ENIQ RECOMMENDED PRACTICE

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Strategy and Recommended Contents for Technical Justifications

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FOREWORD – BRIEF REVISION HISTORY OF RP2

The first issue of ENIQ Recommended Practice 2 (RP2) was produced by the ENIQ Task Group 2.2 and was approved by the ENIQ Steering Committee for publication in September 1998. The second issue of the document combines the contents of, and therefore replaces, two previous recommended practices, RP2 and RP3 Issue 1, which separately dealt with the issues of content and strategy of technical justifications respectively. This third issue of RP2 eliminates duplications of recommendations found in other ENIQ documents, and also includes revised definitions of parameters. As a consequence RP1 is discontinued and its content is now part of Issue 3 of RP2. The objective is to facilitate the understanding and use of parameters in a technical justification.

EXECUTIVE SUMMARY

This Recommended Practice (RP) has been developed as a consensus document amongst the members of NUGENIA Technical Area 8 (TA8) - ENIQ. The main objective of this RP is to support licensees, qualification bodies and inspection vendors to produce and assess a technical justification (TJ). The document includes what and how the contents in a TJ could be described, including the definitions of influential and essential parameters and how these have to be treated. The appendices give examples of parameters that could be influential for three different inspection techniques.

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1. Introduction

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

This ENIQ Recommended Practice (RP) will assist those involved in inspection qualifications in how to, prepare, use and apply a technical justification (TJ) in agreement with the spirit of the European methodology. This RP is relevant to any non-destructive testing (NDT) method.

2. Objectives

The main objectives of this RP are to:

- Indicate how the concept of a TJ could be used in inspection qualification according to the European methodology;
- Justify the selected inspection system against the inspection input parameters in a TJ;
- Assist those tasked with producing a TJ to identify the role of the TJ;
- Identify the appropriate content of a TJ;
- Promote the harmonisation of practices and the transferability of qualifications between organisations and countries by defining a uniform format for TJ documents;
- Give examples of different TJs;
- Explain the proposed concept of influential and essential parameters;
- Give guidance about the classification whether a parameter is influential or essential;
- Give guidance concerning the treatment of essential parameters;
- Give examples of parameters which can be influential as a function of the specific inspection to be qualified for 3 cases: an ultrasonic inspection (UT) of welds, a phased-array ultrasonic inspection (PAUT) of welds and tube inspections using eddy current (EC) inspection technique.

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

Note: This RP is relevant for any NDT method. However, the area in which qualifications have most frequently been applied is the UT method, for which examples are provided. These are generally drawn from UT applications. Although this particular document was originally developed specifically for in-service inspection (ISI) of nuclear power plant (NPP) components, the principles can also be used for qualification of manufacturing inspections or for inspections performed in the non-nuclear field.

3. Concept and use of a technical justification

This section describes the four different situations where a TJ could be used and its benefits.

3.1 Qualification of a complete non-destructive testing system

In a NDT system qualification (where "NDT system" means all those elements, including procedure, equipment, and personnel, which can influence the outcome and quality of the inspection), the TJ can be defined as the collection of all the necessary information which provides evidence that the NDT system can meet its stated objectives. Its purpose is to:

- Provide a technical basis for the selection or justification of the essential parameters of the NDT system and their valid range.

- Provide a sound technical basis for designing efficient test piece trials. As test piece trials are performed on a limited number of defects, it is important that the defects used are selected so that the test piece trials provide the greatest possible added value to the qualification. The TJ can provide evidence which helps the qualification body (QB) / utility to design the test pieces by identifying the "worst case defects" which present the greatest challenges for the specific inspection being considered. The design of test pieces is discussed in RP5 [3].
- Overcome the limitations of a limited number of test pieces.
- Where necessary, to generalise any practical trials results by demonstrating that, if the test piece trial results meet the performance requirements, this implies that similar results could have been obtained for any other of the possible configurations.

There are many parameters which can potentially influence the outcome of an inspection. Some relate to the input information (component, defects to be detected, etc.) and some to the inspection system (probe beam angle, recording level, digitisation rate, time-base linearity, etc.). The identification and treatment of influential parameters in a TJ is discussed in Section 5 in this document.

The degree to which the TJ treats the performance of the NDT system in terms of its influential parameters, can have a significant influence on how future changes to the inspection system might be handled.

E.g. it is likely to be easier and therefore more efficient initially, to demonstrate in a qualification that a particular inspection instrument and a defined set-up is capable of detecting some specific defect, than it is to explore fully what is needed to detect this defect in terms of all the separate essential parameters of the system. However, the efficiencies can quickly be eroded through a change of the inspection system, or even of the set-up, which would then invalidate the qualification making a new qualification exercise necessary.

If, however, the inspection system performance has been adequately described in terms of its influential parameters, it may only be necessary to show that the alternative system or set-up remains within the demonstrated range, which would make re-qualification unnecessary or at least reduce the requirements for re-qualification.

3.2 Extension of a previous qualified system

To justify personnel skill based on existing qualifications:

Generally, personnel qualification means that a person performs a test on a blind test block together with a qualified inspection procedure (IP). Over time, where inspection qualification is routinely used it is likely that an individual will participate and accumulate many personnel qualifications using similar equipment and procedures. In these situations the qualification of inspection personnel, in whole or in part, may be carried out by TJ i.e. an extension from another previously completed and approved qualification.

Operator's qualification validity could be extended through a TJ valid for other procedures without a further practical demonstration. These procedures should be based on equivalent technology, related equipment, calibration and evaluation instructions and be judged on operator's ability to make the same demands on data collection, detection, characterisation and sizing.

To extend an existing qualification:

This type of TJ arises in cases where it is desired to extend an existing qualification to a new situation. If the new situation is similar to the old, it will usually be possible to carry out this extension through a TJ alone, or with only minimal new test-piece trials. The aim is to compare the essential parameters of the existing qualification with the essential parameters of the new qualification. In these cases, the greater the difference in the essential parameters, the more likely it is that supplementary test-piece trials will be necessary.

To extend qualification from one component to another similar component:

If an inspection has previously been qualified for a certain component, it may be possible to extend the qualification to include the same design and similar thickness in a range of dimensions, by the use of physical reasoning based upon the application of any appropriate standards and evidence available in published reports.

It is also worth noting that TJs may sometimes be written from the outset to cover a group of components, e.g. components of similar geometry and dimensions. Such a TJ may enable a single set of test pieces to be used to qualify a range of component geometries. This is a similar situation to the case above; the difference being that here it is decided from the outset to group the different component geometries requiring qualification in order to reduce the number of test piece trials and TJs required.

To extend qualification to a new material structure:

In a similar way to the above, an inspection may have been qualified for a particular material structure, and it may be desired to extend it to a component of the same geometry but with a different material structure, such as might occur if welding is carried out in a different position. This situation applies particularly to the ultrasonic inspection of austenitic welds or cladding. In such cases, it may be beneficial to perform small scale experimental trials to provide evidence specific to the situation under consideration.

To cover changes and upgrades in equipment or software:

This is a situation that arises frequently in practice, as equipment becomes obsolete or software is upgraded to a new version. In general, small, evolutionary changes that improve equipment capability may be justifiable by reasoning alone. More radical changes, such as changing from one inspection system to another from a different manufacturer, are likely to require some level of practical trials to demonstrate that the required level of performance, in terms of the essential parameters of the system, is maintained.

To address changes in the defect description:

For example a new defect type may have emerged that was not envisaged at the time of the original qualification and hence the inspection is not qualified for this defect type. However, provided the new defect type is not radically different to the existing defect types, so that the essential parameters remain the same or similar, it may be possible to extend the qualification by physical reasoning, parametric study or limited empirical trials.

To extend a qualification to cover inspection at a different plant:

Many qualifications are plant specific, but where plants have the same or similar designs and the defects of concern are similar, TJs can be used to extend an existing qualification from one plant to another. Whilst this is clearly most practicable where both qualifications fall under the jurisdiction of a single QB, in principle this type of TJ could be used to address the recognition of qualifications across national boundaries.

Many TJs extending existing qualifications may need to combine elements of several of the types discussed above.

3.3 Re-qualification

NDT inspection system qualifications generally remain active provided there are no changes made to the qualified NDT inspection system. Therefore the degree to which the TJ treats the performance of the NDT inspection system in terms of its essential parameters can have a big influence on how future changes to the NDT inspection system might be handled.

Where the QB determines that changes to a qualified NDT inspection system invalidate the existing qualification, the QB will determine what is required to requalify the NDT inspection system. In principle this is similar to the process used to determine the balance of TJ and practical trials for the initial qualification but as in practice most changes made to an NDT inspection system tend to be evolutionary in nature (for example updating obsolete hardware or software), it will in many cases be possible to make an adequate case for requalification by TJ alone. More radical changes, such as changing from one inspection system to another from a different manufacturer, or replacing multiple probes at discrete beam angles with a single phased array probe, may be determined to require some level of additional practical trial to demonstrate that the required performance of the system is maintained.

3.4 Other applications of a technical justification

Another common situation where a TJ is used is to reason that some changes to a qualified inspection system do not invalidate the qualification. For example, where an IP has been qualified using a specific piece of inspection equipment “A” and it is subsequently decided to use a different equipment “B”, it will be necessary to prove that the performance of equipment “B”, in the particular application to which it is to be applied, is at least as good as that originally obtained with equipment “A”. The case can be made in a TJ and could consist of a reasoned explanation based on the performance characteristics of “A” and “B”, demonstrating that in terms of each of the essential parameters of the inspection, “B” will have the same or better performance than “A”. Alternatively, the results of an empirical trial showing that “A” and “B” give equivalent performance when applied to a representative test specimen could be presented. In some cases it may be most appropriate to use a combination of these two approaches and to have physical reasoning backed up by small scale empirical trial results.

The aim of this section is to provide examples of these different types of TJ, according to their intended application. Applications for which TJs might be used are:

- Justify the use of any intended test pieces and defect populations. This may be done together with RP5 [3] and the justification of test pieces and the intended flaw population:

    This type of TJ aims to prove that the test pieces chosen by the QB, and the types of defects they contain, are realistic simulations of the actual component that are to be inspected and are appropriate for the inspection techniques that are to be applied (ET and UT inspections for example, are likely to have different defect requirements).

    For example, where it is proposed to use test pieces of simplified geometry, or to use simplified defect implantation techniques, the main purpose of the TJ will be to explain the extrapolation of the results obtained on these test pieces to the actual geometries and defect types of the plant to be inspected. A related use might be the justification of the particular selection of defects made for a particular inspection. In this case, the TJ would concentrate on demonstrating that the defects to be introduced into the test pieces really are the most challenging defects.

    This type of TJ differs from most of the other types considered here, in the sense that its issuance is the responsibility of the QB. However, open trial test pieces, can be produced by the plant owner or vendor, and justified in the inspection TJ and then be subject to QB assessment.

- Justify the use of inspection equipment:

    This type of TJ presents evidence from design processes, functional testing and commissioning trials in order to demonstrate that the inspection equipment, including manipulators, data acquisition systems and data processing systems (including software), is capable of fulfilling the requirements specified in the IP.

- Justify the use of IPs:

    Such a TJ presents evidence from physical reasoning (qualitative assessment), computer modelling of coverage and defect response, experimental studies and other sources, to support the procedure’s ability to fulfil the objectives of the inspection.

4. General recommendations for the content of a technical justification

The precise content of the TJ must be determined on a case by case basis depending on the particular application of the TJ, the component and the inspection involved, together with the level of detail and rigour required.

It is recommended that the TJ contains the following sections, although not all the sections listed will be required in every TJ. For consistency between different TJs, it is suggested the section numbering system below be used and any sections not needed should retain the section headings and be marked 'not applicable'. More detailed discussion and examples of possible content for each section are given in Appendix 1.

Summary

A short summary should be given explaining the purpose of the TJ and stating how well the inspection objectives stated in the inspection specification are met. Any significant limitations of the TJ should be also mentioned.

Section 1: Introduction

This section provides a description of the inspection to be qualified.

Section 2: Summary of Relevant Input Information

The input information comprises all the necessary details concerning the component to be inspected, the defects to be detected, any arduous environmental conditions or other external constraints and the inspection objectives to be met. This information can also be defined in a separate Inspection Specification.

Section 3: Overview of Inspection System

This section gives an overview of the NDT inspection system in terms of the inspection method and techniques to be deployed and the procedures, equipment and personnel to be used.

Section 4: Analysis of the Influential and Essential Parameters

This section identifies and analyses the influential and essential parameters of the inspection. The value of the essential parameters including tolerances and/or allowable range should be identified.

Section 5: Physical Reasoning (Qualitative Assessment)

This section contains a qualitative assessment and justification, using physical reasoning, of the essential parameters identified in Section 4.

Section 6: Prediction by Modelling (Quantitative Assessment)

This section explains and presents predictions from theoretical modelling that help show that the required inspection performance for detection, sizing, and characterisation can be achieved.

Section 7: Experimental Evidence

This section presents evidence from:

- Experimental studies on full-scale or simplified test specimens,
- Parametric studies,
- Results from previous qualifications and equipment commissioning trials,
- Experimental results from previous work or the published literature,
- Results from round-robin trials and field experience.

Section 8: Parametric studies

Parametric studies may be presented in this section. These are additional investigations of parameters identified in Section 4, which are performed to supplement the evidence presented in Sections 6 and 7.

Section 9: Equipment, Data Analysis and Personnel Requirements

This section presents evidence to show how:

- the inspection equipment (hardware and software) is able to provide the technical capabilities necessary for achieving the inspection aims;
- the values of essential parameters specified in the IP are consistent with the analysis of essential parameters performed in Sections 4 to 7;
- the system acceptance tests, routine calibration tests and periodic system checks provide assurance that the performance demonstrated in qualification can be achieved and maintained at the point of use.

Section 10: Review of Evidence Presented

This is an important section which must be present in all TJs. It summarises the preceding sections to present the performance that the NDT inspection system can achieve (in terms of defect detection, sizing and characterisation capability) taking into account the identified essential parameters of the input group and NDT inspection system.

Section 11: Conclusions and Recommendations

This section draws together the conclusions from the preceding sections.

References

This section contains a comprehensive and detailed list of all the references cited in the TJ.

5. Concept of influential and essential parameters

Definitions of Influential and Essential Parameters

The influential parameters of an inspection are those parameters which if changed would eventually alter the outcome of an inspection.

The essential parameters of an inspection are those influential parameters which if changed in value would alter the outcome of an inspection in such a way that the inspection could no longer meet its defined objectives.

A case-by-case analysis has to be performed for each particular qualification in order to identify the influential and essential parameters for a specific inspection situation.

An example: The macrostructure of a weld may not be an essential parameter for a ferritic weld that is to be ultrasonically inspected. However, the macrostructure of a stainless steel weld may well be an essential parameter because in this case the ultrasonic beam would be affected to some degree by its macrostructure.

Appendices 2 to 4 give examples of parameters which can be influential for three NDT methods: Ultrasonic inspection of welds with pulse-echo, phased array technique and Eddy Current inspection of steam generator tubes. These can be used as check-lists by those developing, reviewing and justifying inspections in accordance with this RP, to help identify the influential and essential parameters.

Consideration of the influential parameters for any particular inspection shows that they can be divided into two distinct groups described in the following sections.

5.1 Input parameters

This group contains parameters which define the particular inspection situation. Examples are object characteristics, characteristics of material, characteristics of defects to be detected and sized, and environment etc.

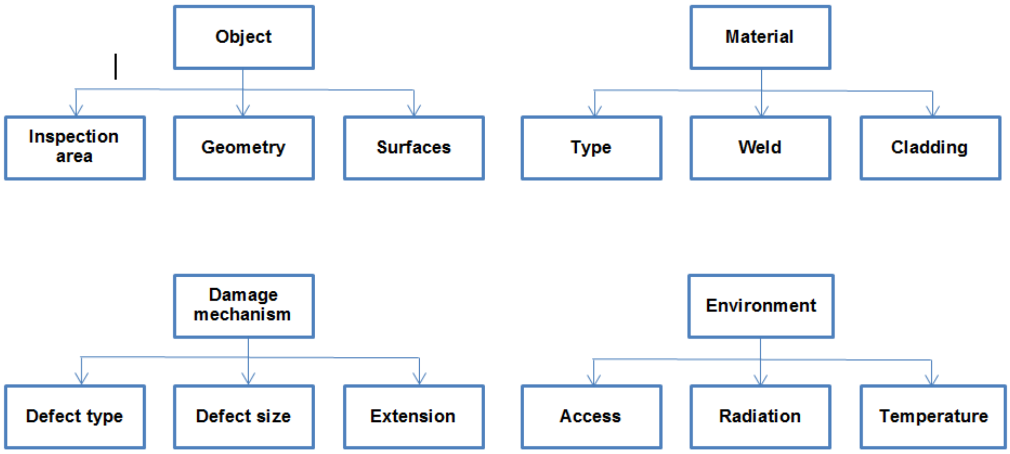

Figure 1: Examples of input parameters

In order to create good input information for the inspection vendor and the QB, reliable data about the test object is required. This data, called input parameters, comprises of basic information such as the characteristics of the defects to be detected and sized, as well as a series of object-specific and working environment related details, which together make up the object description. The generation of this data requires co-operation of a wide range of technical disciplines (see [4]).

5.2 Non-destructive testing inspection system parameters

This group of parameters includes those which are chosen to ensure that the NDT to be used is matched to the component, the defects to be detected (and/or sized) and the performance required. Logically, they result from the value of the parameters in the input group, although code requirements or previous practice sometimes provide the basis of the initial choice.

The NDT inspection system parameters include procedure parameters such as probe frequency, beam angles, recording level; equipment parameters such as instrument model, instrument settings and software version.

Personnel training and certification requirements should be documented in a training and qualification plan that includes scope of training beyond nominal NDT certificates (if applicable) and test and examination requirements.

Often there is a tolerance within selected parameter values which will not affect the outcome of a specific inspection. Ensuring that the equipment parameters remain within such tolerances requires regular calibration and the arrangements considered necessary are presented and justified in the TJ.

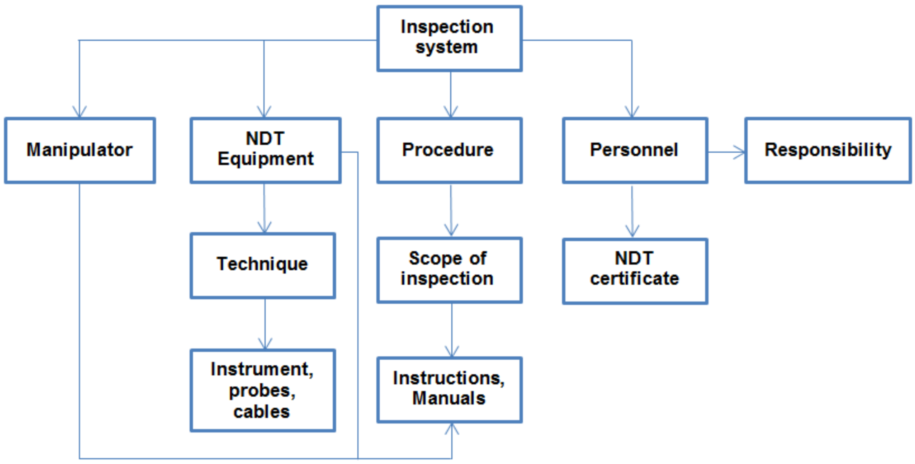

Figure 2: Examples of parameters of the inspection system

5.3 Treatment of influential and essential parameters

The TJ identifies all of the influential and essential parameters of the inspection and it is recommended that these are presented in tabular form. Influential parameters that on analysis are deemed not to be essential may also be included for completeness. This has the advantage that the QB can understand whether the omission of some parameter from the list of essential parameters is deliberate or accidental.

The values of the essential parameters of the NDT inspection system group may be based on previous practice, the requirements of codes or standards, experimental trials or on an assessment of the requirements following from the input parameters. The analysis presented in the TJ will usually involve assessing the proposed inspection system in terms of the identified essential parameters to determine whether its performance matches the requirements. This assessment may reveal deficiencies, and hence lead to a process of iteration to produce a satisfactory inspection system or to a decision to limit the application of the inspection system.

Essential parameters will not generally be restricted to a single absolute value but might be expected to vary within a tolerance or to be selectable within some range of values without materially altering the performance of the inspection. A key part of the TJ analysis process is to identify the bounds within which the essential parameters can be permitted to vary without affecting the inspection output. For inspections with multiple essential parameters which may interact with each other, it may take a considerable amount of effort to determine the overall limits of acceptable inspection performance. Those essential parameters that can vary and are defined with a tolerance should be part of the calibration section in the IP and to be checked before inspection performance.

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 5: Guidelines for the Design of Test Pieces and Conduct of Test Piece Trials - Issue 3,* ENIQ Report no. 56, The NUGENIA Association, 2018.

[4] *ENIQ Position Paper: Guidance on the Specification of Input Parameters to Inspection and Inspection Qualification Requirements*, ENIQ publication no. 50, The NUGENIA Association, 2014.

[5] *ENIQ Recommended Practice 6: The use of modelling in inspection qualification - Issue 3*, ENIQ Report no. 57, The NUGENIA Association, 2018.

APPENDICES

Appendix 1: Content of a technical justification in detail

This appendix gives further details of the possible contents of the various sections of a TJ, using the recommended list of contents given in Section 4. This appendix is intended primarily as a check list of the type of information that might be included in each section of the TJ. It is not intended to be a prescriptive list. The amount of information to be included in any specific TJ will vary from case to case, depending on such factors as the safety consequences of the inspection, the role of the TJ in the overall qualification process, the amount of evidence available, the state of knowledge about the component and so on.

Section 1: Introduction

This section provides a description of the inspection to be justified, including components to be inspected, defect types to be sought and inspection methods to be applied. It also describes the scope and layout of the TJ and any deviations from the ENIQ model.

This section should contain the following information:

- Components covered by the TJ;
- Defects to be considered;
- Inspection methods to be addressed;
- Purpose and scope of the TJ;
- Description of the layout of the TJ.

Section 2: Summary of Relevant Input Information

This section summarizes the input information. That is, all the necessary information concerning the component to be inspected, the defects to be detected, any arduous environmental conditions, the inspection method that will be used and the inspection objectives to be met.

Input information includes all aspects of the components and defects that can influence the outcome of the inspection performed, including, e.g. materials, geometry, inspection volumes, access restrictions, defect descriptions and required performance levels for detection, sizing, characterisation and false call rates. If the information is not available, assumptions may need to be made to permit progress. It is essential that these are agreed between all interested parties at the outset. The need to amend an assumption which is challenged later may undermine the whole qualification.

To assist in the guidance on the specification of the input parameters, the ENIQ position paper no. 50 can be used [4]. It is highly desirable that before commencing work on the TJ, all relevant input information as discussed below is available.

Components

The information which may be needed regarding the components is listed below. All items on the list below may not be needed or may not be available. In the latter case, this should be acknowledged in the TJ. The component information used in the TJ may be included directly or by reference:

- Design and as-built component drawings showing details of the geometry and all dimensions;
- Specifications for all the materials in the component including parent materials, weld materials and buttering materials;
- Welding and buttering procedures used to fabricate the components;
- Details of any weld repairs carried out through the history of the component;

- Details of any known mismatch between components;
- Component surface finish including both small scale roughness and longer scale undulations;
- Details of weld caps and roots where relevant to the inspection i.e. where caps may need to be scanned or defects located near the root;
- Any access restrictions that would limit the application of particular inspection techniques;
- Any time constraints for inspection set by radiation levels or other environmental factors.

Defects

For the defects, the following information may be needed depending on the inspection method to be used:

- Defect types which must be detected;
- Defect sizes to be detected;
- Defect location, in particular, the relationship of defect position to features of welds such as roots, heat affected zones, caps or surfaces, cladding interfaces and other defects;
- Defect orientation ranges in terms of tilt, skew and alignment relative to boundaries, surfaces and welds;
- Defect morphology (roughness, gape, etc.).

Inspection objectives – Inspection performance

Depending on the purpose of the inspection, different parameters defining performance may be of importance. The ones that are relevant for the particular problem should be included in the TJ. The following list indicates some of the parameters that may be specified:

- Inspection area/volume;
- Detection requirements;
- False call rate;
- Sizing accuracy in depth and/or length;
- Defect characterisation requirements;
- Detection of remaining ligaments and measurement accuracy;
- Acceptance and rejection criteria.

Section 3: Overview of Inspection System

This section gives an overview of the inspection system (technique, procedure, equipment and personnel certification and training requirements) to be used. This section is provided largely for the benefit of the reviewer of the TJ. Depending upon the specific purpose of the TJ this section will contain an overview of the IP and/or the inspection equipment which will be used. This section could also contain an overview of the personnel requirements, e.g. background experience, certification level, job specific training and qualification arrangements: (may reference a separate training and qualification plan). Examples of important characteristics of the inspection system for different inspection methods are given below. These lists are not intended to be exhaustive.

Ultrasonic

- Inspection Method: Pulse-echo, TOFD, Phase-Array;
- Probe beam angles;

- Probe types - shear or compression, single or twin crystal, focused or unfocused, focal distance etc.;
- Probe frequencies;
- Scanning extent and pattern;
- Manipulator and control system;
- Scanning and recording sensitivity;
- Sizing method;
- Instrumentation hardware and software for data acquisition and data analysis.

Eddy Current

- Coil type - bobbin, pancake etc.;
- Coil orientation relative to the component surface;
- Inspection method, absolute, driver – pickup, x coil etc.;
- Frequencies;
- Scanning extent and pattern;
- Scanning and recording sensitivity;
- Type of inspection equipment for data acquisition and analysis.

Visual testing

- Inspection method - TV, remote optical, direct visual etc.;
- Lighting level;
- Recording medium;
- Resolution.

In general, and especially when the inspection is complex or difficult or when test pieces are not available, it is likely that parts of the TJ (especially the review of input parameters, the influential parameter analysis and the physical reasoning sections), will be produced in advance of or in parallel with the procedure. This will usually be advantageous, as weaknesses in the inspection design will be identified at an early stage, allowing corrective action to be taken before the procedure is submitted for qualification.

Section 4: Analysis of the Influential and Essential Parameters

Analysis of the influential parameters and identification of the essential parameters is a crucial exercise that helps ensure that all important parameters have been considered. These parameters define the limits for which the capability described in the TJ is valid and are based upon the identified input parameters. The value of the essential parameters including tolerances and/or allowable range should be identified. To identify and define the parameters as influential and essential the guidance given in Section 5 may be followed.

Section 4 lists, explains the influence of, and gives reference to where in the TJ the influential and essential parameters are considered in detail. For those parameters whose precise values particularly impact the inspection, the table may contain a reference to the part of the TJ in which they are treated in detail. For other, less critical essential parameters, the table itself may contain a brief justification of the value chosen.

Where it is not planned to define a value for a particular essential parameter in the TJ, this should generally be stated together with the reason for it, e.g. no information on the value of the parameter is available or there is no way currently known to predict the effect of varying the parameter. Clearly, the essential parameters of the inspection must be specified as soon as possible, since they are the basis of the evidence to be provided in the sections of the TJ discussed hereafter.

Section 5: Physical Reasoning (Qualitative Assessment)

This section contains a qualitative assessment and justification, using physical reasoning, of the essential parameters identified in Section 4. The content of the section will depend on the particular inspection and the information available but the intent is to explain the inspection approach as comprehensively as possible, in terms of the component and defect details and the required performance. As a minimum, the specific procedure / equipment identified for use in the inspection must be addressed. However, the more generic the arguments made, the easier it will be to justify subsequent changes to equipment / procedures without the need for re-qualification.

The physical reasoning section of the TJ may include discussion of the worst case defects (those that by virtue of their size, location, orientation and morphology present the most difficult challenge to the IP being qualified), and may often provide sufficient information to begin the process of designing and procuring test specimens for open and blind trials. Since this is often a lengthy process, it is acceptable to submit the physical reasoning part of the TJ to the QB early, before the whole TJ has been completed. Where a more quantitative treatment of worst case defects is necessary, this may be provided in Section 6.

The information presented in this section justifies the choice of inspection parameters in qualitative terms. Firstly, it should explain, by reference to the component and defect details, why the particular inspection method was chosen. In cases where ultrasonic inspection is the chosen method, this might, for example, include the need to detect embedded defects or ones on the far surface of a component and the need to provide through-thickness size information.

Having explained the choice of the inspection method, the form in which the method is implemented is justified. For example in ultrasonic inspection, the choice of technique (pulse-echo, TOFD, etc.) and of beam angles and allowed tolerances in beam angle, needed to achieve the required coverage for detection, sizing and characterisation, should be explained. Scanned areas may be explained in terms of the expected defect positions and orientations. The probe types and wave modes used must be suitable for the components on which they are to be deployed, for example taking into account the need to work through austenitic structures or to detect near surface defects and so on. The sizing method should be related to the sizing accuracy required.

Although plausible explanations can be given for the choice of inspection parameters in this section, the evidence appears in the sections that follow. For example, there are complex interactions between beam angles, sensitivity settings and defect morphology and the choices made can often only be justified properly using the quantitative approach in the sections of the TJ which follow the physical reasoning one.

What is included in the physical reasoning section will depend on the particular inspection and the information available but the intent is to explain the inspection approach as comprehensively as possible in terms of the component and defect details and the required performance.

Section 6: Prediction by Modelling (Quantitative Assessment)

This section explains and presents predictions from theoretical modelling that help show that the required inspection performance for detection, sizing, and characterisation can be achieved. This can include the extrapolation or interpolation of results obtained from experimental evidence (Section 7) and parametric studies (Section 8) to the case in question.

It is highly desirable that validated models are used (although in some circumstances invalidated models may be used [5]), that any assumptions, limitations and simplifications made are understood and that the model is used within the bounds of its applicability. Guidance on the use of modelling is given in ENIQ RP6 [5].

This section may also be used to provide a quantitative assessment of the worst case defects where this is appropriate.

This section contains any results of modelling calculations performed in order to justify the choice of inspection parameters. This may include predicting defect responses by taking into account defect characteristics and position and orientation effects. Modelling can also be used to predict coverage and (for ultrasonics) beam paths in components of complex geometry. RP6 [5] gives further information on the selection and use of mathematical models.

Models which have been fully validated against experiment are preferred, and where necessary reference should be made to the validation work which supports them. Care should be taken when using models which have not been fully validated against experiments. Such models should only be used in a supporting role, to support experimental results, or should be explicitly validated for the cases of interest as part of the TJ itself. Limitations of models used should be clearly indicated. Care should also be taken that all models are only used within the parameter ranges for which they are valid.

For ultrasonic inspections modelling calculations may be used for the following purposes:

- Show which are the most difficult defects to detect from amongst those in the defect specification. This can be done from consideration of the angles of incidence and access to the defects in the defect specification, for all the different probes used.
- Show that the most difficult defects will generate responses above the recording level with at least one of the probes used and to demonstrate the margin of detection for the probes which detect them. If it can be shown that there is detection by multiple probes, even of the worst case defects, it provides evidence that the IP offers diversity, leading to a higher detection probability.
- Interpolate between cases covered by experimental data (see Section 7), in order to provide a fuller assurance of capability over the ranges of variability of such essential parameters as defect orientation, location and size.
- Show that the above situation applies to all the components covered by the TJ notwithstanding differences in geometry and dimensions.
- Show that diffracted edge signals can be observed at the chosen sensitivity levels, thereby permitting defect size measurement using methods that rely on the observation of such signals.
- Evaluate the effect of the surface conditions, such as presence of weld root and weld crown, etc.
- Analyse the influence of material structure, e.g. in austenitic welds and cladded components or when different materials are joined.

Validated models which predict the ultrasonic response from defects are less widely available when defects are embedded in inhomogeneous anisotropic structures such as austenitic welds or when beams must traverse such materials to reach the defects. The demonstration of performance for such cases may therefore rest more on test piece data obtained from parametric studies than for materials where effective models are available. However, physical reasoning can still be used to highlight the defects which are likely to be most difficult to detect, for example because they exhibit the maximum disorientation to the beams used.

Section 7: Experimental Evidence

In many cases, for logistical reasons, the TJ is produced following experimental trials. If the trials are successful, the TJ will need to show that they would still have been successful over the full range of input parameter values. Most NDT inspection system parameters whose variation does not affect the outcome of the inspection until they vary by considerable margins from their specified value are effectively qualified by the trials. In this situation, the table may simply record which parameters are qualified by the successful trials.

This section presents evidence from experimental studies on full-scale or simplified test specimens, results from previous qualifications, experimental results from previous reports or the published literature, results from round-robin trials and field experience.

Care must be taken to ensure that the evidence presented is relevant to the case in hand and in particular that any inferences or conclusions drawn from pre-existing studies or qualifications are valid. Any references cited should be available to the QB or the relevant information should be summarised and included in the TJ. Evidence of compliance with established practices, including those incorporated into relevant established national and international standards, can also be included in this section.

This section of the TJ contains results for relevant pieces of experimental work, which support, for example, the IP. The work might include the following:

- Results from practical trials associated with previous qualifications;
- Results from round robin trials such as the PISC exercises;
- Results from experimental studies performed in the laboratory, using either fully representative or simplified test specimens. These studies may already exist (e.g. in reports or published papers) or may be conducted explicitly as part of the specific qualification being considered. The work may also involve full-scale test pieces, including those developed for open trials, if the progress of the qualification provides such an opportunity;
- Field experience results.

It is important that any results from pre-existing studies, other qualification exercises or previously conducted round robin trials in the TJ are shown to be relevant. This will involve citing the component, defect and inspection details for the experimental work to show they are sufficiently similar to those in the present case. It is possible that only part of an experimental study is relevant, for example if just a few of the probes used in an ultrasonic inspection correspond to those used in the actual procedure. In such cases, the experimental work can be used to provide support for a part of the procedure, by presenting the relevant results from the experimental study.

If the details of the components, defects and inspections for the experimental work in question are similar but different to the ones for the components which form the subject of the TJ, it may be possible to use modelling or parametric studies to establish the relevance of the results.

Experimental laboratory studies may also be performed specifically for the qualification being considered. Such studies are distinct from the open or blind trials, since they are performed in-house, in order to provide further evidence for the TJ. Open and blind trials, on the other hand, are supervised by the QB, usually use test blocks designed by the QB, and are generally conducted after completion of the TJ. When performing such studies, attention may need to be given to specific characteristics of the component such as material structure, surface condition and access restrictions.

In the case of ultrasonic inspections of austenitic welds or cladded components, the material structure plays an important role and may give problems that are not present for ferritic materials. These stem from the influence of the metallurgical structure on inspection performance and the structure, in turn, is influenced by the precise way in which components are fabricated. This means that any evidence supporting inspection performance arising from previous inspection of real or test components may be very specific to the method used to fabricate those components. This tends to limit the availability of directly relevant evidence. Care should be taken when citing experimental results from austenitic structures, to ensure that the macrostructures of the materials used in the experiments are relevant for the qualification being considered.

In the absence of existing information on the influence of the material structure it may be useful to do measurements on specifically designed representative test pieces. When such experiments are conducted specifically for the qualification, it is desirable that the test specimens are made using the same welding procedures as used on the actual component. This will provide maximum assurance that the macrostructures in the specimens replicate those of the plant.

The exact geometry of the weld root and weld crown can also have a profound influence on the inspection performance and care must be taken to ensure that any evidence from previous inspections or studies is genuinely relevant and not influenced by differences in preparation such as weld crown dressing to allow better access for scanning.

Other parameters which might need to be investigated include the following:

- Component surface roughness and undulations;
- Defect roughness;
- Compressive stress on defects;
- Comparison of responses from real and artificial defects;
- Component mismatch;
- Counter bore position and angle.

Note that parametric studies, as discussed in the following section, can be very useful when addressing these parameters.

Section 8: Parametric studies

Parametric studies are additional investigations of parameters identified in Section 4, which are performed to supplement the evidence presented in Sections 6 and 7. Such investigations will typically use simplified test pieces and concentrate on the influence of a single parameter, to investigate aspects of the inspection that cannot be easily or reliably modelled. The studies cited can be previous work, or work carried out specifically for the component in question.

Parametric studies can be considered as a special type of experimental evidence. They are mentioned separately because of the relative importance they may have. Their purpose is to investigate the influence of parameters such as those listed above, preferably using small and simple test pieces, so that the magnitude of any effects on the inspection can be understood. Another consequence is that open or blind practical trials do not have to take specific account of the particular parameter because the effects of it can be built into the results. Parametric studies on defects produced by artificial methods can be particularly helpful in supporting the use of those defect types in open and blind trial test pieces. Any information which demonstrates the relationship between the responses from the artificial and real defects to the NDT method in use, is particularly valuable for this purpose.

Where relevant work has already been carried out and reported, it can simply be cited in the TJ. The TJ then includes:

- Reference to the work;
- Explanation why the work is relevant to the present case;
- Description in the text of the TJ of what the reference shows regarding the effects of the particular parameter;
- Impact of the parametric study on the theoretical case of the inspection;
- Impact of the parametric study on test pieces for practical trials.

For parameters which have not been subject of relevant studies elsewhere, for example where the influence of cladding and dissimilar metal welds has not been treated by modelling, or where additional supporting evidence is considered to be necessary, specific parametric measurements may be carried out and reported as part of the TJ. The information presented includes the following:

- Description of the parameter concerned;
- Details of the test pieces used;
- Description of the measurements made;

- Analysis and discussion of the results of the measurements;
- Impact of the parametric study on the theoretical case for the inspection;
- Impact of the results on the selection of test pieces for practical trials.

Some parts of parametric studies may be performed by computer modelling (see RP6 [5]). Their results may be reported in Section 6 Prediction by Modelling of the TJ.

Section 9: Equipment, Data Analysis and Personnel Requirements

This section presents evidence to show how the selected inspection equipment (hardware and software) is able to provide the technical capabilities necessary for achieving the inspection aims. It shows that the values of influential parameters specified in the IP are consistent with the analysis of influential parameters performed in Sections 4 to 8. It also explains how system acceptance tests, routine calibration tests and periodic system checks provide assurance that the performance demonstrated in qualification can be achieved and maintained at point of use.

This section may also include a justification of the evaluation / analysis scheme used for data interpretation. If an analysis of the measurement uncertainty has been performed, the results are presented in this section.

Personnel requirements, in terms of specified experience, training and certification, may be justified in the light of the inspection requirements, including rigour, importance and novelty.

Equipment

This section contains the information which justifies the choices made when selecting the inspection equipment. By reference to the essential equipment parameters identified in Section 4, it shows that the equipment is fit for purpose and has the required capability. It also justifies the range / tolerance over which essential parameters can vary and the equipment remains qualified and provides information about calibration and system-check requirements.

Specifying equipment in terms of performance and capability, rather than by make and model, will make it easier to allow for the inevitable operational requirement to make changes to some parameters and also to allow for substitution of equipment in the event of breakdown or updating.

This section also explains and justifies how calibration tests and periodic equipment checks help to ensure that the level of system performance obtained during inspection validation will also be available when the inspection is applied to the actual component.

If the actual inspection conditions will be more extreme than can realistically be addressed in experimental trials (e.g. high radiation levels, extreme temperatures and restricted access), this section may explain how the selected equipment will remain effective under these conditions.

Data analysis

This section contains the information which justifies the choices made for the software for representation and interpretation of the acquired inspection data. The evaluation / analysis scheme used for data interpretation may also be justified for detection and/or sizing as appropriate.

The data analysis scheme used to judge whether the indications found are due to defects is an extremely important part of the IP. All of the decision steps related to the combination and interpretation of the results of the different techniques that allow the analyst to arrive at the final result, should be written down in a clear, logical and traceable manner in the procedure and the most important decision steps should be identified and justified in the TJ.

Examples of decision steps which may need to be justified in the TJ are:

- Criteria used to distinguish indications due to the geometry of the component from those due to real defects;

- Reporting threshold above which indications have to be reported (if not considered elsewhere in the TJ);
- Way the results of different techniques are combined in order to decide if an indication is due to a defect or not;
- Criteria used to characterise defects, for example to determine whether they are surface-breaking or embedded, volumetric or planar;
- Criteria and methods used to determine which signals are used to measure the defect size and how the size of the identified defects is to be measured.

This section states and justifies the defect detection capability of the techniques to be applied, either in terms of the size of the minimum defect that can be reliably detected or in terms of probability of detection and/or false call rates. Where defect sizing is an inspection requirement, the expected sizing performance, including measurement accuracy and reliability requirements are also addressed and any performance figures presented should include sizing tolerances and confidence levels. The methodology and calculations by means of which these figures are derived should also be presented or referenced.

Review of personnel requirements

Personnel qualification is often done on the basis of a basic qualification in line with a national certification scheme, to which is added any job-specific training considered necessary to enhance the basic skills of the inspection personnel, and/or any practical qualification exercises considered necessary to demonstrate that the personnel is capable of adequately applying those skills to the inspection being undertaken. Generally, the more difficult the inspection, the greater the novelty of the techniques to be used and the more serious the consequence of poor inspection, the more rigorous are the personnel qualification requirements and the greater the level and amount of training specified.

This section of the TJ discusses the personnel qualification requirements and any special training provision, in the light of the information relating to the difficulty and novelty of the inspection presented in the rest of the TJ. It then presents the evidence and arguments that demonstrate that the proposed scheme will be adequate. Where inspections are performed by teams made up of personnel with different roles (e.g. scanner operator, data collector and data analyst), the requirements and responsibilities of each role are explained.

This information, including training scope and methods of examination and testing, may be documented in a separate training and qualification plan. In some cases this plan may be applicable to a number of inspections or share elements common to different inspections.

In those countries where national inspection qualification schemes require that only qualified inspection personnel should pronounce on the findings of an inspection, the allocation of responsibility for reporting should be clearly stated.

Section 10: Review of Evidence Presented

This is an important section, which should be present in all TJs. It summarises the preceding sections to present the performance that the inspection system can achieve (in terms of defect detection, size measurement and characterisation capability) taking into account the identified essential parameters. It also justifies, by reference to the input group of influential parameters and the relevant preceding sections, that the personnel training and any qualification arrangements proposed are capable of achieving the inspection objectives. It also identifies any aspects of the inspection that cannot be fully justified and which may therefore require additional empirical qualification by practical trial.

If the evidence shows that it is not possible to meet all the inspection objectives then this should be mentioned clearly in this section. This should be recorded in the final qualification report and / or Qualification Certificate if applicable.

This section of the TJ pulls together all relevant information from the preceding sections and makes an overall statement for the capability of the inspection system. This indicates the performance to be expected, based on the evidence presented, for the defects listed in the defect specification as measured against the required performance for detection, size measurement and false calls. Any shortfalls against the required performance in the input information should be clearly stated.

Furthermore, in this section a review should be made of all the evidence given in the previous sections in view of the essential parameters identified for the NDT System group and for the input group. Issues that could be treated are:

- Extent to which the choice of all identified essential parameters has been justified;
- Further actions required to obtain missing information;
- Identification of the parameters which need not be considered further as a result of the presented evidence;
- Identification of any additional essential parameters that need to be considered or investigated during the qualification process;
- Identification of those essential parameters which are considered during the test piece trials.

The statement should also indicate aspects of the inspection where insufficient theoretical or experimental evidence exists.

This section should also contain any comments on the personnel qualification requirements which emerge from the analysis of procedure capability in the TJ. If personnel requirements are included these can be commented on directly. If they are not, comments should be made on the desirable features of any requirements to be incorporated later.

Section 11: Conclusions and Recommendations

This draws together all conclusions from the preceding sections. It makes a statement of capability for the IP being justified that states how and to what extent, the inspection is capable of meeting the inspection objectives, as specified by the input group essential parameters. Any significant weaknesses of the inspection or of the TJ are declared and any recommendations as to how these weaknesses might be addressed, for example by additional limited open trials, can be given for consideration by the QB.

This section lists all major conclusions of the TJ, including a clear statement of any limitations in performance identified when compared to the requirements stated in the input information. It also lists the recommendations emerging from the TJ for issues such as test piece design, personnel qualification requirements or equipment design.

Appendix 2: Ultrasonic pulse-echo technique

Checklist of parameters, which can be influential for an ultrasonic pulse-echo inspection of welds.

1. Input group parameters

1.1 Component related parameters

- Geometry of the component;
- Access possibilities (including radiation, etc.);
- Surface conditions;
- Weld crown configuration;
- Weld root configuration;
- Wall thickness of the straight pipe;
- Diameter of the pipe;
- Counter bore;
- Counter bore dimensions;
- Weld mismatch (misalignment);
- Macrostructure of the base material;
- Macrostructure of the weld;
- Presence of buttering (in case of dissimilar metal welds);
- Temperature.

1.2 Defect related parameters

- Type of defect;
- Length of defect;
- Degradation mechanism;
- Shape of the defect;
- Through-wall extent of the defect;
- Position of the defect through the thickness of the component;
- Position of the defect along the axis of the component;
- Tilt angle of the defect;
- Skew angle of the defect;
- Roughness/branching of the defect;
- Presence of residual stresses.

2. NDT inspection system group parameters

2.1 Procedure parameters

- Wave mode;
- Probe type;
- Probe configuration (pulse echo, tandem, pitch/catch, etc.);
- Probe size;
- Frequency;
- Beam angle (In ultrasonic testing, the beam angle is a key parameter and must be chosen according to the orientation of the defects being sought. If the component geometry is complex, the angles of incidence on the defects in relation to the beam angles selected may

require detailed calculation and this should be included in the TJ. Justification of the beam angles selected for the inspection will usually be a key part of the TJ of an ultrasonic inspection. Beam angle is an example of a parameter that must be justified in detail in the TJ even though its tolerance is usually of little consequence.);

- Pulse length;
- Focal characteristics of (twin crystal) probes;
- Sensitivity for scanning and recording;
- Scanning pattern and step;
- Scanning speed;
- Scanned area on component surface;
- Personnel training, experience and qualification;
- Personnel testing and / or examination;
- Sizing method;
- Characterisation- and detection methods;
- Recording/identification criteria;
- Data analysis scheme.

2.2 Equipment parameters

The influential parameters of the NDT equipment are classified in different categories:

- Hardware pulser / receiver and data acquisition;
- Cable;
- Transducers;
- Scanner.

2.2.1 Hardware pulser / receiver and data acquisition

- Vertical linearity (screen height);
- Horizontal linearity (time base);
- Resolution of digitiser;
- Sampling rate;
- Averaging rate;
- Points per A-scan sampling;
- Pulse amplitude of the emitter;
- Pulse width of the emitter;
- Pulse fall time of the emitter;
- Pulse rise time of the emitter;
- Bandwidth of receiver;
- Available gain of receiver;
- Band pass filter of receiver;
- Time base setting for pulse echo probes;
- Time base setting for TOFD probes;
- Sampling gate.

All of these parameters will in general be parameters to be fixed within a tolerance in the IP. Calibration requirements will be chosen to ensure that unacceptable variations do not occur.

2.2.2 Cable

- Cable length;
- Impedance.

2.2.3 Probe

- Probe frequency (an example for a parameter is probe centre frequency in ultrasonic. The parameter is essential because if it is increased by an order of magnitude or more from its specified value, the inspection can be affected by material noise whereas if the frequency is too low, the inspection resolution and sensitivity to defects will diminish);
- Probe index point;
- Beam shoe angle;
- Probe shoe angular deviations (squint angle);
- Twin crystal probe shoe focal characteristics;
- Bandwidth.

2.2.4 Scanner

- Linearity of the scanner;
- Repeatability;
- Resolution;
- Water path (for immersion inspection).

The following procedure parameters concerning the scanner were already mentioned:

- Scanning pattern and step;
- Scanning speed;
- Scanned area on component surface.

Appendix 3: Ultrasonic phased-array technique

Checklist of parameters, which can be influential for an ultrasonic phased-array inspection of welds.

1. Input group parameters

1.1 Component related parameters

- Geometry of the component;
- Access possibilities (including radiation, etc.);
- Surface conditions;
- Weld crown configuration;
- Weld root configuration;
- Wall thickness of the straight pipe;
- Diameter of the pipe;
- Counter bore;
- Counter bore dimensions;
- Weld mismatch (misalignment);
- Macrostructure of the base material;
- Macrostructure of the weld;
- Presence of buttering (in case of dissimilar metal welds);
- Temperature.

1.2 Defect related parameters

- Type of defect;
- Length of defect;
- degradation mechanism;
- Shape of the defect;
- Through-wall extent of the defect;
- Position of the defect through the thickness of the component;
- Position of the defect along the axis of the component;
- Tilt angle of the defect;
- Skew angle of the defect;
- Roughness/branching of the defect;
- Presence of residual stresses.

2. NDT inspection system group parameters

2.1 Procedure parameters

- Wave mode;
- Probe type;
- Probe configuration (pulse echo, tandem, pitch/catch, etc.);
- Probe size;
- Frequency;
- Beam angle (In ultrasonic testing, the beam angle is a key parameter and must be chosen according to the orientation of the defects being sought. If the component geometry is complex, the angles of incidence on the defects in relation to the beam angles selected may

require detailed calculation and this should be included in the TJ. Justification of the beam angles selected for the inspection will usually be a key part of the TJ of an ultrasonic inspection. Beam angle is an example of a parameter that must be justified in detail in the TJ even though its tolerance is usually of little consequence.);

- Pulse length;
- Focal characteristics of (twin crystal) probes;
- Sensitivity for scanning and recording;
- Scanning pattern and step;
- Scanning speed;
- Scanned area on component surface;
- Personnel training, experience and qualification;
- Sizing method;
- Characterisation- and detection methods;
- Recording / identification criteria;
- Data analysis scheme.

2.2 *Equipment parameters*

The influential parameters of the NDT equipment are classified in different categories:

- Hardware pulser / receiver and data acquisition;
- cable;
- Transducers;
- Scanner.

2.2.1 Hardware pulser / receiver and data acquisition

- Vertical linearity (screen height);
- Horizontal linearity (time base);
- Averaging rate;
- Points per A-scan sampling;
- Pulse amplitude of the emitter;
- Pulse width of the emitter;
- Pulse fall time of the emitter;
- Pulse rise time of the emitter;
- Bandwidth of receiver;
- Available gain of receiver;
- Band pass filter of receiver;
- Time base setting for pulse echo probes;
- time base setting for TOFD probes;
- Sampling gate;
- Sampling rate / digitizing frequency;
- Scan type (for example, azimuthal, linear, static, depth);
- Applied gain—encompassing hardware gain and focal law gain;
- Compression;
- Digitizing frequency;
- Dynamic depth focusing (DDF) interpolation;
- Element configuration (element arrangement / wiring sequence);

- Emission focus position start / stop / resolution;
- Focal plane position offsets / depths;
- Focusing type (for example, true depth, half path, projection, focal plane);
- High-pass filter;
- Low-pass filter;
- Minimum wedge footprint;
- number of connectors (for example, single, dual);
- Pitch catch / pulse echo;
- Points quantity;
- Time base;
- Triggering (pulse increment);
- Symmetric / asymmetric;
- Recurrence / PRF of individual channel / focal law;
- Reception focus position start / stop / resolution;
- Primary axis pulser start / stop / resolution / pitch / aperture;
- Secondary axis pulser start / stop / resolution / pitch / aperture;
- Primary steering angle start / stop / resolution;
- Secondary steering angle start / stop / resolution;
- Voltage;
- Sound beam velocity (velocity in part);
- Refracted angle start / stop / resolution.

All of these parameters will in general be parameters to be fixed within a tolerance in the IP. Calibration requirements will be chosen to ensure that unacceptable variations do not occur.

2.2.2 Cable

- Cable type / maximum length / intermediate connectors;
- Impedance.

2.2.3 Probe

- Probe frequency;
- Probe index point;
- Beam shoe angle;
- Probe shoe angular deviations (squint angle);
- Twin crystal probe shoe focal characteristics;
- Bandwidth;
- Probe separation;
- Pulser / receiver connection;
- Element size and spacing;
- Height to the middle of the first element;
- Primary axis offset at the middle of the first element;
- Secondary axis offset at the middle of the first element;
- Primary axis position of wedge reference;
- Secondary axis position of wedge reference;
- Total crystal size (combined element size);

- Total number of elements used;
- Velocity in wedge material;
- Wedge contour;
- Spacing (kerf).

An example of a parameter is probe centre frequency in ultrasonic. The parameter is essential because if it is increased by an order of magnitude or more from its specified value, the inspection can be affected by material noise whereas if the frequency is too low, the inspection resolution and sensitivity to defects will diminish.

2.2.4 Scanner

- Linearity of the scanner;
- Repeatability;
- Resolution;
- Water path (for immersion inspection).

The following procedure parameters concerning the scanner were already mentioned:

- Scanning pattern and step;
- Scanning speed;
- Scanned area on component surface.

Appendix 4: Eddy current technique

Checklist of parameters, which can be influential for an eddy current inspection of steam generator and heat exchanger tubes.

1. Input group parameters

1.1 Component related parameters

1.1.1 General geometry and environment

- Access restrictions;
- Channel head dimensions;
- Manway configuration;
- Temperature;
- Radiation;
- Structure (internals).

1.1.2 Geometry of tubes

- Diameter;
- Wall thickness;
- U-bend radius;
- Length;
- Expansion geometry;
- Nature of deposits (copper, sludge, etc.);
- Presence of denting, etc.;
- Presence of tube supports or anti-vibration mounts.

1.2 Defect related parameters

- Type of defect;
- Degradation mechanism;
- Origin of defect (inside or outside);
- Through-wall extent of the defect;
- Length of defect;
- Orientation of defect;
- Location of defect.

2. NDT inspection system group parameters

2.1 Procedure parameters

- Number of probes;
- Probe type;
- Probe dimensions;
- Frequency;
- Type of generation of frequencies (simultaneous or multiplexed);
- Number of channels (number of probes / frequencies);
- Sensitivity for scanning and recording;
- Scanning pattern;

- Scanning speed;
- Personnel training, experience and qualification;
- Detection method;
- Sizing method;
- Characterisation method;
- Recording / identification criteria;
- Data analysis scheme.

2.2 Equipment parameters

2.2.1 Transmitter

- Total harmonic distortion;
- Output impedance;
- Linearity of phase;
- Linearity of amplitude.

2.2.2 Receiver

- Input impedance;
- Amplifier linearity and stability;
- Bandwidth.

2.2.3 A/D converter

- A/D resolution;
- Dynamic range;
- Sample rate.

2.2.4 Cable

- Type;
- Length;
- Impedance.

2.2.5 Probe

2.2.5.1 General

- Type of probe;
- Impedance;
- Frequency range;
- Resonance frequency.

2.2.5.2 Bobbin coil

- Effective scan field width;
- Fill factor coefficient;
- Depth coefficient;
- Axial length coefficient;
- Transverse width coefficient;
- Phase to depth curve;
- D.C. saturation strength.

2.2.5.3 Pancake coil

- Effective scan field width;
- Lift-off value;
- Depth coefficient;
- Axial width coefficient;
- Transverse width coefficient;
- Phase to depth curve.

2.2.5.4 Scan device

- Axial accuracy;
- Accuracy of scan speed;
- Speed range.

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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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