons (Complex 1, as well as 2 and 3 levels), the criteria for the experts involved in the work of IQG generally cover specific professional expertise and experience. In case of lower levels (level 1), where the IQG staff number is 1, the primary criteria for the expert involved is to have overall complex knowledge and experience.

Appendix 3: Example of the Rolls Royce Approach to the Application of Qualification Levels to Fabrication Inspections

Background to the Specification of Qualification Levels

Inspection qualification (IQ) of both in-service and fabrication examinations was introduced to Rolls-Royce reactor plant components in the mid-1990s. Originally, IQ was reserved for the inspections of only the most risk significant components with no differentiation in the manner in which it was implemented.

Since then a risk-based approach to the demonstration of Structural Integrity (SI) has been developed by Rolls-Royce as Technical Authority (TA). A key element of this approach is the introduction of two levels of IQ. The two levels of IQ are termed Qualification Level A (QLA) for the highest risk components and Qualification Level B (QLB) for the next level of lower risk components. The overarching principle being that the highest risk locations require more diversity, redundancy and reliability of NDT than the lower risk categories (see Table 4).

The IQ of the inspection of the most risk-significant components remains the same (QLA) (extensive TJ, modelling, open/blind trials) but the introduction of a lower level of qualification (QLB), targeted at lower risk components has allowed a wider application of IQ principles without a significant increase in cost but with a significant overall safety benefit.

The following example considers the application of qualification levels to fabrication inspections. A methodology for the application of qualification levels to ISI is currently under consideration.

Table 4: Risk-Informed qualification requirements for fabrication inspections

Consequence of Failure

(Safety Classification)

Damage Tolerance[1]	Class 1			Class 2	Class 3
	Catastrophic	Major	Serious		
Low	QLA	QLA	QLB	N/R[2]	N/R[2]
Medium	QLA	QLB	N/R[2]		
High	QLB	N/R[2]	N/R[2]		

Overview of Qualification Levels A and B

QLB is a streamlined approach to IQ relative to QLA. As compared to QLA, QLB relies on:

- A simpler inspection specification;
- Generally lower novelty/less complex inspection systems;
- Wider use of qualitative arguments within the TJ;
- The QB exercising more engineering judgement in assessing the acceptability of the TJ;

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[1] Damage Tolerance: A judgement based measure of defect tolerance and, hence, likelihood of failure.

[2] N/R: No requirement for qualified fabrication inspections.

- No blind trials.

Both QLA and QLB are consistent with the European Methodology for Qualification of Non-Destructive Testing [1] (ENIQ Methodology) and, at a high level, both qualification processes are common. In both cases the capability of the inspection system (personnel, procedure and equipment) to achieve certain prescribed defect detection requirements is demonstrated through a combination of physical reasoning and evidence (experimental and theoretical) in accordance with the ENIQ Methodology [1].

The principal differences in the execution of QLA and QLB are a relatively simple inspection specification and a more qualitative approach to assembly and assessment of evidence for QLB compared to QLA. These aspects are discussed in more detail in the following sections and summarised in Table 5.

Qualification Body

In general, the QB for both levels is a Type 2 body in accordance with [3] with typically four members: a chairperson, co-chairperson together with internal and external experts. All members will be experienced in the application of IQ principles in accordance with the ENIQ Methodology and the applied inspection techniques. The required level of expertise and appointment process of the QB is the same for QLA and QLB. For a QB undertaking a QLA qualification, a typical composition would be Chairperson and deputy with both being Rolls-Royce full-time employees with two external members as the independents. For a QLB qualification the requirement for independent members would generally be relaxed to one.

Inspection Qualification Process

Grouping of Similar Locations

To ensure the maximum benefit from the qualification, consideration may be given to the grouping of similar locations. In terms of qualification, similar would be considered as locations where the inspection requirements; geometry and inspection procedure are sufficiently alike such that a single qualification could cover several areas.

Although the grouping principle may apply to QLA or QLB it is most likely to be utilised for QLB. This follows as QLB is generally more widespread over a range of similar component features whereas QLA is primarily restricted to the highest risk regions (major vessels). Any grouping will be assessed by the QB.

Specification of Input Parameters / Inspection Specification

In general, for the highest risk components, the qualification defect size will include a reserve factor against the supporting analysis and therefore will typically be a smaller defect with a wider range of orientations. All defects within scope will be subject to QLA. The more complex inspection specification will therefore drive a correspondingly more complex inspection solution and qualification procedure.

For the lower risk components where QLB is appropriate, the qualification defect size will generally be larger due to there being no requirement for a reserve factor in the supporting analysis. Further, the QLB target defect population is divided into primary defects (for which qualification is required) and secondary defects (for which qualification is not required but some capability demonstrated). For a given defect type, primary represents the most likely or nominal orientation and secondary represents the likely variation of tilt and skew away from the primary orientation.

Hence, for a given application, the Inspection Specification will be simpler for QLB than QLA.

Technical Justification

The TJs for both QLA and QLB contain the same elements or sections which align with ENIQ RP2 [5].

For QLA the expectation would be that any claims made in the TJ would be substantiated by quantitative arguments adequately supported by direct modelling or experimental evidence. Careful consideration would have to be given to adequately identify the worst case defects (WCDs) over a wide range of possible defect orientations. All WCDs would typically be inserted into representative test-pieces or modelled in detail. This expectation, together with a generally smaller qualification defect size and wider orientation range, is most likely to result in a complex and extensive inspection system and TJ.

For QLB the expectation would be for more widespread use of reasoned argument and judgement, in place of detailed and specific experimental and modelling evidence. For QLB, noting the restricted nature of the primary defects, the WCDs will correspond directly to the primary orientations. All WCDs would typically be inserted into representative test-pieces or modelled in detail. The greater use of reasoned qualitative argument, together with a simpler inspection specification will, generally, result in a less complex TJ.

Blind Trials

The expectation is that blind trials would only be invoked, by the QB, for QLB in exceptional circumstances whereas for QLA would be more widespread in situations where correct data interpretation is problematic (i.e. low Signal to Noise Ratio [SNR]).

Table 5: Summary of Differences between Qualification Levels A and B (QLA and QLB)

	Qualification body	Grouping of qualification sites/inspections	Inspection requirements	TJ			Blind trials	Assessment by QB
				General	**Open trials / experimental results**	**Theoretical modelling**		
QLA	Type 2 - A QB which is an independent part of the utility's organisation set up on a permanent or long-term basis. Generally, two external members as independents.	Generally not used. Each inspection application likely to be relatively unique.	Detection; characterisation and, typically, sizing. Reserve factor against the supporting analysis - typically a smaller target defect size with a wider range of orientations (than if QLB).	Expectation that any claims made in the TJ would be substantiated by quantitative arguments adequately supported by direct modelling or experimental evidence. This expectation together with a generally smaller qualification defect size and wider orientation range is most likely to result in a complex inspection system and TJ.	A range of experimental results supporting claims made in Physical Reasoning section. Experimental evidence on a broad range of targets covering majority of allowable orientations and sizes together with WCDs. Sizing results would be expected.	As appropriate to supplement the experimental results. Models would be expected to be suitably validated and accepted for the range and types of defect response to be simulated.	Yes – in cases where data interpretation provides a particular challenge. For instance, austenitic weld inspection, small target sizes at long range/difficult geometry.	Detailed review of TJ and trials evidence. QB would expect claims made in TJ to be supported by direct experimental and/or theoretical arguments. The scope of the NDT data sheet will generally drive an extensive TJ. Quantitative assessment of the evidence/arguments with an overall acceptance of capability 'beyond reasonable doubt'.
QLB	As QLA but, generally, one external member as an independent.	Yes – where feasible. The inspection specification is likely to be similar over a range of components which facilitates the development of a generic inspection procedure and, consequently, a generic qualification.	Detection and characterisation. Target defect population is divided into primary defects (qualification is required) and secondary defects (qualification is not required but some capability demonstrated). No requirement for a reserve factor results in a, generally, bigger qualification defect size.	Expectation would be for more widespread use of reasoned argument and judgement, in place of detailed and specific experimental and modelling evidence. The greater use of reasoned qualitative argument together with a simpler inspection specification will, generally, result in a less complex TJ.	A range of results supporting claims made in Physical Reasoning section. Experimental evidence would be expected to be limited to the primary defect(s) orientation(s). Generally wider use of reasoned argument.	Can be used in lieu of experimental results (provided valid). The extent of model validation would not be expected to be so rigorous.	No (except in exceptional circumstances). In most cases where data interpretation provides a particular challenge, prior experience and QB witnessing of open trials data interpretation are sufficient.	Detailed review of TJ and trials evidence. QB would expect claims made in TJ to be supported by relevant experimental or theoretical arguments. The scope of the NDT data sheet will generally drive a concise TJ. Acceptance of the evidence/arguments may contain a level of qualitative judgment with an overall acceptance of capability 'on the balance of probabilities'.

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ABOUT NUGENIA AND ENIQ

NUGENIA is an international non-profit association under Belgian law established in 2011. Dedicated to the research and development of nuclear fission technologies, with a focus on Generation II & III nuclear plants, it provides scientific and technical basis to the community by initiating and supporting international R&D projects and programmes. The Association gathers member organisations from industry, research, safety organisations and academia.

The activities of NUGENIA cover plant safety & risk assessment, severe accidents, reactor operation, integrity assessment and ageing of systems, structures & components, development of fuel, waste & spent fuel management & reactor decommissioning, innovative light water reactor design & technologies, harmonisation and in-service inspection & their qualification.

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 for nuclear power plants. Since its establishment in 1992 ENIQ has issued over 50 documents. Among them are the “European Methodology for 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 became Technical Area 8 of NUGENIA in 2012.

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