6th International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components
October 2007, Budapest, Hungary

Inspection Qualification I

Qualification Methodology of Inspection Systems at Spanish NPP's: Status and some Examples

R. Martínez-Oña, Tecnatom S.A., Spain

INTRODUCTION

In-service inspections of critical and complex components by means of Non-destructive Examination (NDE) have not obtained the expected results in certain occasions. Therefore, it is necessary to verify the performance of the inspection system to assure that it is able to achieve the expected results under real examination conditions. This process is named qualification.

The qualification is a combination of practical demonstration of the inspection system and a compilation of information about the component to inspect and required inspection objectives, the inspection system, and evidence about reliability of NDE technique. It exists different methodologies and qualification schemes in accordance with the applicable normative.

In this paper are presented the main antecedents that gave place to the present qualification schemes in Europe and the United States. Then, the main characteristics of the Qualification Methodology of NDE Systems used in the in-service inspection of Spanish Nuclear Power Plants are described. Finally, illustrative elements of implemented technical justifications are included.

ANTECEDENTS

Supported by the OECD and the European Commission (EC), and organised by the Joint Research Centre (JRC) of the EC, in 1978 the Programme for the Inspection of Steel Components (PISC I) was launched with the objective of determining the performance of the inspection techniques required by the inspection Codes of different countries. The obtained results showed of that the inspection techniques did not reach the sufficient effectiveness. The following phases, PISC II and PISC III, with similar objectives than the first one, demonstrated that the applied techniques obtained better results but for specific type of defects there were sizing problems. Then, normalisation organisms, nuclear power plants, inspection vendors, and research centres involved in these round robin tests started to consider the need of performance demonstration of the inspection techniques in test block with defects.

With this purpose, in 1991 the JRC launches the European Bureau of Inspection Validation; in 1992 this is renamed as European Network for Inspection Qualification (ENIQ). In 1995 the European Methodology for Qualification of Inspection Systems is issued and reviewed in later years. Recommended practices are also prepared that develop technical details of the European methodology. European Regulators of the ten European countries with nuclear power plants establish a working group to define their position; two years later, they issue a consensus document in which the ENIQ qualification approach is accepted. Furthermore, the CEN/TC 138 Committee has produced the norm CEN/TC 578 "NDT: Methodology for qualification of NDT". To conclude, each European country with nuclear power plants develops the ENIQ Methodology taking into consideration its legal requirements at national level.

In the USA, as a consequence of PISC results, ASME XI Appendices VII and VIII related to "performance demonstration for ultrasonic examination system" are published. All the nuclear power plants establish the "Performance Demonstration Initiative" to give an answer to the new requisites of ASME XI; an Ad-hoc Committee is created and the working programme is developed in the EPRI NDE Centre. In 1999, the requisites of performance demonstration for ultrasonic examination systems established in ASME XI Appendix VIII come into force.

In Spain, in the framework of UNESA (Spanish Association of the Electrical Industry), a Methodology of Validation of NDE Systems utilised in the In-service Inspection of NPPs is prepared following the recommendations of ENIQ. It is approved by the CSN (Spanish Nuclear Safety Council) in 1999, and received favourable valuation for application in 2004.

SPANISH QUALIFICATION METHODOLOGY

Description

The Spanish Qualification Methodology of inspection systems takes into consideration the ENIQ European Methodology and, according to the Spanish Law, the requirements of the country of origin of the nuclear power plant.

The qualification of an in-service inspection system requires the evaluation of inspection procedures, equipments and personnel. The validation should be carried out by means of a combination of the following two elements:

- *Technical justification* made of all evidence available regarding the reliability of the inspection system.
- *Practical demonstration* (open or blind) performed on representative or simplified mock-ups of the component to be inspected.

For each situation of qualification the scopes of technical justification (TJ) and practical demonstration should be determined. Regarding the type of defects, three cases are considered:

- Areas or components with specific defects[1]: An open practical demonstration with mock-ups containing specific defects is required. Technical justification will be prepared in order to complement and generalise the results obtained in the practical demonstration.
  (1): Specific defect refers to a defect already detected in the area or component of the considered NPP.
- Areas or components with postulated defects[2]: Technical justification will in-depth analyse the technical characteristics of the inspection procedure, the essential variables, and similar practical and theoretical evidences. When the TJ provides enough evidence regarding the required issues, the open practical demonstration will not be required. When the TJ does not provide evidence of any of the essential variables, this should be complemented with experimental data of the non justified essential variable.
  (2): this type of defect refers to a defect postulated according to design requisites or according to applicable experiences in similar areas.
- Areas or components with non determined defects[3]: A simplified TJ, which shows that the inspection procedure verifies the actual norms, is required.
  (3): this type of defect refers to a non detected defect and not expected to appear.

The TJ should include all evidence (bringing forward theoretical analyses and practical experience) that shows that a specific inspection is capable to verify all established requisites. The TJ should contain all the information of interest to facilitate the understanding and the assessment of the inspection system and inspection procedures. Its essential elements are: input information, description of the inspection system, analysis of essential variables, physical reasoning, theoretical evidence and experimental evidence that provide applicable results regarding the techniques to use.

The practical demonstration for qualification of inspection procedures and equipment is an open trial, in order to determine their capability and separate the potential influence of the human factor; thus the results of the open trial have to be explained and justified. For personnel qualification blind trial is required.

The sequence of the qualification process is sketched in Fig 1. The first step is defining the qualification objectives and gathering all related information such as the information regarding the area or component to inspect, type and features of defect, and qualification objectives. This material is compiled by the NPP in a document, named IOV, and it is reviewed by the Independent Organisation of Qualification (OIV).

The inspection procedure is prepared by the inspection vendor taking into consideration the IOV report, approved by the NPP and reviewed by the OIV. The procedure should specify the tasks sequence and all essential parameters; as a minimum, it would include: applicable requisites, brief description of inspection system, calibration process, scanning method, analysis process, data recording and essential variables. Essential variables refer to those parameters of the equipment and procedure that affect the result of the inspection and therefore should be defined and controlled.

The TJ is prepared (according to the content depicted above) by the inspection vendor once the inspection procedure is defined and optimised, and reviewed by the NPP and the OIV.

The following step is related to the type of defect considered in the area of interest. If the defect is “specific” an open practical demonstration would be carried out; this implies the assessment of existing mock-ups or, if these are not adequate, the specification and manufacturing of new ones. If the defect is “postulated” or “non determined” a practical demonstration is not required unless additional practical evidence is needed.

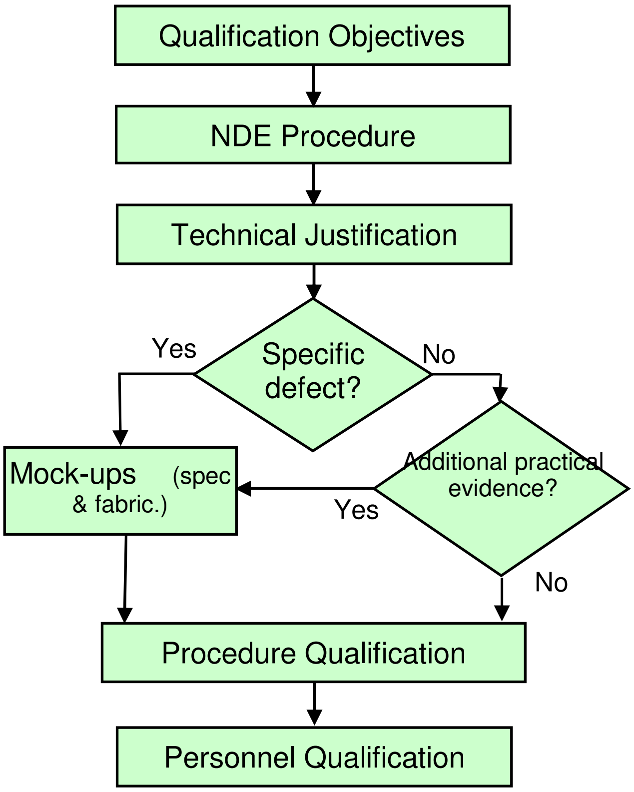


Figure 1 - Flow chart of qualification process

The qualification of the inspection procedure, that also includes the qualification of the equipment, implies either: a) the assessment of the inspection procedure (in case of postulated and non determined defects) or b) the assessment of the inspection procedure and a practical demonstration (in the case of specific defects). The results of the practical demonstration are evaluated based on the following parameters: probability of detection, false call rate, and errors sizing. The results are assessed by the NPP and the OIV, and the certificate is issued by the OIV.

The qualification of personnel implies either: a) the NDE certification required by the NPP (in case of postulated and non determined defects) or b) the NDE certification required by the NPP and a practical demonstration (in the case of specific defects); it is open for equipment calibration and data acquisition and blind for data analysis. The results are assessed by the NPP and the OIV, and the certificate issued by the OIV.

The qualification final report would include: description of the area or component to inspect, types of defects, qualification objectives of the inspection procedures, qualified inspection procedure, definition of essential variables, description of mock-ups and results of practical demonstrations, technical justification, definition of qualification requisites, personnel certifications, conclusions about fulfilment of requisites, and quality system applied.

Organisations involved

The organisations involved in the qualification process are the NPPs, the CSN and the inspection vendors. Within the NPPs can be distinguished two independent groups with different functions and responsibilities: the group currently dealing with in-service inspection issues, and the ad-hoc independent organisation of qualification (OIV).

The NPP is responsible of: supplying information and preparing the qualification objectives report (information of component, type and features of defect, parameters of inspection objectives, grouping of inspection areas), approving the inspection procedure, reviewing the technical justification, deciding to carry out practical demonstrations, issuing the qualification final report, recording and archiving the qualifications carried out.

The OIV is responsible of: verifying the fulfilment of the established objectives in the qualification process, evaluating the inspection procedure, evaluating the technical justification, preparing the evaluation report of practical demonstration results, evaluating the qualification final report, and issuing the qualification certificate.

The CSN has the function of tracking and evaluating the safety requirements of NPPs. Thus, in the context of the qualification methodology, he will approve the basic requisites established in it and in the associated Technical Documents.

The inspection vendor has the function of carrying out the in-service inspections of the required areas. He is responsible of: preparing and optimising the inspection procedures, preparing the technical justifications, certifying and calibrating the equipment, carrying out the practical demonstrations required, qualifying the personnel, recording and archiving the documentation generated during the qualification process.

Scope

The framework for defining the areas and components of systems subjected to qualification is the in-service Inspection Programme established according to ASME Code Section XI. These are the following:

- Appendix VIII areas and components, namely:
  Supplement 2: Wrought Austenitic Piping Welds.
  Supplement 3: Ferritic Piping Welds.
  Supplement 4: Clad / Base metal interface of Reactor Vessel.
  Supplement 5: Nozzle Inside Radius Section.
  Supplement 6: Reactor Vessel Welds other than Clad / Base metal interface.
  Supplement 7: Nozzle to Vessel Weld.
  Supplement 8: Bolts and Studs.
  Supplement 9: Cast Austenitic Piping Welds.
  Supplement 10: Dissimilar Metal Piping Welds.
  Supplement 11: Full Structural Overlaid Wrought Austenitic Piping Welds.
- Other Section XI areas and components, not included previously, in which exist any specific defect, and
- Those required by the CSN.

Based on this above and taking into consideration the characteristics of the component (materials and geometry) under consideration, 52 Qualification Groups have been defined (see Table 1). Associated to every area of interest of the Qualification Groups, a report of qualification objectives (named IOV) has been prepared; in total, for all the Qualification Groups, 52 IOV reports are available. Regarding the qualification of the inspection systems, it is expected to produce around 50 inspection procedures and 50 technical justifications.

Degree of implementation

The development work already started in 2004; qualification process should conclude in 2008. Much evidence, both theoretical and experimental ones, has been carried out and some more should still be generated to allow justification of all essential variables.

Table 1 - List of Qualification Groups

Group no.	Description
1	Clad/Base Metal Interface & Reactor Vessel OD (BWR)
2	Clad/Base Metal Interface & Reactor Vessel ID (PWR)
3	Nozzle Inner Radius with cladding
4	Nozzle Inner Radius without cladding
6	Nozzle to Vessel OD (BWR)
7	Nozzle to Vessel ID (W PWR)
8	Nozzle to Vessel ID (S PWR)
9	Vessel Head Penetrations
10	Vessel Bottom Penetrations
11	Stud without bore
12	Stud with bore
14	Westinghouse Steam Generator with Inconel tubes
15	Siemens Steam Generator with Incoloy tubes
16	Westinghouse Steam Generator with Incoloy tubes
17-23 & 25	Westinghouse Ferritic Piping
24	Siemens Ferritic Piping
26, 28-31 & 34-37	Wrought Austenitic Piping (PWR)
27, 32 & 38	Wrought Austenitic Piping with CRC (BWR)
33	Thermal Sleeve
39 & 40	Cast Austenitic Piping
41-49	Dissimilar Piping (OD)
50	Dissimilar Piping (ID)

Table 2 - Documents foreseen to be produced

Type	Quantity	Progress
Qualification Objectives Reports	52	100 %
Inspection procedures	55	45 %
Evidence	18	65 %
Technical Justifications	55	33 %

Four types of documents should be produced associated to the qualification process: qualification objectives reports (named IOV), inspection procedures, evidence (either theoretical or experimental) to support the selection of essential variables, and technical justifications. The IOV reports have been prepared taking into account the requisites of the Methodology. There are two categories of inspection procedures, one addressing defect detection, and the other defect sizing. These are being drafted based on the specification of IOV reports and the previous procedures. In many cases, existing experience is valid and rewriting the procedures is not a big issue. However, in several cases is necessary to generate additional evidence to support the selection of essential variables. In addition to this, writing the technical justifications represent a big effort because they should be prepared from the very beginning including comprehensive information to facilitate the understanding and the assessment of the inspection system and inspection procedures.

The progress of planned documents is the following: 100% of IOVs, nearly 50% of procedures, and 33% of the TJ. In a more detailed manner, Table 2 summarises the percentage of documents already implemented.

ILLUSTRATIVE EXAMPLES

Here below are shown some illustrative examples about information that is included in TJ and the purpose it receives.

Example 1. Table of essential variables. To facilitate the assessment and checking of essential variables (EV) a table is prepared that includes working range, unit, tolerance, how appear in the procedure, and how is treated in the TJ (information / justification). An example of EV table of probes used in ferritic piping inspection is shown in Figure 2

Description	ID	Range	Unit	Tolerance	Accredited Procedure		Inspection Procedure				TJ	Notes
					Initial	Periodic	I	Fc	Cn	Id		
Bandwidth	T10	--	> 30% f_0	±20%	MN-20.11	MN-20.11	X			UT-108	Justif,	
Beam angle	T11	--	45°, 60°, 70°	±3°	MN-20.11	MN-20.11		X		UT-108	Justif.	
Central frequency	T12	--	2,25 y 5,0 MHz	±20%	MN-20.11	MN-20.11	X			UT-108	Justif.	(1)
Exit point	T13	--	Nominal	±3 mm	MN-20.11	MN-20.11		X		UT-108	Inform.	
Manufacturer	T14	--	X	--	--	--	X			UT-108	Inform.	
Shoe – squint angle	T15	--	0°	±1°	Technical sheet	--				--	Inform.	
Active elements	T16	--	X	±2%	Technical sheet	--	X			UT-108	Justif.	(2)
Type	T17	--	E - R	--	MN-20.11	--	X			UT-108	Justif.	
Wave	T18	--	transversal	--	MN-20.11	--	X			UT-108	Justif.	

Fig. 2 - Table of essential variables of detection probes for piping inspection

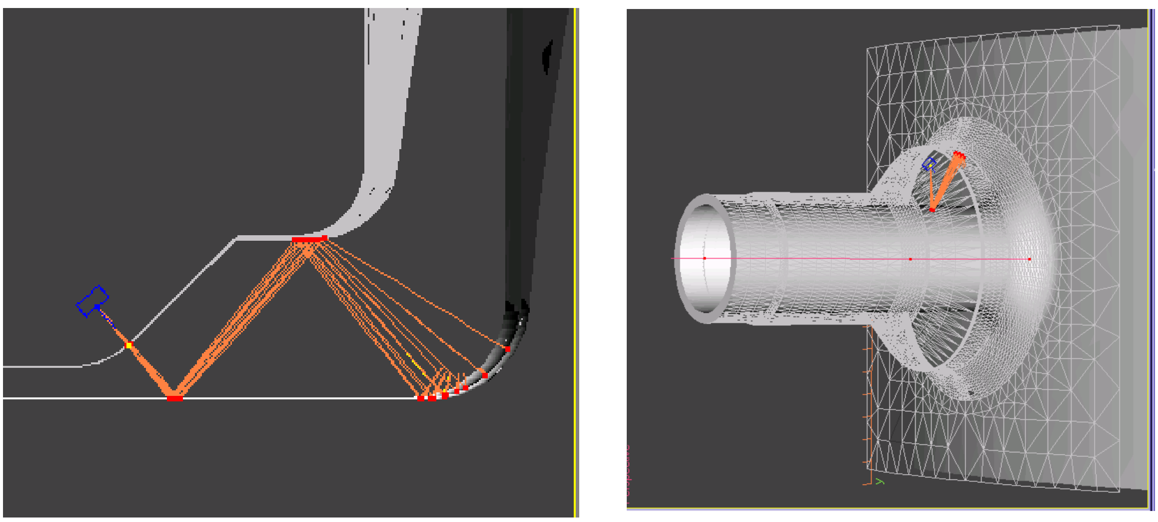
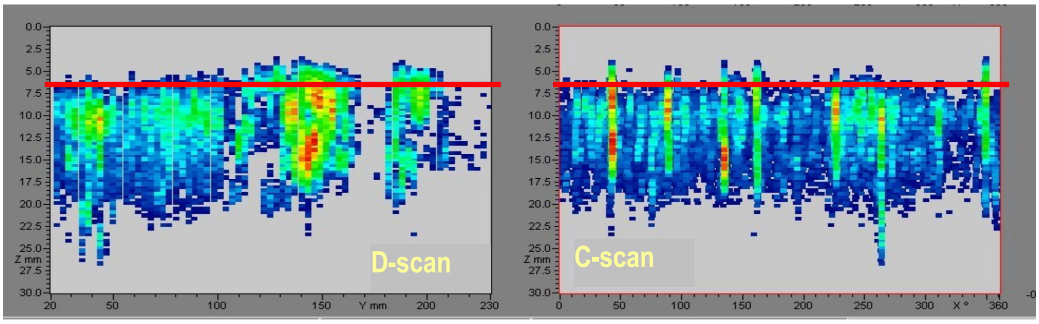


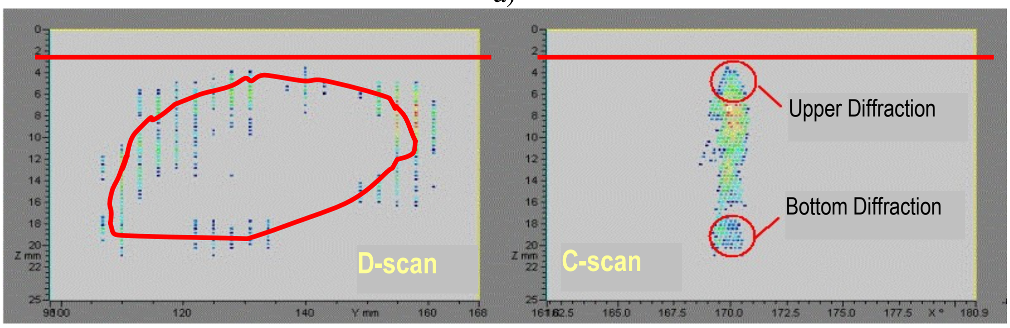
Fig. 3 - Simulation of 45º probe beam propagation on a nozzle to shell geometry

Example 2. Coverage study. To test the adequacy of a technique, one of the first steps is to check the inspection volume coverage and the map of reflection amplitudes of postulated defects. When the component geometry is simple the analysis can be easily made by means of 2D drawings, however when complex components such as nozzle to shell configurations are considered it is advisable to use graphic tools. In Fig. 3 is shown the simulation of a 45º probe beam propagation on a nozzle to shell inner radius configuration with Tecnatom's *Ray Tracing* programme.

Example 3. Justification of data analysis. In the physical reasoning chapter of essential variables, among other, the data analysis process should be explained. For instance, how data are acquired and displayed (see Fig. 4a), how coupling and (cladding, weld) interface signals, geometric echoes, diffraction signals (see Fig. 4b) are identified, etc. Finally, it is necessary to provide evidence that support the statements initially presented.



a)



b)

Fig. 4 - C and D-scan of under cladding crack, a) raw data, and b) analysed data

CONCLUSIONS

The necessity of achieving high levels of reliability in the in-service inspections by NDE and the results obtained in the PISC Programmes motivated the development of methodologies for qualification of inspections.

In the 90s, the ENIQ under the management of the JRC developed and issued the European Methodology for Qualification of Inspection Systems. Few years later and taking ENIQ methodology as base, the Spanish NPP utilities have developed their own qualification methodology that has been approved by the Nuclear Safety Authority.

The Qualification process is an on-going activity that started in 2004 and should be finished by mid 2008. The documentation required for completion of this process is above 45%.

It is expected to complete the Qualification process next year as it is planned.

REFERENCES

(1) European Methodology for Qualification, EUR 17299 EN, 1997.
(2) UNESA CEX-120, “Qualification Methodology of NDE systems used in the In-service Inspection of Spanish NPP’s”, April 2003 (in Spanish).
(3) ENIQ Recommended practice 2: Recommended content for a technical justification, EUR 18099 EN, July 1998.
(4) ENIQ Recommended practice 3: Strategy document for technical justification, EUR 18100 EN, July 1998