

Inspection Qualification and Implementation of ENIQ in Sweden

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ABSTRACT

Many countries are currently considering their approaches to inspection qualification and risk-informed in-service inspection (RI-ISI) and are carefully assessing experience data. In Europe most of the utilities operating nuclear power plants have joined together to form the European Network for Inspection Qualification ENIQ.

In practice, qualification can be performed with varying degrees of complexity and cost, varying from capability statement based on existing evidence, through to an extensive qualification consisting of a detailed Technical Justification (TJ) together with open and blind trials on full-scale test blocks.

An Inspection Qualification is an investigation and demonstration, which confirm that an inspection system has the ability to solve its specific tasks. The qualification is a Quality Assurance of an inspection system based on documents and practical trials.

A reliable inspection system, based on a reliable qualification and correct prerequisites, will reduce total costs for Licensees and increase the credibility of the inspection result. To get such inspection system, which could be valid for many years, it's of necessity to fulfil all included parts in the process. It begins with the Technical Specification from Licensee, where input data and requirements about the actual component are specified. To get an inspection system that could live over time, the Technical Justification is of importance. Finally the test blocks and used simulation techniques play an important part of the final result, and these test blocks together with TJ form the basis for qualification body's decision.

KEYWORDS

Inspection Qualification, ENIQ, SQC

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1. Background and purpose of Inspection Qualification

An Inspection Qualification is an investigation and demonstration, which confirm that an inspection system has the ability to solve its specific tasks. Many countries are currently considering their approaches to inspection qualification and risk-informed in-service inspection (RI-ISI) and are carefully assessing experience data. In Sweden a qualitative RI-ISI is used since many years, based on structural integrity analysis.

In Europe, most of the utilities operating nuclear power plants have joined together to form the European Network for Inspection Qualification ENIQ.

In practice, qualification can be performed with varying degrees of complexity and cost, varying from capability statement based on existing evidence, through to an extensive qualification, consisting of a detailed Technical Justification (TJ) together with open and blind trials on full-scale test blocks.

From Swedish point of view, experience is that a reliable inspection system, based on a reliable qualification and correct prerequisites, will reduce total costs for utilities and increase the credibility of the inspection result.

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2. ENIQ methodology

2.1. General principles

Qualification of an inspection may require assessment of any NDT-system, composed of any combination of NDT procedure, equipment and personnel [1]. This qualification or assessment can be considered as the sum of the following items:

- Technical Justification, which involves assembling all evidence on the effectiveness of the inspection system, including previous experience, laboratory studies, mathematical modelling and physical reasoning.
- Practical trials, both open and blind, conducted on representative test blocks for each particular case.

2.1.1. Technical Justification

According to the qualification process, relevant data for a specific inspection situation must be presented in a document called a Technical Justification (TJ). The Technical Justification consist of the combined presentation of all the work carried out and all the information produced to substantiate and justify that the inspection system satisfies the requirements stipulated in conjunction with a specific inspection situation. The structure of the Technical Justification essentially conforms to that recommended by ENIQ in “Recommended Practice 2” [2].

The accredited inspection laboratory normally prepares the Technical Justifications. However, some information that must be included in the TJ may be supplied by other sources. For example, the licensee normally provides information concerning the object as well as the requirements that the inspection system must satisfy on the actual inspection at plant.

It is important to understand that the structure of a Technical Justification is chosen to ensure that also the reader will understand what is being dealt with, and not only the author. When preparing the data that will be described in the TJ, this work will probably be carried out in a different order to the subdivision shown below.

- | | |
|---|---|
| 1. Introduction | 7. Experimental investigation |
| 2. Conditions and requirements | 8. Parametric studies |
| 3. Overview of the inspection system | 9. Equipment and evaluation criteria |
| 4. Analysis of influential and essential parameters | 10. Summary of presented evidence |
| 5. Physical reasoning | 11. Test piece for practical demonstrations |
| 6. Modelling | 12. Conclusions and recommendations |

2.1.2. Inspection procedure

The purpose of an Inspection Procedure, written by accredited inspection laboratory, is to be a governing instruction for inspectors. Therefore shall the procedure be written in an unambiguous way, which means that different inspectors will do the same actions and come to similar result when they follow the procedure i.e. a clear instruction describing **what** and **how** to perform the inspection and **not why**. The purpose “**why**” will be described in the Technical Justification.

Main contents of an inspection procedure:

- Scope of inspection and object description
- Type of equipment
- Calibration activities
- Data acquisition
- Analysis
- Report
- Formula for notes in appendix, traceability for future

2.1.3. Practical trials

Practical trials may involve test blocks replicating the component being inspected in size and geometry. The defective condition may also be accurately replicated. If metallurgical flaws are involved, the test piece will be designed to contain flaws of the type judged to be possible in appropriate positions and will normally include the “worst case” defects judged most difficult to detect, characterized and sized for the given inspection situation.

Such test blocks will produce realistic result but are expensive to manufacture and can usually only replicate a small fraction of the flaws which might occur.

Practical trials on test blocks are an important part and have a very high influence of the decision of qualification results, together with the technical justification.

The defect simulation techniques, which are used to implant defects in test blocks, have a very important role, and the signal response with actual inspection technique shall be similar as from a corresponding real defect.

2.1.4. Qualification dossier

The qualification dossier contains all data and results generated during the qualification. Evaluation of results must be done according to rules set out in the qualification procedure, written by qualification body.

The Qualification body shall store the dossier, which includes classified information.

3. Implementation in Sweden

3.1. General principles

The regulations governs how recurring non-destructive testing should be carried out in Swedish nuclear power plants and stipulate that certain areas are tested with qualified inspection systems. For this purpose, Sweden has a Qualification body, named SQC, which is approved by the Swedish Radiation Safety Authority SSM.

In order for qualifications to be carried out in a proper and standardised manner, SQC and the licensees have jointly developed a qualification process that will be followed during the qualification work, see Figure 1. This qualification process describes the various activities that are included in a qualification. The Qualification body must conduct an independent examination and assessment of the overall work that is carried out within a qualification with regard to the specific inspection situation. In order for this examination to be able to be carried out correctly, it is a great advantage if it is presented in a standardised way and in accordance with the same structures.

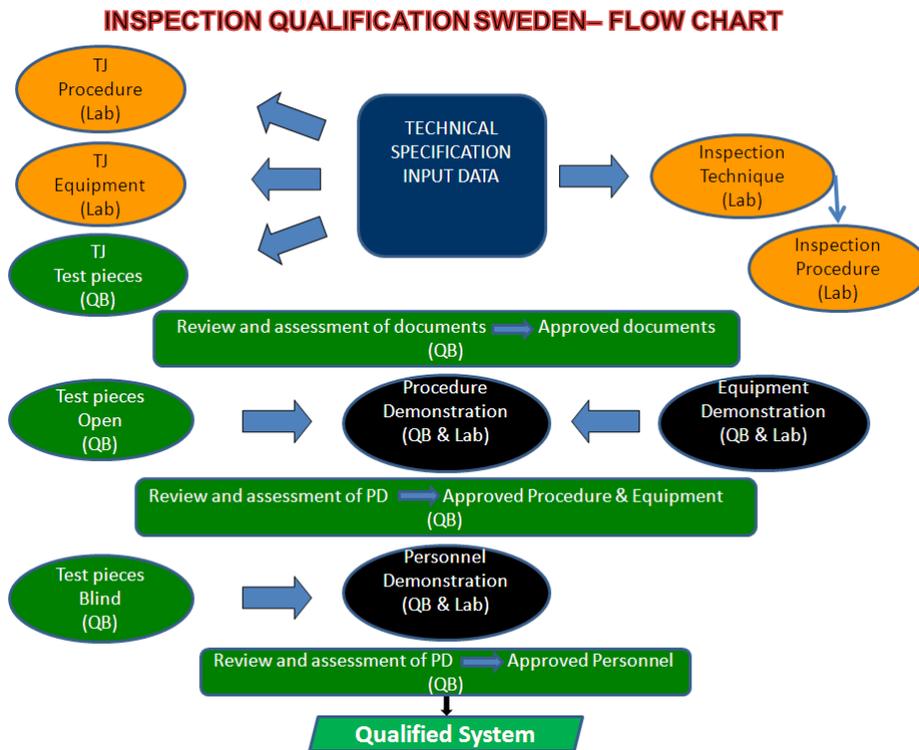


Fig.1. Qualification Process used in Sweden

3.2. Roles and responsibilities in Sweden for work in inspection qualification

- Regulator:** Responsible for national requirement
- Licensee:** Overall responsible for NPP, inspection specifications and results from inspections. Licensee will report to Regulator.
- Qualification body:** A third party organisation with an impartial and independent role, which has been assessed and approved by Regulator, and is responsible of all qualification activities.
- Accredited inspection Laboratory:** Responsible for inspection procedures, technical justifications and to perform inspections at NPPs in accordance to the qualified system.

Prerequisites/input data, written by licensee, are based on structural analysis, i.e. a qualitative Risk Informed ISI. Defect sizes are based on fracture mechanic calculations for the different objects and will, what we call in Sweden, result in a detection target. That is the smallest defect the inspection system is required to detect, characterize and size. In Fig. 2, the principle is described between the three defect sizes acceptable defect, qualification defect and detection target and how these defect sizes takes inspection interval and measurement accuracy in consideration.

3.3. Technical Justification

The Technical Justification has an important role in Swedish qualification activities. SQC, on behalf of the Swedish utilities, developed a Guideline including an example of contents and how to obtain an acceptable TJ.

This Guideline follows the intension in ENIQ Recommended Practice RP 2.

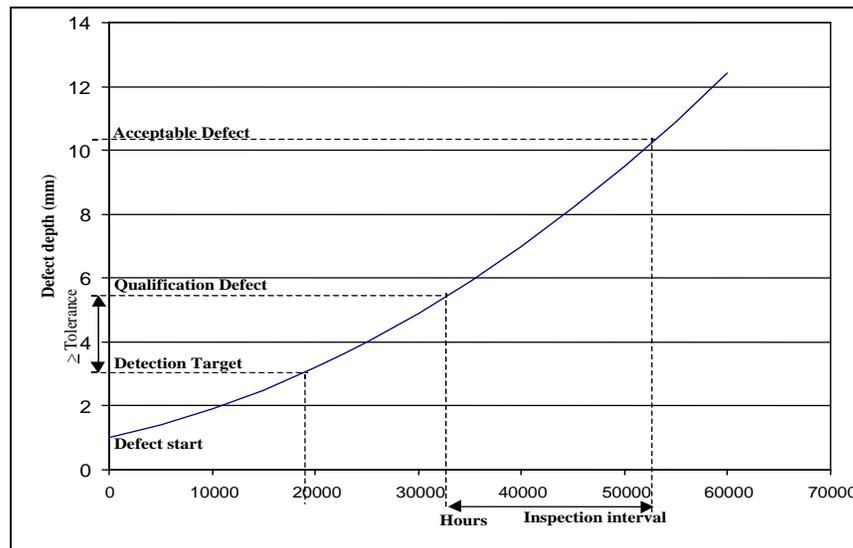


Fig.2. Example of defect size estimation

The Swedish experience and the purpose of a well-written TJ and specified parameters are:

- To identify parameters which have to be stated in procedure that have to be kept constant or be measured within a tolerance to ensure the procedures capability to detect, characterize and size defects over time.
- To facilitate for a future revision of a previous qualified inspection system.

Definition of Influential/Essential Parameters defined in SQC Guideline [3]:

Influential parameters are those parameters that can affect the results of an inspection. These have to be included with a short description in what way they effect the inspection.

Essential parameters are those influential parameters that, in the event of a modification, can vary in such a way that the inspection result can no longer encompass the requirements that have been stipulated.

These parameters have to be listed and motivated out from:

- Given prerequisites,
- Which they are and why they have been chosen,
- How to control and calibrate them to be valid over time.

When revise a previous qualified inspection system, a well written TJ will be of advantage and can minimize work and costs.

Below three different cases are described about how a TJ can be used when revising a previous qualified system.

1. If essential parameters are unchanged and not affected from previous approved qualification, QB has to assess changes and if necessary, issue a new Qualification Report and Certificates.
Example: Inspection extended to another plant with the same objects, or minor changes of the manipulator.
2. If essential parameters are changed in such way that previous qualification in main part can be referred, only the changes will be reviewed by QB of theirs influence on previous qualified system.
Example: Upgrade of software, extend to a similar object (not exactly the same geometry but same material.)
3. If essential parameters are totally changed and a previous qualification not can be referred, a new

qualification will be necessary.

Example: New prerequisites from Utility such as detection target, new inspection technique, changed criteria for evaluation.

3.3.1. Measurement accuracy as part of the TJ

The qualification system in Sweden requires uncertainty analysis as part of the Technical Justification to prove that inspection system gives a reliable value of the uncertainty. Licensees have almost requirements on sizing tolerances of length and depth, and accredited inspection laboratories have to prove that their system fulfil these requirements.

Different laboratories carry out uncertainty analysis in various ways and with various levels of quality and details. Approximately 10 to 20 measurements on a test block is not a reliable base to prove this. Therefore SQC developed a Guideline [4] and computer program to assist licensee and accredited inspection laboratories to perform uncertainty analysis in a correct way that also fulfils requirements according to established standards for methods UT and ET.

Some effects with uncertainty analysis are:

- Justifies tolerances for parameters in the Technical Justification,
- Gives information which parameters that contributes most to the total uncertainty,
- Support accredited inspection laboratories to fulfil demands from authorities,
- To increase the technical knowledge.

The Guideline gives detailed information of the technical uncertainty. However, it also gives guidance how human errors can be included. The program concentrates on random errors but gives also guidance how systematic errors can be identified and corrected. It works with two independent statistical methods, Gauss approximation and Monte Carlo simulation.

The Gauss approximation is used to summarize statistical uncertainty for certain parameters as well as combined uncertainty, for example height sizing.

The Monte Carlo simulation is a numerical method where a random generator gives values with respect to selected distribution form and the uncertainty of the parameter.

There are two different types of errors:

- Technical and human errors, and both can be of:
 - Statistical (random errors) contributes just randomly in an interval. These errors are also named as standard uncertainty or standard deviation,
 - Systematic errors contribute in one direction which can be compensated for. Mean values deviating from zero indicates systematic errors. It's important that accredited inspection laboratories identify systematic errors based on skills in the inspection technology. The goal is that systematic errors are eliminated from the inspection system.

The program is able to do calculation for the following NDE methods:

- Ultrasound pulse-echo (UT-PE)
- Ultrasound – separate transmitter and receiver facing each other (TOFDT)
- Eddy Current (ET)

Different type of inspection cases and geometries that can occur in the NPP environment can be handled by the program for respectively NDE methods UT and ET, see Fig. 3.

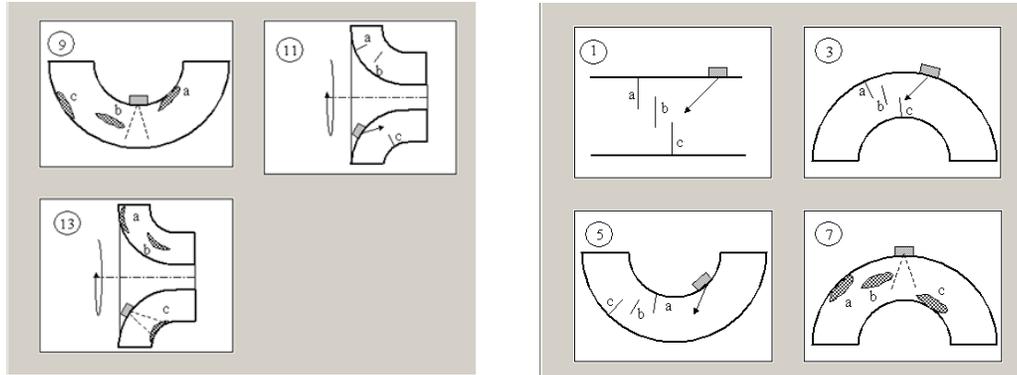


Fig. 3. Example of possible geometries

3.4. Test blocks

Practical trials on test blocks are an important part and have a very high influence of the decision of inspection qualification, together with the Technical Justification.

The defect simulation techniques, which are used to implant flaws in test blocks, have a very important role, and the signal response with actual inspection technique shall be similar as from a corresponding real flaw.

SQC, in collaboration with Swedish licensees, has worked with test blocks and flaw simulation projects for more than 10 years. The objective with those projects has been to develop simulation techniques of implanted flaws to get a similar signal response as from real flaws.

To secure that test blocks correspond to the specification and to verify that flaws give a relevant signal response, SQC perform fingerprint of all new test blocks.

About 600 test blocks, both open and blind, replicated objects in Swedish NPP's are documented in a data base. Those test blocks could be borrowed by other organisations like QB's and licensees.

3.5. Experience of qualified inspections in Sweden

Experience shows that the value of a qualified inspection system is that:

- Inspection techniques, described in a procedure and TJ, has been proved and demonstrated to fulfil requirements and prerequisites,
- That manipulators have been well tested before use in plant and
- Those personnel have been trained for use of the procedure.

Licensees in Sweden today have a better trust of an inspection result, and a qualified system will be a good basis for further decisions when defects have been detected.

Direct costs for qualification activities are high during the development of the process, but will be reduced after some years when qualifications could be realized through Technical Justification based on previous qualified systems and on existing test blocks.

We have a system for qualification in Sweden since 1996 and have find out that some parts of it could perhaps be done in a more cost-effective way.

Basically the following criteria must be fulfilled to get an efficient qualification system:

- There must be clear rules from the National Regulator
- Qualification body must have clear and distinct QA-system describing:

- Criteria for assessment of documents
- Criteria for assessment of test blocks
- Criteria for assessment of practical demonstrations
- Rules for re-qualification of personnel and extension of existing procedure

Beyond this will collaboration between different Qualification Bodies be of benefit and could help to reduce costs.

Below some examples are proposed of areas where changes could facilitate for a more cost-effective qualification system [5].

3.5.1. Qualification levels

Different levels of requirements could be based on:

- If there is an identified type of damage or not
- Risk for damage and the consequence of itA result could be to have different levels of TJ and practical demonstration depending on object and inspection interval, for instance to use standardized defects for areas without an identified damage. The work with structural analysis could be reduced and it would be possible to use generic test blocks.

3.5.2. Generalization

One purpose of generalization is to reduce repetition of similar qualifications. Following examples suggest areas where the process could be performed in a different way.

Manipulators

A suggestion is to qualify manipulators performance, including influential and essential parameters, instead of doing it together with each specific inspection procedure. The benefit is that several manipulators could be used for a specific inspection situation if they fulfil requirements and are within the frame of essential parameters for the actual inspection.

Technique

A suggestion is to qualify generic TJ describing requirements, criteria and framework for a group of similar objects. The benefit of this is that accredited inspection laboratories only need to produce a new procedure and to justify that inspection technique fulfils requirements and will be within the framework of essential parameters. Time for accredited inspection laboratory's work and qualification body will decrease.

Personnel

Another cost-effective suggestion is to qualify personnel in a matrix of a combination of similar materials, dimensions, inspection techniques and equipment. The benefit of this would be that personnel don't need to qualify for every inspection procedure. It will be possible to refer to a previous qualification of a similar inspection technique.

Documents

Purpose is not to repeat the same information in all type of documents and also minimize the number of them.

4. Conclusion

The qualification is a Quality Assurance of an inspection system based on documents and practical trials. To get a reliable inspection system, which could be valid for many years, it's of essential to fulfil all included parts in the process. All begin with the Inspection Specification from licensees, where input data and requirements about the actual component are specified. To get an inspection system that could live over time, the Technical Justification is of importance. Finally the test blocks and used simulation techniques are very important. These test blocks, together with TJ, form the basis for QB decision.

Swedish experience is that a reliable inspection system, based on a reliable qualification and correct prerequisites, will reduce total costs for utilities and increase the credibility for the inspection result. The whole process can be visualized in a Process Chart, which facilitate for all involved parties to get an understanding of what to do and show respectively organizations responsibility.

References

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