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ENIQ TGQ DISCUSSION DOCUMENT

European Methodology for Inspection Qualification: An Overview for the Non-Specialist

ENIQ report No 40

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ENIQ TGQ DISCUSSION DOCUMENT

EUROPEAN METHODOLOGY FOR INSPECTION QUALIFICATION: AN OVERVIEW FOR THE NON-SPECIALIST

July 2010 ***ENIQ Report nr. 40*** ***EUR 24428 EN***

Approved by the ENIQ Task Group on Qualification

ENIQ, the European Network for Inspection and Qualification, publishes three types of documents:

Type 1 — **Consensus documents**
Consensus documents contain harmonised principles, methods, approaches and procedures and emphasize the degree of harmonisation between ENIQ members.

Type 2 — **Position/Discussion documents**
Position/discussion documents contain compilations of ideas, express opinions, review practices, draw conclusions and make recommendations for technical projects.

Type 3 — **Technical reports**
Technical reports contain results of investigations, compilations of data, reviews and procedures without expressing any specific opinion or evaluation on behalf of ENIQ.

This 'ENIQ TGQ Discussion Document: European Methodology for Inspection Qualification - An Overview for the Non-Specialist' (ENIQ Report No 40) is a type 2 document.

FOREWORD

The present work is the outcome of the activities of the ENIQ Task Group Qualification (TGQ).

ENIQ, the European Network for Inspection and Qualification, is driven by the nuclear utilities in the European Union and Switzerland and managed by the European Commission's Joint Research Centre (JRC). It is active in the field of in-service inspection (ISI) of nuclear power plants by non-destructive testing (NDT), and works mainly in the areas of qualification of NDT systems and risk-informed in-service inspection (RI-ISI). This technical work is performed in two task groups: TG Qualification and TG Risk.

A key achievement of ENIQ has been the issuing of a European Methodology Document, which has been widely adopted across Europe. This document defines an approach to the qualification of inspection procedures, equipment and personnel based on a combination of technical justification (TJ) and test piece trials (open or blind). The TJ is a crucial element in the ENIQ approach, containing evidence justifying that the proposed inspection will meet its objectives in terms of flaw detection and sizing capability. A qualification body reviews the TJ and the results of any test piece trials, and issues the qualification certificates.

The purpose of this document is to provide an overview of the ENIQ Qualification Methodology and how the process of Inspection Qualification is commonly applied within Europe and elsewhere. It is intended as a reference source for a wide audience of engineers and technical staff, such as safety engineers, stress analysts, etc., who may not be routinely involved with either non-destructive examination or inspection qualification, but who may benefit from a greater understanding and appreciation of the ENIQ Qualification Methodology. It will also benefit those personnel who have a responsibility to provide practical assistance in the preparation of the qualification process.

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1 PURPOSE

The purpose of this document is to provide an overview of the European Network for Inspection and Qualification (ENIQ) Qualification Methodology [1] and how the process of Inspection Qualification is commonly applied within Europe and elsewhere.

It is intended as a reference source for a wide audience of engineers and technical staff, such as safety engineers, stress analysts, etc., who may not be routinely involved with either non-destructive examination or inspection qualification, but who may benefit from a greater understanding and appreciation of the ENIQ Qualification Methodology. It will also benefit those personnel who have a responsibility to provide practical assistance in the preparation of the qualification process.

2 INTRODUCTION

Most industries and associated human activities have developed codes and procedures to deal with the aspect of safety; Inspection Qualification is simply an addition to these. Inspection Qualification (IQ) may be defined as:

> "*the systematic assessment of an inspection system, by all those methods that are needed to provide reliable confirmation, to ensure that it is capable of achieving the required performance under real inspection conditions.*" [1]

Under the ENIQ methodology, IQ consists of a combination of technical justification, which involves assembling all supporting evidence for test capability (results of capability evaluation exercises, feedback from site experience, applicable and validated theoretical models, physical reasoning) and test piece trials using deliberately flawed test pieces. IQ is mostly aimed at those involved in the development, control and physical application of NDE techniques, primarily in the nuclear field, although the philosophy developed may be applied in other industries. What is less prominent is information to assist non-NDE organisations and individuals in their understanding of IQ and the role it plays in support of plant structural integrity justifications and safety assessments. This report seeks to address this situation by outlining the history of IQ, the organisation behind it and issues that are pertinent to Regulators, Plant Designers and the Utility.

It has long been accepted that non-destructive examination, especially in the nuclear industry, needs to be controlled in such a way as to provide the maximum of confidence in its results. One initiative to achieve this goal is embodied in ASME Section XI, Appendix VIII. This is a prescriptive code-based approach limited to ultrasonic examination of certain specified components. As designed, it is aimed at gaining confidence that individual inspectors can achieve correct results. However, recognising that correct results rely on the inspection system as a whole, the actual application of ASME XI Section VIII is supplemented by a number of other processes and procedures which are not specified within the code itself but are integral to the effectiveness of the overall process.

ENIQ has evolved a different approach based on the experiences gained through the inspection and qualification of European nuclear reactors. The methodology adopted was formulated through the foundation of the European Network for Inspection and

Qualification (ENIQ), which was set up under the control and guidance of the Joint Research Centre (JRC). The main objective of ENIQ was to co-ordinate and manage at the European level expertise and resources for the development of schemes for the assessment and qualification of NDE in-service inspection techniques and procedures, primarily for nuclear components. It was also recognised that harmonisation in the field of codes and standards for inspection qualification would represent important advantages for all parties involved, with the ultimate goal of increasing the safety of nuclear power plants. More information on the ENIQ network and its activities can be found at http://safelife.jrc.ec.europa.eu/eniq/.

The ASME Section XI approach and that of ENIQ, although substantially different, have the same objective, namely to confirm that the inspection process (procedure, equipment and personnel) is capable of producing correct results. However, whereas ASME Section XI may be considered a detailed prescriptive process, the approach of ENIQ is a flexible methodology that may be applied to any component (nuclear or non-nuclear) and any NDE method/technique.

In 1995, ENIQ produced the document 'European Methodology for Qualification', which is now in its third issue dated 2007. Since then, ENIQ has produced, and continues to produce, Recommended Practice (RP) documents. These provide guidance on such issues as generation of technical justifications, test piece design, personnel/equipment qualification, types and responsibilities of qualification bodies, modelling, qualification levels, etc.

It is important to point out the difference between the more widespread personnel certification described in CEN-EN 473: 2008 NDT Qualification and Certification of NDT Personnel and the qualification of an inspection system and personnel in accordance with the ENIQ Methodology for Qualification. A certification scheme developed in accordance with CEN-EN 473 provides confidence that any operator who is successfully certified has a broad knowledge of the principles, application and capability of a particular NDT method in a range of situations. In other words, it is a 'method' based certification scheme for personnel. Qualification in accordance with the ENIQ Methodology for Qualification is a more stringent process that demonstrates the combination of inspection system and personnel are capable of achieving very specific defect detection and sizing criteria in a particular situation. In other words it is a 'performance' based certification scheme that demonstrates the complete inspection system (including personnel) is 'fit-for-purpose'.

3 European Network for Inspection and Qualification

3.1 Organisation – Task Groups

ENIQ work is carried out by two sub-groups: the Task Group on Qualification (TGQ) focuses on the qualification of in-service inspection (ISI) systems and is responsible for the Methodology and Recommended Practices on qualification produced by ENIQ. The Task Group on Risk (TGR) focuses on risk-informed in-service inspection (RI-ISI) issues. The TGR has published the European Framework Document for Risk-Informed In-service Inspection, and is producing more detailed recommended practices and discussion documents on several specific RI-ISI issues. Both task groups consist of experts from European member countries, including those who operate nuclear plants, and work under the control and guidance of the ENIQ Steering

Committee with overall management provided by the JRC. This report only covers qualification - not RI-ISI.

3.2 European Qualification Methodology Document

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

The European Methodology for qualification of a non-destructive examination may require assessment of an inspection system, consisting of any combination of inspection procedure, equipment and personnel. This qualification or assessment can be considered as the sum of the following items:

- Practical assessment (blind or non-blind), conducted on simplified or representative test pieces resembling the component to be inspected. Where automated systems are concerned, the procedure may be applied in two distinct parts: data acquisition followed by data interpretation of the recorded signals.

- Technical Justification, which involves assembling all evidence on the effectiveness of the test including previous experience of its application, laboratory studies, mathematical modelling, physical reasoning and so on.

The appropriate mix of the above sources of evidence must be judged separately for each particular case, although the use of technical justification is highly recommended.

The first version of the European Methodology document was issued by the PISC III Action 8 Group, dealing with support for codes and standards. The document was further developed and finalised by ENIQ. The first issue was approved by the Steering Committee of ENIQ at its meeting of 15 March 1995 in Petten and was published as ENIQ Report 1. This document was the first to be published in Europe on this issue and contained a number of innovative proposals, such as the use of technical justification, the separation between procedure/equipment and personnel qualification and the use of non-blind trials for procedure and equipment qualification.

3.3 Recommended Practices

Recommended Practices are the next level of document below the European Methodology. They are general guidelines to support the production of detailed qualification procedures by individual countries.

The European Methodology does not include detailed descriptions of how the inspection of specific components should be qualified. Recommended Practices are documents produced by ENIQ to support the production of detailed qualification procedures and are applicable in general to any qualification. This general scope means that valuable advice can be given by ENIQ to promote a uniform approach to qualification throughout Europe, but the detail of how qualification is to be done is determined at the national level in line with the regulatory and technical requirements in that country. Organisations are free to make use of the existing Recommended

Practices, but it is important to note that they are only recommendations not instructions, and as such, are open to interpretation.

The Recommended Practices are relevant to any non-destructive testing method. Also, it is emphasised that the general principles given in any of the Recommended Practice documents can also be used for qualification of manufacturing inspections or of inspections performed in the non-nuclear field, although they were developed primarily for in-service inspection of nuclear power plant components.

The following is the current list of available ENIQ documents and Recommended Practices relating to qualification:

- ENIQ Report Nr 31 (Issue 3): European Methodology for Qualification of Non-Destructive Testing, [1].
- ENIQ RP 1 (Issue 2): Influential/Essential Parameters, [3].
- ENIQ RP 2: Strategy and Recommended Contents for Technical Justifications, [4].
- ENIQ RP 3: Strategy Document for Technical Justification, [5]. SUPERSEDED. See note below.
- ENIQ RP 4: Recommended Contents for the Qualification Dossier, [6].
- ENIQ RP 5: Guidelines for the Design of Test Pieces and Conduct of Test Piece Trials, [7].
- ENIQ RP 6: The Use of Modelling in Inspection Qualification, [8].
- ENIQ RP 7: Recommended General Requirements for a Body Operating Qualification of Non-Destructive Tests, [9].
- ENIQ RP 8: Qualification Levels and Approaches, [10].
- ENIQ RP 10: Personnel Qualification, [11].

NOTE: Recommended Practice 3 (EUR 18100 EN, July 1998) is superseded. It has been replaced by the new issue of RP2 (ENIQ report No 39, EUR 24111 EN, June 2010), which combines the contents of the first issue of RP2 (EUR 18099 EN, July 1998) and RP3.

4 Role of Inspection Qualification

At some level it is necessary to establish the structural integrity requirements commensurate with the safety significance of a particular component or system.

The basis of sound nuclear design and safety is the application of a well-established national or international design code.

The principal design code that is used for the design and construction of pressure-retaining components in many nuclear power plants in Europe and the US is ASME Section III. Subsections NB, NC and ND of ASME III cover Class 1, Class 2 and Class 3 components respectively. There are other major codes used for the design of PWR plant, for example the code produced in France where a considerable amount of work has been done to develop their nuclear plant design. The French design and

construction rules for mechanical components of PWR nuclear islands are contained in the RCC-M code.

Application of these codes in their entirety - selection of materials, basic design, stress/fracture analysis and, crucially, NDE provides a level of assurance in component reliability. Generally speaking, within each code the more serious the consequences of component failure, the more stringent are the requirements to demonstrate structural integrity and, by implication, to underpin higher levels of component reliability. Typically this is controlled through the application of a classification system that corresponds to the consequences of component failure.

In terms of NDE, for components where the consequences of pressure boundary failure lead to unacceptable levels of fission product release and/or fuel failure (higher classified components), the requirements for NDE and Inspection Qualification become correspondingly more stringent. Thus, the requirement for Inspection Qualification arises from the overall requirement to underpin very high levels of structural integrity in components where failure would be unacceptable. The following describes a three-stage process for the determination of major factors associated with plant safety:

Stage 1 relates to assessing the plant protection and ‘defence in depth’ and is aimed at assigning component reliability targets, which are dependent upon the Failure Mode, Effects, and Criticality Analysis (FMECA) consequences of the component or system.

Stage 2 involves establishing whether further work beyond Code compliance is required - in particular, whether a flaw tolerance study is necessary. This is dependent upon the level of reliability sought and whether there is a known or postulated degradation mechanism.

Stage 3 involves consideration of the role of NDE in the safety case and the assigning of an appropriate level of inspection, and inspection qualification, to support the safety case (commensurate with the component reliability targets).

5 Organisation and Responsibilities

This section describes the roles and the responsibilities of the different parties involved in inspection qualification. It should be stressed that the responsibilities, as described in this section, are applicable to the inspection of nuclear power components only. For the inspection of non-nuclear components or for manufacturing applications, some or all of the responsibilities described in this section are either not necessary or are taken over by other parties.

The roles and the responsibilities of the different parties, and the interaction between them, should be defined and documented, for example in the qualification procedure.

The different parties involved in inspection qualification are generally:

- Plant Designer
- Plant Operator
- Manufacturer
- Regulatory Body

- Vendor of Inspection Services
- Qualification Body

5.1 Plant Designer

The ultimate responsibility for ensuring overall structural integrity normally lies jointly with the plant designer and plant operator. It is the former who usually determines whether the NDE methods proposed should be subject to Inspection Qualification, this being dependent upon how critical a factor inspection is in the overall safety case. It is important that the component is designed with inspectability in mind, which in turn helps the process of qualification. This means, wherever possible, being cognizant of the following:

i) Minimal use of differing materials, especially where ultrasonics is concerned. Where sound needs to pass from one medium to another, distortion and attenuation can occur in varying degrees, ultimately affecting the integrity of the inspection.

ii) Where welds are considered, weld caps preferably should be machined flat or, if this is not possible, excessive contour should be minimised through hand dressing. This helps to provide for better coupling between material and probe and minimises variation in the probe beam path through the component.

iii) Provision of inspection surfaces that are conducive to the type of inspection to be performed. For ultrasonics this should be the best that is practically possible, as the passage of sound between the probe and component, facilitated by couplant, requires intimate contact between the two.

iv) Where possible, the component geometry should be sympathetic to the requirements of an inspection. This may mean keeping complex shapes to a minimum.

v) Access should also be a consideration, both at the manufacturing stage and when in service. It should be such that, where possible, optimum inspection methods can be applied to the area of interest.

vi) An extremely important issue is the size of flaw identified as requiring detection. It should be appreciated that, normally, the smaller the flaw the greater the effort needed to find it. Commensurate with this is the increased cost associated with the greater effort required. Due cognizance of this should be taken by ensuring, through fracture analysis and expert elicitation, that flaws which are overly difficult to detect and size are not identified for detection and subsequently inspection qualification.

vii) Commensurate with (vi) is the need to properly define the flaw characteristics. A key feature of the ENIQ qualification methodology is the provision of a comprehensive qualification flaw description or Data Sheet. The qualification flaw description must include all parameters pertinent to the successful detection and sizing of the flaw that is causing concern. For an ultrasonic inspection this would include flaw size, morphology, surface roughness, tilt, skew and a number of other parameters. The appropriate selection of these parameters is crucial to the design of the inspection system and inspection qualification process. An example of a typical flaw Data Sheet is shown in Fig 1. A document “Guidance on the Specification of Inspection Requirements for Input to the Inspection Qualification Process” is currently being proposed which will encompass the development of a Data Sheet. See also Section 6.1 below.

5.2 Plant operator/owner

In all jurisdictions the plant operator (licensee), being responsible for the safety of nuclear installations, has to take care of the surveillance of the power plant. This is normally done, among other means, through in-service inspections assigned to vendors of inspection services. The plant operator has to guarantee the adequacy of the inspections and has to provide the evidence to the safety authority. The plant operator provides input for the qualification dossier that should be prepared by the qualification body; additional information may be required to complete the qualification dossier, if judged necessary. The following actions are thus the responsibility of the plant operator:

i) The plant operator decides on the items that require the assembling of a qualification dossier (by considering the area to be inspected and the flaws to be detected). The list of such cases is updated taking into account national and international in-field experience.

iI) The plant operator provides to the vendor of ISI services and to the qualification body all the required input information (components, experienced and postulated degradation mechanisms, objectives of the qualification) pertaining to ISI, including the inspection performance to be met for each of the cases.

iii) The licensee, usually the plant operator, is ultimately responsible for the NDT procedure and technical justification.

iv) The plant operator may assess the qualification procedure proposed and comment on it. Depending on the particular relationship between operator and regulatory body, the plant operator could approve the qualification procedure in some countries.

v) The plant operator takes the necessary steps to enable the qualification body to keep the qualification dossier updated with national and international in-field experience.

vi) The plant operator supervises the whole of the inspection activities that affect inspection system performance, especially receipt and verification of the equipment, qualification of the personnel, contents of the procedures, logistics of the operations, and evaluation of the results.

vii) The plant operator will normally discuss with the Qualification Body appropriate facilities such as light and power and sufficient space to perform the qualification safely.

viii) It is normal for the plant owner to retain the critical inspection data for the life of the NPP.

5.3 Plant manufacturer

If a component is to be subject to IQ at certain hold points within the manufacturing process, it is important that these inspection hold points are chosen to optimise the benefit of applying the inspection at those particular stages in the manufacture. For example, if the intention is to ultrasonically examine a buttering interface it may be advantageous to leave on excess material to compensate for any probe dead zone. This of course would require the agreement of the customer.

Accepting that IQ during manufacture is a contractual requirement, it is normal for the manufacturer to be asked to provide suitable facilities for this to be carried out.

5.4 The regulatory body

In all countries the regulatory body is assigned the task of monitoring and evaluating safety and that the licensees fulfill the conditions of their site licences. In the context of NDT qualification the regulatory bodies either define or review the basic qualification requirements that must be met from a safety point of view. The regulatory body may also undertake audits, periodic reviews and monitor the licensees' compliance with the qualification requirements.

5.5 Vendor of inspection services

The vendor develops the NDE techniques in accordance with the inspection objectives, writes or details the NDT procedure and the technical justification, if required by the plant owner, and performs the inspection. The vendor normally will provide all the necessary information allowing the qualification body to set up the qualification dossier. Some aspects of technique development and qualification set-up may be shared between the vendor and the plant operator. The vendor has to participate in the qualification of the NDT procedure, if requested, e.g. when instruments and personnel are included in the qualification. The vendor also attests to the qualification and experience of the individual inspection operators. (Some jurisdictions use the term "Inspection Service Provider"). The vendor is also responsible for organising the inspection and defining the operator roles.

The vendor helps the qualification body to keep the qualification dossier up to date.

The vendor may also directly submit an NDT procedure and technical justification for qualification. In that case the vendor assumes the specific roles of the plant operator.

5.6 The qualification body

The responsibility of the qualification body in this text refers to the NDT procedure and to the personnel in the cases where operators are involved in the qualification.

The qualification body comprises a number of personnel who have specific expertise that is pertinent to the technique under review. They are normally nationally recognised within their subject field and attest to the appropriateness of the proposed inspection to the defined objectives of the inspection, based on the evidence submitted in the technical justification and test piece trials.

The qualification body has the following responsibilities.

i) Preparation of the proposed qualification approach
ii) Preparation of the detailed qualification procedure
iii) Assessment of the NDT procedure and technical justification
iv) Review of personnel requirements
v) Identification or design of test pieces and their fabrication
vi) Invigilation (or proctorship) - if applicable - of the qualification trials
vii) Assessment of the qualification results
viii) Assembling and issuing of the final qualification dossier (or associated summary of technical evidence)
ix) Issuing of qualification certificates.

The need for the qualification body to be separate from the plant owner is a matter to be determined by the plant owner and the regulatory body if qualification is carried out as a result of regulatory requirements. Where it is necessary for the qualification body to be independent but within the plant owner's organisation, the qualification body should have a quality system which guarantees its independence from commercial or operational considerations or pressures.

The ENIQ Recommended Practice 7: Recommended General Requirements for a Body Operating Qualification of Non-Destructive Tests [9] identifies three types of qualification body:

- Type 1: A qualification body which is an independent third party organisation
- Type 2: A qualification body which is an independent part of the utility's organisation set up on a permanent or long-term basis
- Type 3: An ad hoc qualification body set up for a specific qualification.

Any of the above three types of qualification body is acceptable within the ENIQ methodology, provided that certain criteria regarding independence from operational pressures can be met. Further guidance on this may be found in ENIQ Recommended Practice 7, see [9].

6 Inspection Qualification Process

6.1 Information Required by the IQB Prior to Qualification

All necessary input information for the qualification must be made available prior to the start of inspection qualification. It is important to note the crucial role of non-NDE personnel in the decision on whether or not to qualify, and in the determination of input information for qualification. Fracture mechanics specialists are needed to provide a qualification flaw size and materials specialists to provide advice on flaw types, orientations, locations, roughnesses etc. Safety engineers are needed to provide guidance about the safety relevance of the component and the consequences of failure. These input data are typically:

- objectives of the inspection qualification
- full description of the component to be non-destructively examined
- qualification size and type of flaws to be detected and/or sized
- the inspection performance (missed call and false call rates, sizing and locational tolerances) to be achieved
- the NDT procedure, equipment and personnel requirements

The determination of the safety relevance of components or flaws is often also part of the input information to be provided. This information may be important to the overall safety case, and, if so, it may also have a bearing on the manner in which the qualification is conducted. It may also influence the decision as to whether an inspection is to be qualified or not.

It is important to note that the Qualification Body does not take part in the generation of the input information. However, the Qualification Body should check that the input information is clear and unambiguous from the qualification point of view.

The French RSEM Code (ENIQ methodology based code) defines the following three types of qualification dependent upon the potential damage impact on plant safety:

- Applications with “conventional” qualification: It may be necessary in the interests of safety to examine some areas of these components, even though no design or operational data give cause to suspect the presence of any flaw which may affect plant integrity (unspecified flaw). The purpose of this type of qualification is to demonstrate the performance of the NDE application. The recording threshold is based on a reference 2mm Ø side drilled hole, with the aim of achieving a defined inspection sensitivity.
- Applications with “general” qualification: The damage mechanism is presumed, but no occurrence has been reported. The purpose of a “general” qualification is to demonstrate that the NDE application will be able to detect, locate and size the postulated flaws.
- Applications with “specific” qualification: A “specific” qualification is required on components with identified flaws and where actual occurrences are reported. In this case, the purpose of qualification is to demonstrate that the NDE application will detect, locate and size specific flaws.

6.1.1 Qualification Flaw Size

A crucial part of the input information is the definition of the qualification flaw size, a_{qual}. In the majority of cases a_{qual} will relate directly to the critical flaw size established by means of flaw tolerance studies (a_{crit}).

a_{crit} is determined by the flaw tolerance studies (fracture mechanics analysis) and, as such, the input parameters (fracture toughness etc.) will have been chosen to give a suitably conservative analysis and achieve certain reserve factors – either on toughness or flaw size. Thus, the fracture mechanics critical flaw size, a_{crit}, will itself be a conservative value.

However, in terms of Inspection Qualification, it is likely that further conservatism may be included to arrive at a_{qual} and a so-called qualification factor will be included to provide enhanced margin against the fracture mechanics critical flaw size.

Thus,

$$a_{qual} <= a_{crit}$$

or equivalently,

$$a_{val} = \text{qualification factor} \times a_{crit,} \qquad \text{(where qualification factor} < 1)$$

An important point to note is that, although it is tempting from a structural analysis point of view to make the qualification flaw size as small as possible (so as to increase the overall reserve factor), this can often lead to substantial practical difficulties in developing and qualifying the subsequent inspection system for such small flaws.

Another important point to note is the explicit link of the qualification flaw with a fracture mechanics analysis. This has a major influence both on the definition of the qualification flaw and on the choice of inspection method that will be subject to qualification. As the qualification flaw is defined via a fracture analysis, it is by

definition planar or crack-like in nature - this is quite logical, as such flaws are the most damaging from a structural integrity perspective. This aspect leads directly to ultrasonic inspection being the dominant technique in qualification because it provides a through-thickness inspection capability that is very sensitive to planar flaws.

6.1.2 Other Parameters

In addition to identifying the qualification flaw size there are also other parameters that govern the detectability of a particular flaw and which need to be specified as input into the qualification process. These are typically the 'input group' of the 'essential parameters' (Reference ENIQ RP1) and would include:

- type of flaw
- degradation mechanism
- shape of the flaw
- through-wall extent of the flaw
- position of the flaw through the thickness of the component
- position of the flaw along the axis of the component
- tilt angle of the flaw
- skew angle of the flaw
- roughness/branching of the flaw
- flaw detection and sizing tolerances
- geometry of the component
- access constraints
- weld crown configuration
- weld surface root configuration
- inspection volume

The choice of the values (nominal and tolerances) for each of the above should be agreed between the licensee, the inspection vendor and the design engineer/safety case author before commencing qualification.

A suggested format for input of these values would be via a so-called Qualification Flaw Data Sheet. This sets out all the relevant input parameters both for qualification and for inspection development (Figure 1), and is the subject of a proposed ENIQ TGR document, as described in Section 5.1 (vii).

6.2 Technical Justification

In most cases where qualification is a requirement it is necessary for a technical justification to be provided. This includes a written statement of the evidence which supports the case that an inspection system (procedure, equipment and personnel) is capable of meeting the defined requirements. It consists of a mixture of experimental evidence and theoretical assessment, as appropriate.

A technical justification may include:

- Measurements on practical test pieces, if relevant.
- Physical reasoning.
- Feedback from field experience.
- Previous qualifications (where available).
- Relevant round robin trials, such as PISC.
- Feasibility studies and practical trials.
- Mathematical models.
- Laboratory studies (where relevant).
- Description of the equipment by the manufacturer.
- Experimental development results.

A fuller insight into the contents of a technical justification may be found in ENIQ Recommended Practice 2: Recommended Contents for a Technical Justification [4].

6.3 Blind and Open Trials

The qualification process may also require a practical assessment. This could involve test pieces replicating the component under test in geometry, material and implanted flaws. These will contain flaws judged to be possible and will often include the 'worst case' flaws. Such test pieces, dependent upon the accuracy, in terms of simulation of the flaws inserted, can produce realistic results. They are however expensive and time-consuming to produce and may only contain a small proportion of the flaws requiring detection. These are normally the worst case flaws in terms of inspection system performance (as determined by the QB) in terms of their size, orientation and location.

In terms of the qualification process, 'worst case' flaws are those considered to be the most difficult to detect and size. The identification of 'worst case' flaws is often not straightforward and depends upon both the inspection requirements and the overall inspection system design – particularly the choice of inspection method/techniques. For example, for a given set of inspection requirements it is possible that two different vendors will propose different inspection solutions. Both may be successfully qualified, but if the choice of techniques and transducers is sufficiently different then there are likely to be different sets of 'worst case' defects in the two cases.

An important point to note is that 'worst case' defects, identified during the qualification process, are different to those identified as part of a structural mechanics analysis. The latter are typically oriented normal to the principal stress direction (through pressure boundary), extended in length and have significant through-thickness size (ie the most threatening to the integrity of the structure). Thus, 'worst case' structural defects are unlikely to correspond to the most difficult to detect and size.

Another consideration is whether or not the non-destructive examination is performed without prior knowledge of the flaw location and size, i.e. whether it is blind or open. It is recommended that the personnel qualification is separated from the procedure/equipment qualification, with any practical trials being open for

procedure/equipment qualification. A blind trial, on the other hand, can provide a realistic assessment of whether the combined personnel, equipment and procedure, or some combination of these, can produce satisfactory inspection results. A more detailed insight of the requirements for a practical trial can be found in ENIQ Recommended Practice 5: Guidelines for the Design of Test Pieces and Conduct of Test Piece Trials, Issue 1 [7].

In France, a blind trial is not deemed necessary, as the vendor of inspection services attests to the fact the inspection personnel are suitably trained and qualified to operate the inspection system in question. This is also the approach in Canada, where the IQB is required to review and approve the associated training programme.

6.4 Qualification - Certification

On successful completion of qualification, appropriate certification is awarded for the procedure and, where applicable, for the personnel. The qualification/certification of the procedure is normally valid indefinitely, unless changes are made to the procedure, equipment or to any requirement that must be met. The European Methodology document recommends that qualification for personnel is for a limited time period, with provision for renewal through continued satisfactory involvement in the qualified inspection and/or re-qualification.

The certification documents, together with supporting documentation such as the inspection procedure and technical justification, are kept in a Qualification Dossier. This may be in the form of hard copies or in electronic form. It should be kept up to date and may be open to audit by a regulatory authority.

7 REFERENCES

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11. ENIQ RP 10: Personnel Qualification, ENIQ Report nr. 38, EUR 24112 EN, June 2010, available for download from: http://safelife.jrc.ec.europa.eu/eniq/docs/rec_prac/ENIQ%20report%2038.pdf.

[1] NOTE: Recommended Practice 3 (EUR 18100 EN, July 1998) is superseded. It has been replaced by the new issue of RP2 (EUR 24111 EN, January 2010), which combines the contents of the first issue of RP2 (EUR 18099 EN, July 1998) and RP3.

Database reference:	Workfile reference:

NDE Data Sheet
Name of Component
CODE ITEM: XXX *(if applicable)*

Scope	Plant Description	Type	In-manufacture, In-service etc.

Inspection Qualification Required?	Yes or No

Weld And Material Information	
Manufacturing Details:	Relevant details of manufacturing process
Appropriate Drawings:	List of those applicable and relevant to inspection
Parent Material:	*e.g. low alloy steel (MnMo) forgings (DGS MS LAS 4301/F)*
Welding Material:	As applicable
Buttering Material:	As applicable
Weld Crown Configuration:	*Machined flush, as welded, hand ground etc.*
Surface Roughness:	The roughness of the scanning surface

Defect Description			
Nature of Defect		**Tilt**	**Skew**
Brief description of the type and location of the defect(s) *e.g. buried weld defects, lack of sidewall fusion and defects close to/penetrating into cladding on nozzle bore* *-growing from manufacturing ("original sin") defect by fatigue (mechanical or thermal)* *-straight or perhaps bent, no branching*		Orientation of defect(s) *For example:* *i) Longitudinal with the following local deviations:* *tilt up to ±20°, skew up to ±5°* *ii) Lack of bond between cladding and ferritic*	
Gape:	Distance between faces of defect *eg 25µm (min)*	**Roughness:**	Roughness of defect faces *eg Between 3µm and 20µm*
Qualification Defect Size	*i) a=xx mm, L=yy mm* *ii) a=ww mm, (circular defect, diameter a)* *iii) a=zz mm, (circular defect, diameter a)* } ***Qualification not required (note 1)***		
Sizing accuracy:	*To be determined during technique development*		
Locational Accuracy:	*Accuracy of determining distance from clad/ferritic interface (δ) and the circumferential location is to be determined during technique development.*		
Examination Volume:	*Refer to A-B-C-D-E in ??*		
Notes:	*1. Detection of defect ii) unlikely to be achievable and coverage of iii) limited to scanning from nozzle O/D parallel section.* *2. The cladding thickness is to be measured (from surface to interface with ferritic HAZ) local to any defects that may be detected.* *3. Longitudinal defects are orientated nominally in a plane that is parallel to the direction of welding (direction of cladding in the case of clad and underclad defects) and passing through the weld centre line. Transverse defects are orientated nominally in a plane that is perpendicular to that containing longitudinal defects. Angles of tilt and skew apply to the individual defect planes.*		

Authorised for issue:

Component Engineer	Signature 1
NDT Specialist	Signature 2
Inspection Qualification Body Representative	Signature 3

Figure 1 Example of NDE Data Sheet

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Appendix 1 - Commonly Qualified NDE Techniques

Qualified NDT techniques may be manual or automated, and may be ultrasonic, eddy current, radiography or other techniques. In France, for instance, around 90 NDT applications on the primary and secondary circuits have been qualified, of which around 50% are manual and 50% automated. Of these 38% are UT, 29% RT, 18% ET and 15% others.

A1.1 Ultrasonics (UT)

The technique most commonly subject to Inspection Qualification is ultrasonic examination. This utilises a phenomenon known as the 'piezoelectric' effect to convert electrical energy to mechanical energy, resulting in the production of ultrasound waves. These waves propagate within the medium being tested. The manner in which these waves change and scatter within the medium can be used to evaluate the condition of the material under test, thereby enabling volumetric examination. From such an examination, information can be obtained as to the structural integrity of the component with regard the presence of anomalies such as cracks, etc.

A1.2 Eddy Current Testing (ET)

This is an electrical method where the material properties to be measured have to be correlated with appropriate electromagnetic properties. Eddy current testing involves the observation of the interaction between electromagnetic fields and metals. Basic requirements are a coil or coils carrying an alternating current, a means of measuring the current or voltage in the coil, and the metal specimen to be tested. The test coil can be either a single coil or a pair of coils. The coil can be held in a probe which is moved over the surface of the specimen, it can be wound on a bobbin to move along the inside of a tube or hole or, alternatively, can be an encircling coil used for inspecting solid cylindrical components.

An alternating current through the coil, of a chosen frequency, produces eddy currents in the specimen, which modify the exciting current. The resultant current is then related to some of the properties of the specimen. This resultant current is converted into a visual display where the type of anomaly with which it is associated may be interpreted. Eddy currents are commonly used to detect surface or near-surface flaws.

A1.3 Radiography (RT)

Radiography uses X-rays or gamma-rays to produce an image of an object on a film or a medium that may be read electronically. The image is usually natural-size. Both X and gamma rays are very short wavelength electromagnetic radiation which can pass through solid material, being partially absorbed during transmission. Thus, if an X-ray source is placed on one side of a specimen and a photographic film on the other, an image is obtained indicating the thickness variations - whether these are surface or internal - in the specimen. It is a well established technique which provides a permanent record and is widely used to detect internal flaws in weldments and castings. The source of radiation is either an X-ray tube or a pellet of radioactive material emitting gamma-radiation.

In many cases radiography, most commonly ultrasonics, is used to complement other inspections.

European Commission

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Title: ENIQ TGQ DISCUSSION DOCUMENT: EUROPEAN METHODOLOGY FOR INSPECTION QUALIFICATION — AN OVERVIEW FOR THE NON-SPECIALIST

Author: Peter KELSEY (Rolls-Royce Marine Power)
Editors: Thomas SELDIS (DG-JRC-IE)
Luca GANDOSSI (DG-JRC-IE)

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Abstract
The purpose of this document is to provide an overview of the European Network for Inspection and Qualification (ENIQ) Qualification Methodology and how the process of Inspection Qualification is commonly applied within Europe and elsewhere.
It is intended as a reference source for a wide audience of engineers and technical staff such as safety engineers, stress analysts etc. who may not be routinely involved with either non-destructive examination or inspection qualification, but who may benefit from a greater understanding and appreciation of the ENIQ Qualification Methodology. It will also benefit those personnel who have a responsibility to provide practical assistance in the preparation of the qualification process.

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