NUGENIA

Nuclear Generation II&III Alliance

ENIQ Position on

Guidance on Inspection Qualifications of Non-Nuclear Island Components

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ENIQ

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NUGENIA Technical Area 8

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Executive Summary

This position paper / discussion document has been developed as a consensus document amongst the members of NUGENIA Technical Area 8 (TA8) – European Network for Inspection and Qualification (ENIQ), and specifically the Sub-Area for Qualification (SAQ). The objective of this position paper is to show how the ENIQ framework can be applied to qualification of inspections of non-nuclear island components or non-nuclear applications in a cost-effective manner and the resulting benefits.

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1. Background

The ENIQ Methodology [1] and accompanying ENIQ recommended practices provide a framework for the qualification of Non-Destructive Testing (NDT) systems. The aim is to gather evidence in the form of complete Technical Justifications (TJs) or practical assessment results that demonstrate the NDT system, including the inspection procedure (IP), has been designed to achieve the objectives and can meet them reliably.

The ENIQ Methodology [1] has been widely adopted for highly critical nuclear primary system inspections where the component failure has significant consequences. It has rarely been utilised for other industries or nuclear balance-of-plant components of lower safety significance due to perceived costs and timescales. It is the purpose of this position paper to show how the ENIQ framework can be applied in a cost-effective manner and bring benefits to other areas.

The Research Centre Rez (CVR) of the Czech Republic has been working to show such benefits with an initial focus on fossil power plant inspections.

ČEZ fossil power plants were used as a case study with five non-destructive inspections and one diagnostic inspection method qualified by CVR in accordance with the ENIQ framework.

Although the qualified inspection methods are for fossil power plants, they serve as examples of the suitability of application of the ENIQ Methodology to qualify inspections in numerous other areas outside of the nuclear primary systems.

2. Introduction

The objective of inspection qualification is to provide assurance, or confidence, that an inspection reliably achieves the objectives defined within the input information for the inspection, or inspection datasheet. The importance of inspection reliability and therefore the effort and resources typically applied to demonstrating reliability, is dependent on:

1) The role of that inspection within the component and/or plant safety case.
2) The safety risk posed by the failure of that component, where risk is expressed based on the combination of the likelihood and consequence of the failure (see reference [2] for further details).
3) The regulatory or statutory requirements applicable.

The ENIQ Methodology allows for different qualification levels and approaches to be applied under the guidance of ENIQ Recommended Practice RP8 [3].

By applying a graded approach to qualification, the effort and resources applied to achieve confidence that the inspection will be capable of meeting its objectives can be targeted for greatest safety benefit.

In some circumstances the risk posed by the failure of non-nuclear components can be significant and potentially comparable to nuclear components. For example, components with a high non-nuclear consequence of failure (risk to life, release of substances hazardous to health and impact to the public, significant financial loss etc.) when combined with a heightened likelihood that a significant defect may be present, can pose a heightened risk. In certain situations the failure of non-nuclear components can conceivably result in the failure of nuclear plant and corresponding nuclear consequences thereby increasing risk (e.g. as a result of flooding, fire, missile generation etc). It is therefore important to consider the risk posed by component failure and the role of the inspection within the safety case when selecting a qualification level. In general, the risk posed by components in non-nuclear applications is lower than nuclear components and therefore a lower qualification approach would typically be appropriate.

Advantages of using the ENIQ approach include:

1) The Qualification Body (QB) (the group that oversees the qualification process and issues certifications) can be established within the organisation or as third-party organisation to suit the need, hence retaining control at the plant level.
2) Qualification may be performed according to a reduced TJ explaining how the procedure meets the specifications only (depending on the country's regulatory requirements).
3) Applying an objective-based approach in-lieu of one of a fixed rigour to the inspection design may provide higher confidence that the defects of concern are detected with the inspection applied.
4) The organisation has auditable evidence in the form of the qualification dossier that the inspections applied to their components will meet the requirements of the inspection specifications. This evidence can be provided to external certification or insurance bodies with interest in reliability and safety of the plant.
5) Diagnostic and NDT inspection vendors have evidence that their personnel, equipment and inspection procedures are qualified for the specific inspections to be performed according to qualified inspection methods.

3. Objectives

This document aims to encourage the use of the ENIQ Methodology for qualification of NDT systems in non-nuclear diagnostic and non-destructive applications and aims to demonstrate the advantages over existing approaches. It is intended as a guide on how to use the ENIQ principles to qualify inspections in areas that do not require the highest rigour usually applied to critical nuclear primary system inspections.

A map of consequences and probabilities typical to non-nuclear industries can be used as a guide to drive when the use of an ENIQ type approach to inspection qualification is valid. Table 1 summarizes considerations.

CONSEQUENCES				INCREASING LIKELIHOOD					RISK
PEOPLE	ASSETS	COMMUNITY	ENVIRONMENT	A	B	C	D	E	
				Never	Rare (Less than once per year)	Occasional (Has happened more than once per year in the industry)	Occasional (Has happened more than once per year at the location)	Frequent (Has happened often at the location)	
No injury or health effect	No damage	No effect	No effect						LOW
Slight injury or health effect	Slight damage	Slight effect	Slight effect						MED - LOW
Minor injury or health effect	Minor damage	Minor effect	Minor effect						MED - HIGH
Major injury or health effect	Moderate damage	Moderate effect	Moderate effect						
Permanent Total Disability or up to 3	Major damage	Major effect	Major effect						HIGH
More than 3 fatalities	Massive damage	Massive effect	Massive effect						

Table 1: Examples of a risk map for non-nuclear industries.

4. Considerations when applying ENIQ Qualification Approaches and Levels

Having optimised and efficient maintenance programmes in place is critical for reliable cost-effective operations for power generation companies. It is essential that the diagnostic and NDT systems provide reliable and trustworthy results.

Inspections are usually performed in accordance with the applicable national standards or the client's internal specifications. The procedures produced are the intellectual property of NDT contractors. The non-nuclear plant operators are then fully dependent on these contractors and must rely on the output from NDT systems, which are used by the plant operator for operation and maintenance planning.

Components such as turbines, generators, boilers, steam pipelines, heat exchangers, high pressure and flammable or toxic fluid lines, etc., may fail leading to the extended shutdown of the production units and or safety issues leading to impact on staff and public safety. It is thus important for the operator to have high confidence in the results of the inspections of these components.

Non-nuclear plant operators may also need to consider the mandatory requirements of accredited national organisations such as the requirements for complying with legal obligations for pressure retaining equipment etc.

Accredited national organisations do not generally require inspection qualifications as a means to increase industrial safety, although it can be used to support claims made for improved quality or simply that the applied inspections will detect the intended fault conditions. One way to demonstrate this is to qualify the inspections in accordance with the structured ENIQ framework. A prerequisite for the use of such qualified inspections could be the consent of the accredited national organisation.

When setting up an internal QB to perform the qualification, it is important to select appropriate personnel. The members of the QB should be well versed in the process of qualification and have the technical ability to assess the inspections being qualified. The qualification framework needs to be clear, and the qualification procedures should ensure that qualifications are conducted consistently.

Introducing qualified inspections in plants that currently do not qualify their inspections may meet resistance. The process and the advantages of the qualification must be explained to all personnel from the inspectors to the senior management.

Diagnostic and inspection personnel may incorrectly assume that a non-qualified inspection does not need to be performed to the same standard as for a qualified inspection. It must be emphasised to all personnel that the same quality (care and attention to detail) must be applied to all diagnostic and NDT inspections.

Based on the above, input and output of the use of the ENIQ qualification approach can be illustrated as in Figure 1.

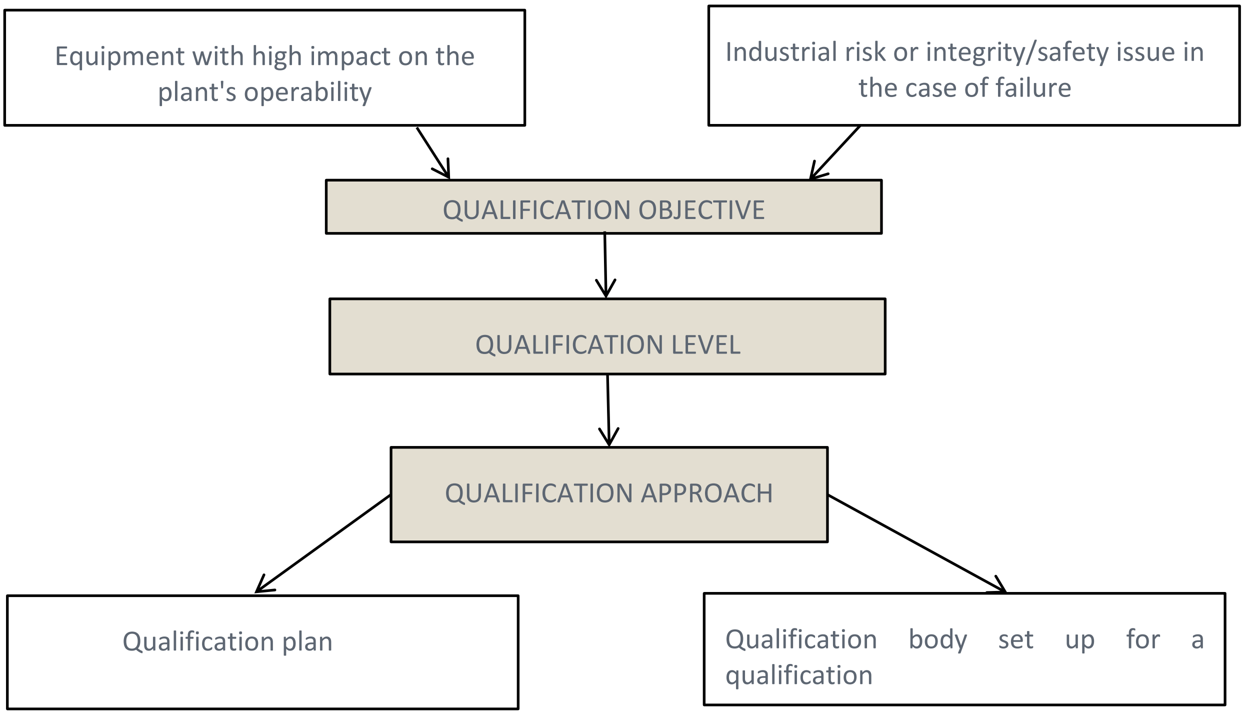


Figure 1: Inputs and outputs of the ENIQ approach

5. Determining the Qualification Objective

The qualification objective is defined by the plant owner in the form of written specifications for the inspection. The specifications must explain in detail the performance requirements that the inspection needs to meet and be assessed against. Details should be included for the component scope, the inspection environment and the defects or conditions to be detected.

6. Determining the Qualification Level

The qualification level is chosen and agreed on early in the qualification process. It is determined largely based on the risk of component failure and subsequent consequences.

For nuclear applications the utility / licensee normally determines the qualification level, in some cases in agreement with the regulator. For non-nuclear applications, the determination would involve plant operational staff, plant management and potentially external insurance or technical authorities. The specifications of the qualification level do not involve the QB as it relates only to issues concerned with the safety and structural integrity of the plant.

Specific concerns for non-nuclear applications include:

1) There are accredited national organisations such as for pressure equipment etc., but generally, they have limited inspection qualification experience.
2) Inspection qualifications may be justifiable for equipment that has a high impact on the plant's operability and/or with industrial/safety risk.
3) An approach using the ENIQ Methodology may not be considered due to concerns of cost. It is important to evaluate the cost vs benefit of applying such a rigorous assessment in such cases.
4) Many plants do not have experience in inspection qualifications. Expertise can be contracted to manage the qualification, acting as a member of the utility QB.
5) The management of the qualification should be entrusted within the power plant, e.g. to a technical control department, which is independent from the plant operation or maintenance management.

7. Determining Qualification Approach

A brief extract on determining qualification approach is included here but refer to the Recommended Practice 8 [3] for a full discussion.

Once the qualification level has been defined, the QB specifies the qualification approach considering both the qualification level and, where considered appropriate, the difficulty or novelty of the inspection.

While the qualification level is dependent on the operational or safety risk of the plant, the approach is dependent on the factors that may impact the effectiveness of the qualification, including the novelty, complexity and difficulty of application of an inspection due to factors such as environmental and access restrictions.

A higher-level approach should be applied to all components that could cause a significant safety risk to personnel, plant operators and the public and where inspection play the primary role in assuring integrity. The need for good repeatability, accuracy and coverage may drive the rigour of such qualification. A lower-level approach would be used where the failure of the component could cause less significant operational issues, or where other factors such as maintenance or ongoing monitoring play a more significant role and may not justify the level of rigour for higher risk items.

Differences in approaches may be reflected in:

- **Low qualification level**: Not all influential parameters of the inspection are analysed in the TJ, with less rigorous demands on specific personnel qualification.
- **Higher qualification level**: Use of existing evidence and information, supported by practical trials on actual systems which can also be used as a personnel qualification.

In general, once the qualification level has been determined it will drive the corresponding qualification approach.

1. Qualification Plan

The qualification approach involves a qualification plan, which should include requirements for information on components, inspection objectives, test pieces requirements, qualification documentation requirements. The plan will include number and types of samples, tests, training, and evaluations etc.

2. Type of QB

The qualification approach determines the type of QB in accordance with ENIQ RP7 [4]. The QB should have a documented quality mandate, and its composition is recommended per RP7. For a lower-level qualification, the QB will typically employ staff from the organization requiring the inspection and may be set up for the duration of the specific activity only i.e. not a permanent structure

8. Example of an Inspection Qualification Process

An example process for an inspection qualification in accordance with the ENIQ Methodology is given below.

1) Plant owner / engineering unit sets the inspection objective.
2) Plant owner / operator / technical authority decides on the qualification Level based on risk.
3) The plant owner appoints the QB.
4) QB produces the qualification plan in accordance with the inspection objective and approach.
5) Inspection vendor designs the inspection to meet the objective.
6) Inspection vendor produces the TJ justifying why the NDT system (procedure, equipment and personnel) meets the inspection objective.
7) QB assesses the inspection procedure and TJ against the inspection objective.
8) If required, the QB or plant owner / engineering designs test pieces to practically assess the inspection against the inspection objective.
9) QB assesses the inspection vendor's NDT system via open trials.
10) QB compiles the qualification dossier containing all evidence.
11) QB issues qualification certificate.
12) The inspection vendor carries out the qualified inspection on the plant.
13) Plant owner can justify the reliability of the inspection applied to the critical components in scope.

9. Conclusions

The ENIQ approach gives a methodology to provide assurance, or confidence, that an inspection reliably achieves the objectives. In any situation where the consequences of failure have a measurable impact and there is a desire to provide a means to reduce the likelihood of such failures this approach can be used. The methodology documents graduated levels of qualification that can be matched to the risk level. The details of the individual qualification process can be tailored to suit the risks and benefits for each situation. This approach is equally applicable to any industry where there is a need to demonstrate confidence in inspection results.

References

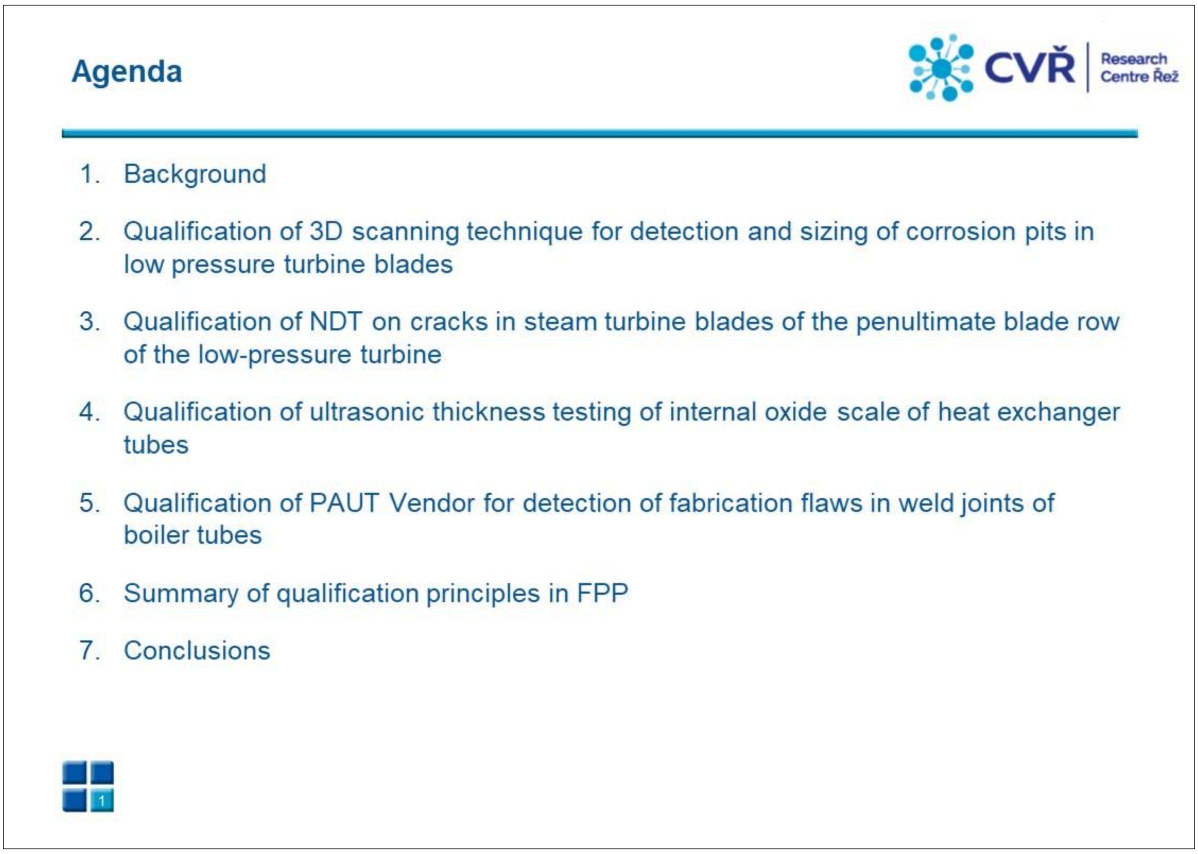
[1] *The European Methodology for Qualification of Non-Destructive Testing - Issue 4*, ENIQ Report no. 61, The NUGENIA Association, 2019.

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

[3] *ENIQ Recommended Practice 8: Qualification Levels and Approaches – Issue 3*, ENIQ Report no. 74, The SNETP Association, 2025.

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

Appendix 1 – Adaption of the ENIQ Methodology for Non-Nuclear Applications

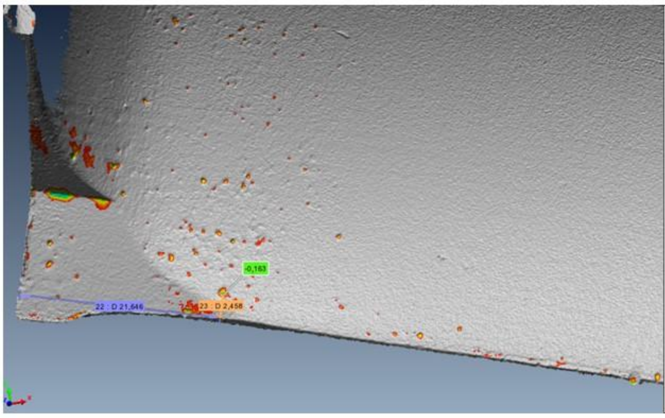


1. Background

Four non-destructive inspection methods and their subsequent qualification developed by the Research Centre Rez, Czech Republic are discussed. Two non-destructive inspection methods are for low pressure turbine blades, one is for ultrasonic thickness measurement of internal oxide scale and the last one for the PAUT inspections of boiler weld joints. For their qualification the ENIQ Methodology was followed. Although these NDT inspection methods are for coal fired power plants, they serve as an example of the applicability of the ENIQ Methodology for other industries and non-nuclear applications.

2. Qualification of 3D scanning technique for detection and sizing of corrosion pits in low pressure turbine blades

- 3D scanning using a laser scanner with measuring arm
- The output from the 3D measurement is the report where the coordinates and the size of the depth are determined for each blade. Attached to the report are also the scans of the blades with the largest pits



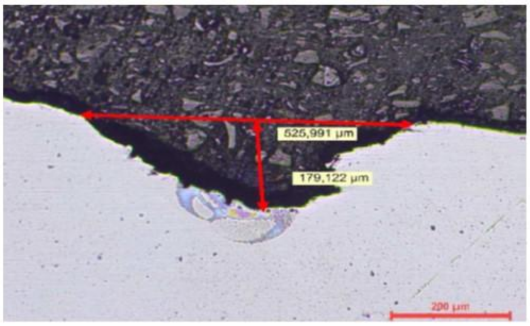
Output from the 3D measurement

Laser scanner with measuring arm

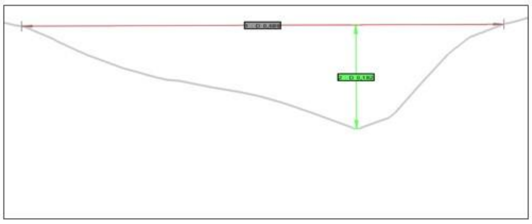
2. Qualification of 3D scanning technique for detection and sizing of corrosion pits in low pressure turbine blades

CVŘ

Verification of the depth measurement accuracy by 3D Surface Scanning was performed by comparing the results with those obtained from light optical microscopy (LOM) which showed a ± 20µm match. An example of comparison is shown in figures below:



LOM results:
depth 76µm (+28µm oxide) × width 403µm



3D scan results – cross-section in the plane of LOM (tolerance ±25µm): depth 74µm × width 398µm

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2. Qualification of 3D scanning technique for detection and sizing of corrosion pits in low pressure turbine blades

CVŘ

Qualification criteria:

For detection:

K1: the maximum allowable deviation of the pit position at its distance from the root is 2 mm

K2: the maximum allowable deviation of the pit position in the Z-axis projection is 1 mm

K3: Detection of all pits of depth a ≥ 100 µm contained in the test piece

K4: detection of at least 75% of pits a depth in the range of 50-100 µm contained in the test piece

For sizing:

K5: The maximum permissible overvaluation/understatement of depth for pits with a depth a ≥ 100 µm in the test piece is 25 µm

K6: The maximum allowable undervaluation/underestimation of the width for pits with depth a ≥ 100 µm in the test piece is 40% of their value

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3. Qualification of NDT on cracks in steam turbine blades of the penultimate blade row of the low-pressure turbine

CVŘ

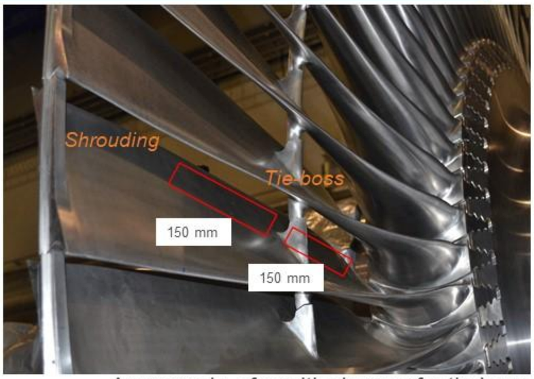
Current scope of inspections:

- Magnetic particle inspections as a main method
- Eddy current inspections used only in exceptional cases

New scope of inspections:

Two main methods

- Eddy current array inspections for initial screening (Ectane 2 inspection equipment with flexible array probe and Magnifi SW)
- Magnetic particle inspections (not cover 100% surface of blade because of limited access)



An example of a critical area of a tie-boss blade on the trailing edge

Supplemental methods in the case of indication detection

- Dye Penetrant testing (high difficulty for surface preparation; Duration of inspection; No record)
- Ultrasonic testing using Rayleigh waves (Epoch 600 inspection equipment) is used in the case of indication detection or if eddy current method cannot be performed
- Ultrasonic phased array testing (in the case that indication isn‘t through blade and it is only used for determination of crack depth)

6

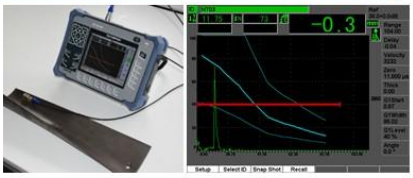
3. Qualification of NDT on cracks in steam turbine blades of the penultimate blade row of the low-pressure turbine

CVŘ

Qualified nondestructive methods:

- ET
- PAUT

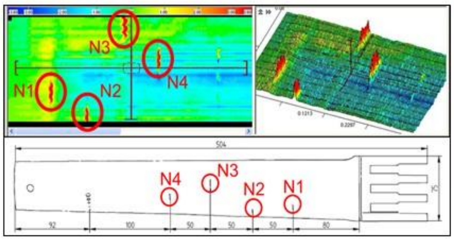
Qualification criteria:


UT: Rayleigh waves

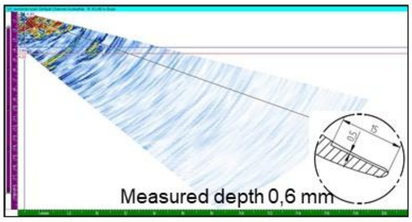
K1 (ET): Detection of all flaws of crack type contained in test pieces with crack length l ≥ 2 mm.

K2 (PAUT): Depth of not through wall cracks with an accuracy of ± 0,32 mm (half wavelength) for cracks of length l ≥ 10 mm


Flexible probe for eddy current array testing



ET results from test piece testing



Results from phased array testing

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4. Qualification of ultrasonic thickness testing of internal oxide scale of heat exchanger tubes

CVŘ

Internal Oxide Scale

- A significant limiting factor affecting tube life in fossil fired steam boilers
- Iron oxide scale (magnetite) grows on the inside / outside tube surfaces
- It forms under long term exposure to very high temperatures and acts as a thermal insulator (thermal conductivity of oxide is only about 5% that of steel)
- Insulation effect limits heat transmission into the water vapor inside the tube.
- It causes of chronic overheating of the tube wall and promotes accelerated metallurgical failure.
- The effect of scale is relatively insignificant up to thicknesses of approximately 0.3 mm.

Ultrasonic equipment and probes

- Ultrasonic pulse/echo thickness measurement technique.
- Handheld ultrasonic probe with relatively high frequency 20 MHz, broadband, i.e. highly damped.
- Delay line type normal incidence shear wave transducer must be used with special high viscosity couplant.
- The internal oxide layer must be bonded to the tube wall.
- UTT results were verified with results from scanning electron microscopy (SEM) analysis. The comparison showed +/- 5% match.

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4. Qualification of ultrasonic thickness testing of internal oxide scale of heat exchanger tubes

CVŘ

Qualification criteria:

K1: Detection of the oxide scale with a thickness greater than 0.2 mm

K2: The mean thickness of the oxide layer determined by SEM is equal to the mean value of the oxide layer determined by ultrasound method with an accuracy of 10%

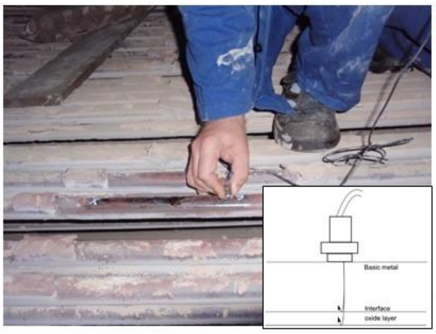
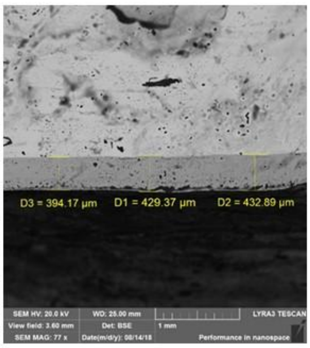


Photo from in-situ inspection

Screen of Epoch 600



Results from SEM

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5. Qualification of PAUT Vendor for detection of fabrication flaws in weld joints of boiler tubes

CVŘ

Qualification Goal

Qualify the PAUT technique of the welded joints of the boiler tubes after their fabrication on site for the presence of fabrication flaws.
Replacement of RT by qualified PAUT.

Characteristics of inspection area

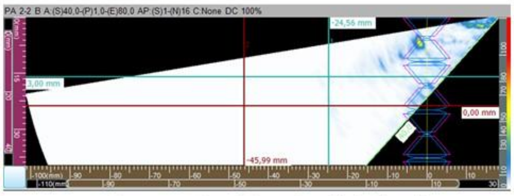
The area subject to PAUT is homogeneous welded joints of ferritic steel boiler tubes of dimensions (in mm x mm) and of the materials specified in brackets:

- 31.8 x 4 (16Mo3)
- 38 x 5 (15128.5)
- 60.3 x 5 (P235GH)

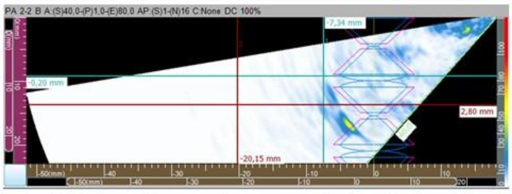
All welded joints are accessible from both sides.

Qualification criteria:

Detection of all defects in all test pieces from one or both sides of the weld joints.



S-scan of weld root spill indication



S-scan of incomplete penetration indication

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5. Qualification of PAUT Vendor for detection of fabrication flaws in weld joints of boiler tubes

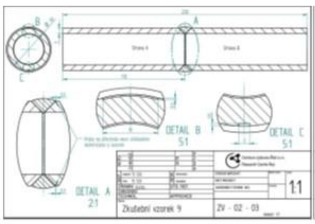
CVŘ

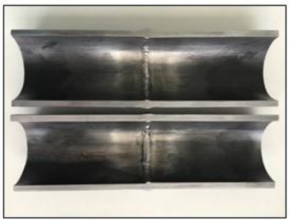
Past Activities

1. Manufacturing of open test pieces for each dimension of the tube being inspected:
   i. Test pieces with internal and external notches
   ii. Test pieces with fabrication flaws
2. The first practical demonstrations carried out by PAUT Vendor and supervised by CVR
3. Elaboration of revised Inspection Procedure reflecting practical demonstration results
4. Conducting repeated practical demonstrations
5. Elaboration of technical justification

Future Activities

1. Developing a standard for CEZ FPP defining a qualification plan to qualify PAUT of boiler tube weld joints
2. Manufacturing of blind test pieces for personal qualifications





Test piece with EDM notch

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6. Summary of qualification principles in FPP

1. **Qualification plan** - follows selected parts of ENIQ methodology
2. **Qualification Body Type**
   i. Type 3 acc. to ENIQ (An ad hoc qualification body set up for a specific qualification)
   ii. Chairman: from CEZ FPP
   iii. Members: from CEZ FPP and external companies (like Research Centre Řež etc.)
3. **Elements of Inspection Qualification**
   i. Technical justification, which involves assembling all evidence on the effectiveness of the inspection and analysis of influential and essential parameters
   ii. Practical demonstrations conducted on simplified or representative test pieces resembling the component to be inspected
4. **Qualification Level**
   - Medium Qualification Level (Qualification Approach: use of existing evidence and information)
5. **Content of the Qualification Dossier**
   - Relevant documentation is included
6. **Developing qualification plan standards for qualifying specific non-destructive or diagnostic methods**

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6. Summary of qualification principles in FPP

Certificates (responsibility of CEZ FPP)

- Validity of the certificates: unlimited, provided that records of uninterrupted activity of qualified person are carried out every 3 years. Records are made by NDT Vendors.
- The certificate contains information about:
  - ✓ Inspection procedure
  - ✓ Technical justification
  - ✓ Qualification dossier
  - ✓ Test pieces
  - ✓ Inspection equipment
  - ✓ Qualification Body
  - ✓ Qualified person
  - ✓ Date of qualification

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7. Conclusions

The presentation showed:

- A limited or simplified ENIQ-based qualification approach can generally be used to qualify different non-destructive and even diagnostic methods not only in nuclear but also in non-nuclear applications.
- Diagnostic inspection qualifications make sense for those components of fossil power plants that have an impact on the plant's operability or whose repair is costly (such as boilers, turbines, steam pipelines, etc.).

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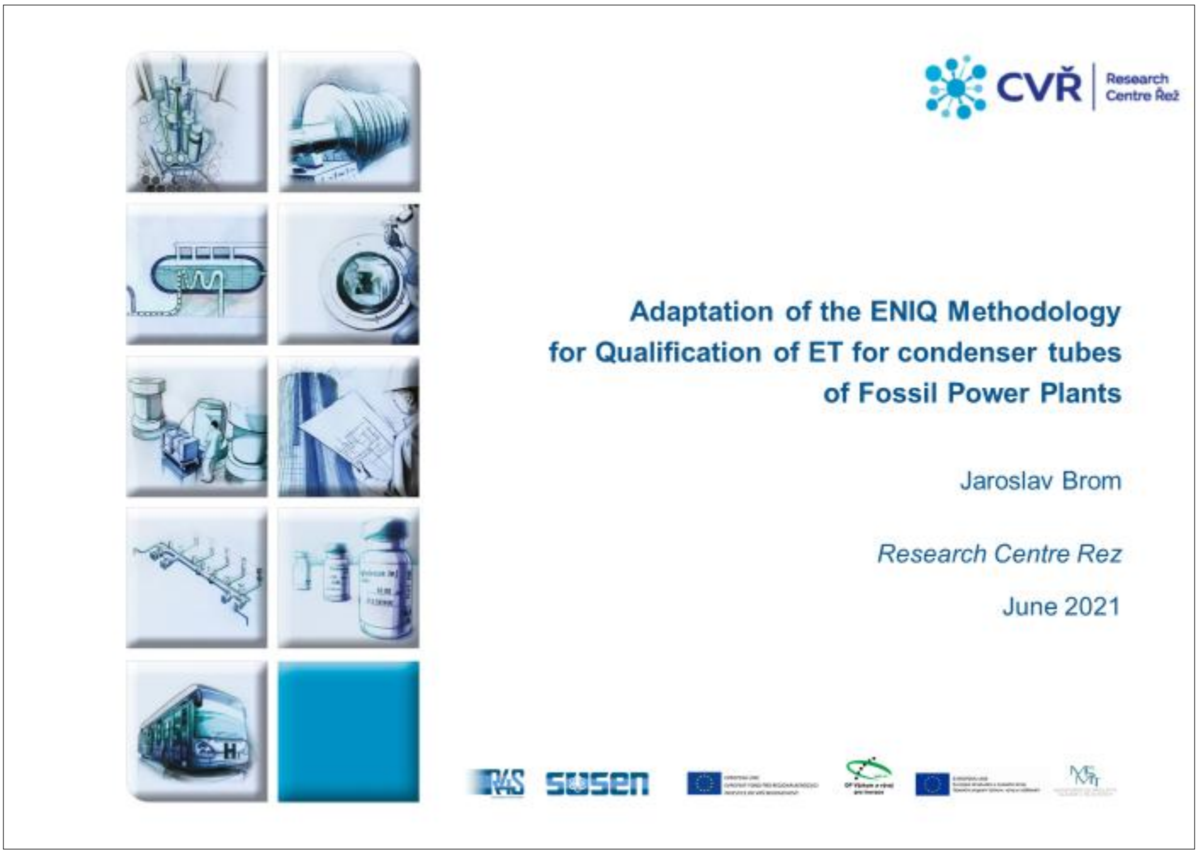
Appendix 2 – Qualification of Eddy-Current Inspection of Condenser Boiler Tubes



1. Background

Qualification of ET of condenser tubes for ČEZ FPPs are discussed.

The qualification followed the ENIQ Methodology.

The qualification is performed for the condensers of those fossil power plant units for which the ČEZ energy company is considering their operation even after 2030.

There are two tube materials with different diameters (from 20 to 28 mm) and thicknesses (0,7 or 1,0 mm):

- Austenitic 1.4541+AT resp. 1.4541
- Brass Ms70A, Ms70 resp. Ms77

2. Qualification of ET for detection and sizing of flaws in condenser tubes

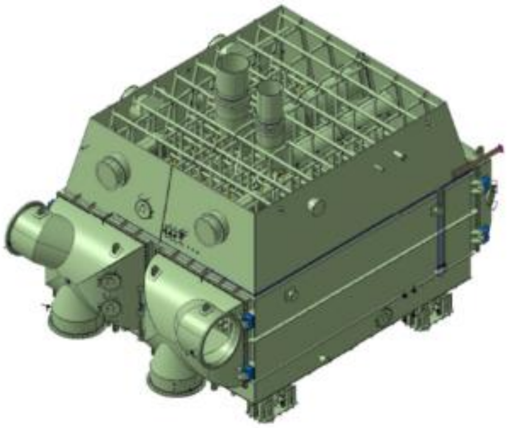
CVŘ

Current scope of inspections:

- Not qualified ET of different NDT providers with different approaches, outputs and data archiving
- No trends in the development of indications are possible

New scope of inspections:

- Only qualified ET will be applied
- The method of data recording and archiving enables indication trending
- Personnel certificates are divided for data collection and data analysis



Main condenser of Prunéřov 2 plant

3

2. Qualification of ET for detection and sizing of flaws in condenser tubes

CVŘ

Qualification principles

Qualification Body Type

1. Type 3 acc. to ENIQ (An ad hoc qualification body set up for a specific qualification)
2. Chairman: from CEZ FPP
3. Members: from CEZ FPP and Research Centre Řež

Qualification criteria:

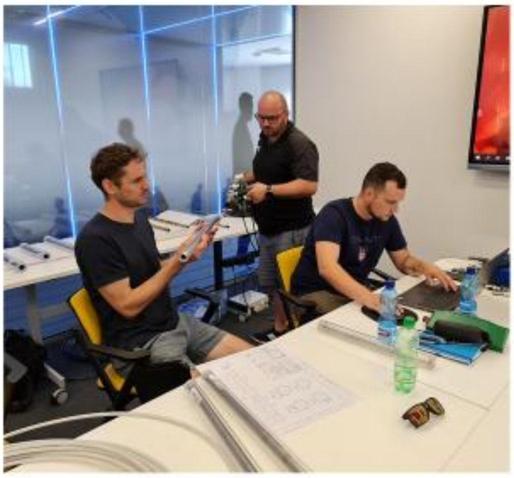
For detection:
K1: detection of 100% of defects
For sizing:
K2: - Acceptance criterion from the point of view of quantification of the loss of wall thickness during the qualification test
K3: Acceptance criterion from the point of view of quantification of the defect position during the qualification test
For false indications
K4 - No false indication allowed

Elements of Inspection Qualification

i. Technical justification
ii. Practical Trials

Test pieces:

3 test pieces with totally 16 defects (3 x EDM notch, 3 x fretting wear, 3 x ID pitting, 3 x OD pitting, 4 + 1 outer bore, 2 x outer flat bottom hole) were used for one qualification



Data recording during the qualification

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ENIQ

European Network for
Inspection & Qualification
NUGENIA Technical Area 8

ABOUT ENIQ AND NUGENIA

The **European Network for Inspection and Qualification (ENIQ)** is a utility driven network working mainly in the areas of qualification of non-destructive testing (NDT) systems and risk-informed in-service inspection (RI-ISI) for nuclear power plants (NPPs). Since its establishment in 1992 ENIQ has issued over 70 documents. Among them are the "European Methodology for the Qualification of Non-Destructive Testing" and the "European Framework Document for Risk-Informed In-Service Inspection". ENIQ is recognised as one of the main contributors to today's global qualification guidelines for in-service inspection.

ENIQ is Technical Area 8 of NUGENIA, one of the three pillars of the Sustainable Nuclear Energy Technology Platform (SNETP) that was established in September 2007 as a R&D&I platform **to support technological development for enhancing safe and competitive nuclear fission in a climate-neutral and sustainable energy mix.** Since May 2019, SNETP has been operating as an international non-profit association (INPA) under the Belgian law pursuing a networking and scientific goals. It is recognised as a European Technology and Innovation Platform (ETIP) by the European Commission.

The international membership base of the platform includes industrial actors, research and development organisations, academia, technical and safety organisations, SMEs as well as non-governmental bodies.

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