In-service inspection and qualification of critical components: key issues for the Life Management Programmes

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- Inspection Qualification Methodologies
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- Conclusions

Introduction (1/2)

- The standard design life of a NPP is 30-40 years.
- Based on the accumulated experience and multiple assessments, many plants will request to operate in excess of their design lives.
- A key element to assess plant life is to determine the integrity of structural materials more critically subjected to degradation.
- In-service inspection is a powerful approach to achieve this objective.

Introduction (2/2)

- Safety codes require periodic inspections of critical components
- These components are subjected to stringent environmental conditions (radiation, temperature, etc.) and have difficult access.
- Thus inspection systems should have powerful capabilities to examine these components.
- Due to complexity and stringent requirements of ISI, inspection systems should be qualified to perform with reliability and efficiency.

In-Service Inspection Approaches (1/3)

- In-service inspection is intended to identify conditions that are prone to produce structural failures.
- In the past, ISI were performed based on prescriptive requirements (experience, engineering judgement, etc.)
- Currently there is a tendency to assess and implement risk informed processes considering failure probability and consequence impacts.

In-Service Inspection Approaches (2/3)

- Supported by OECD, and organised by the JRC of EC, in 1978 was launched the Programme for the Inspection of Steel Components (PISC).
- PISC showed of that the inspection techniques currently applied did not reach the sufficient effectiveness.
- Thus, different organisations considered to implement performance demonstration of inspection techniques in test blocks with defects.

In-Service Inspection, implications (3/3)

- It is necessary to use special inspection systems with powerful features to accomplish ISI of many critical areas included in RBI inspection programmes but not in previous prescriptive programmes.

- It is necessary to qualify the inspection system due to the complexity and stringent requirements of these examinations.

NDE qualification: systematic assessment, by the methods that are needed to provide reliable confirmation, of an NDE system to ensure it is capable of achieving the required performance under real inspection conditions

Inspection Qualification Initiatives (1/2)

- In 1992 the JRC launched the European Network for Inspection Qualification (ENIQ). In 1995 the European Methodology for Qualification of Inspection Systems was issued.
- In the USA, all NPPs established the Performance Demonstration Initiative (PDI) to give answer to ASME XI Appendices VII & VIII new requisites. In 1999, performance demonstration for ultrasonic examination systems came into force.

Inspection Qualification Initiatives (2/2)

- In 1996 the IAEA initiated the development of a methodology for qualification of ISI systems for WWER NPPs. In 1998 the methodology was issued.
- In 1997, European Regulators issue a consensus document in which the ENIQ qualification approach is accepted.
- Each European country develops the Methodology taking into consideration its legal requirements at national level.
- In 1999 UNESA (Spanish Association of the Electrical Industry) prepared the Methodology of Validation of NDE Systems utilised in the In-Service inspection of NPPs following the ENIQ recommendations.

ENIQ Methodology Approach

- Qualification of a NDE inspection requires the assessment of the NDE system that is made of a combination of *inspection procedure*, *equipment*, and *personnel*.

- Qualification is the sum of:
  - *Practical assessment* conducted on test pieces resembling the component to be inspected.
  - *Technical justification* involves assembling all evidence on the effectiveness of the test. Comprises a mixture of experimental evidence and theoretical assessment.

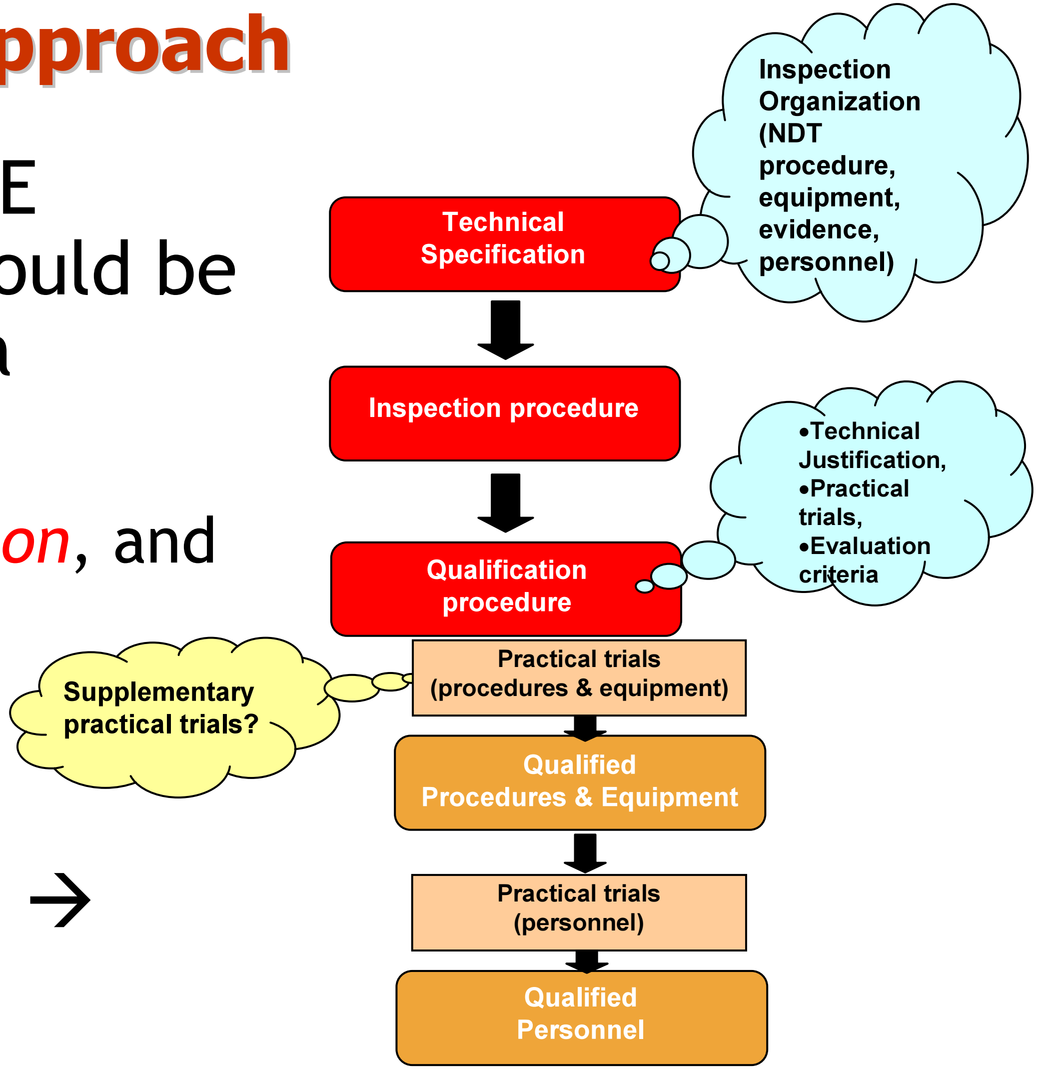
ENIQ Methodology Approach (2/2)

- Qualification of *inspection procedure /equipment* is carried out by technical justification, open trials or both.
- Qualification of *personnel* is made through any combination of NDE personnel certification scheme, theoretical and/or open practical examination, and blind trials.

IAEA Methodology Approach

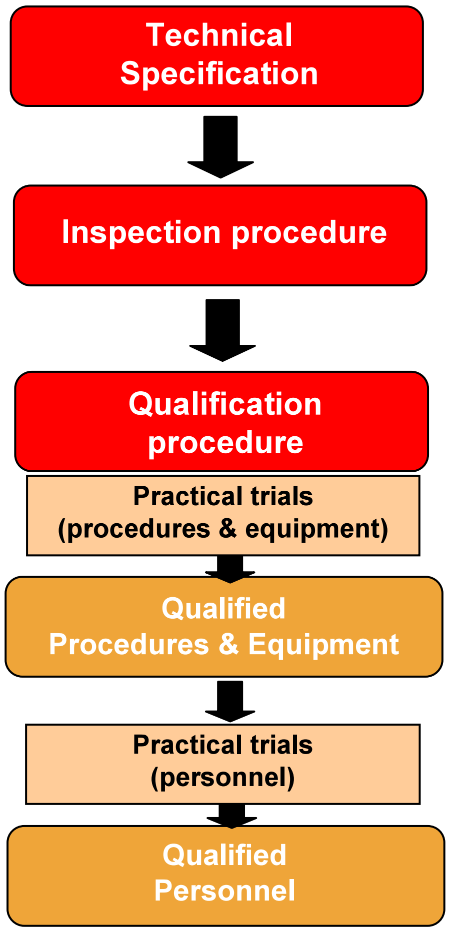
- Qualification of a NDE inspection system should be carried out through a combination of
  - *Technical justification*, and
  - *Practical trials*.

- Qualification process →



IAEA Qualification Process

- **Technical specification**: code requirements, area to be inspected and postulated defects, NDE method, inspection effectiveness.
- **Inspection procedure**: NDE technique, essential parameters, equipment description, operational conditions, calibration process, indication's reporting, discrimination criteria.
- **Qualification procedure**: technical justification, practical trials, evaluation of qualification results.
- **Certification**: qualification dossier, certificates.



Spanish Methodology Approach

- In Spain there are different types of nuclear rectors from different suppliers: PWR (Westinghouse), BWR (General Electric), PWR (KWU)
- In Spain (1997-99), in the framework of UNESA, a Methodology of Validation of NDE Systems utilised in the ISI of NPPs was prepared following the ENIQ recommendations.
- In 1999, the Methodology was approved by the CSN.
- Spanish Methodology takes into consideration ENIQ methodology and, according to the Spanish Law, the requirements of the country of origin of the NPP.

UNESA: Spanish Association of the Electrical Industry

CSN: Spanish Nuclear Safety Board

Spanish Methodology Approach

Qualification is carried out as in previous cases by a combination of:

- **Technical Justification** of all evidence available regarding reliability of inspection system showing that a specific inspection system is capable to verify all established requisites:
  - Input information. Inspection system description, Analysis of essential variables, Physical reasoning, Theoretical and experimental evidence
- **Practical Demonstration**, for qualification of inspection procedures and equipment, by an open trial of the inspection system on a representative mock-up.
  - To determine their capability and separate the potential influence of the human factor.
  - Thus, the results have to be explained and justified.
- **Personnel qualification** is a blind trial.

Spanish Methodology. Cases

- Three cases according to defect type:
  - Area with *specific* defects:

    TJ : yes, comprehensive **PD** : yes.
  - Area with *postulated* defects:

    TJ: yes **PD**: no.
  - Area with *non-determined* defects:

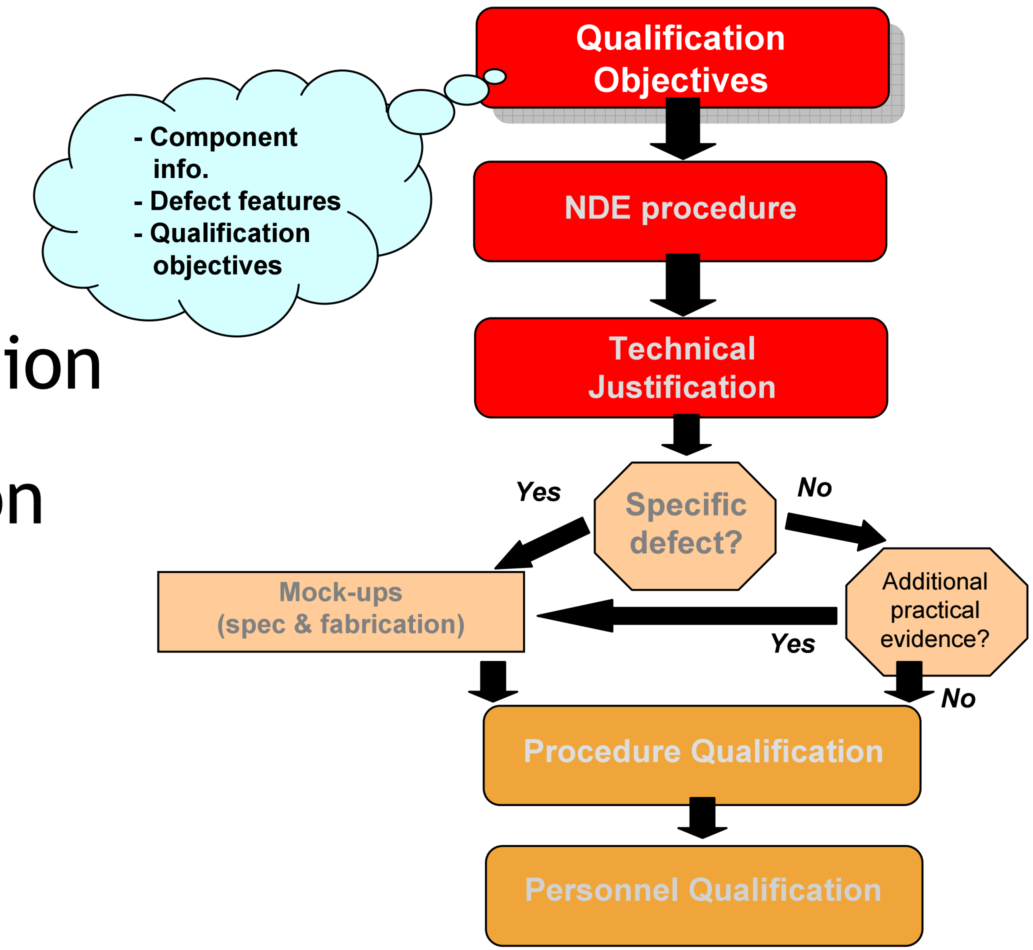
    TJ: yes, simplified **PD**: no.

Specific defect: a defect already detected in the area
Postulated defect: defect according to design requisites
Non-determined defect: a non detected defect and not expected to appear

Spanish Qualification process (1/5)

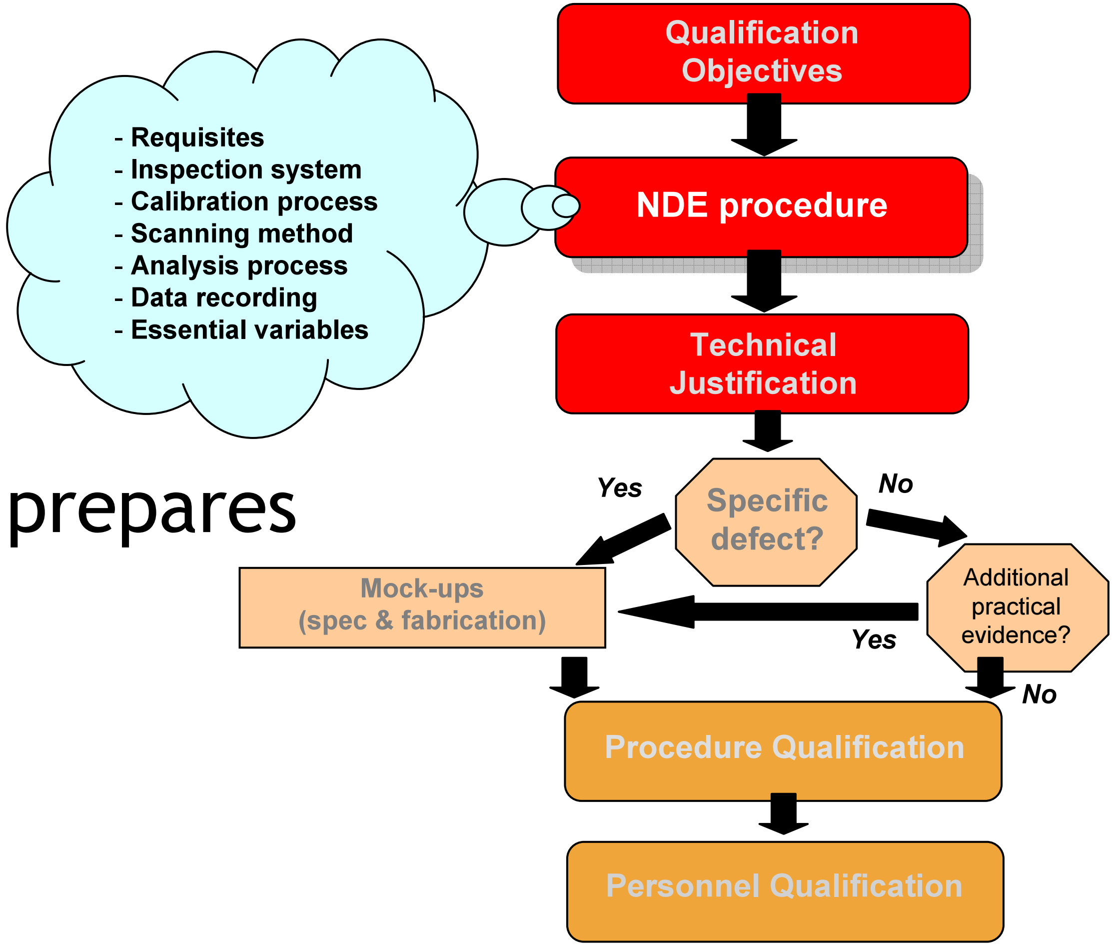
Qualification Objectives

- NPP compiles information
- OIV reviews information



Spanish Qualification process (2/5)

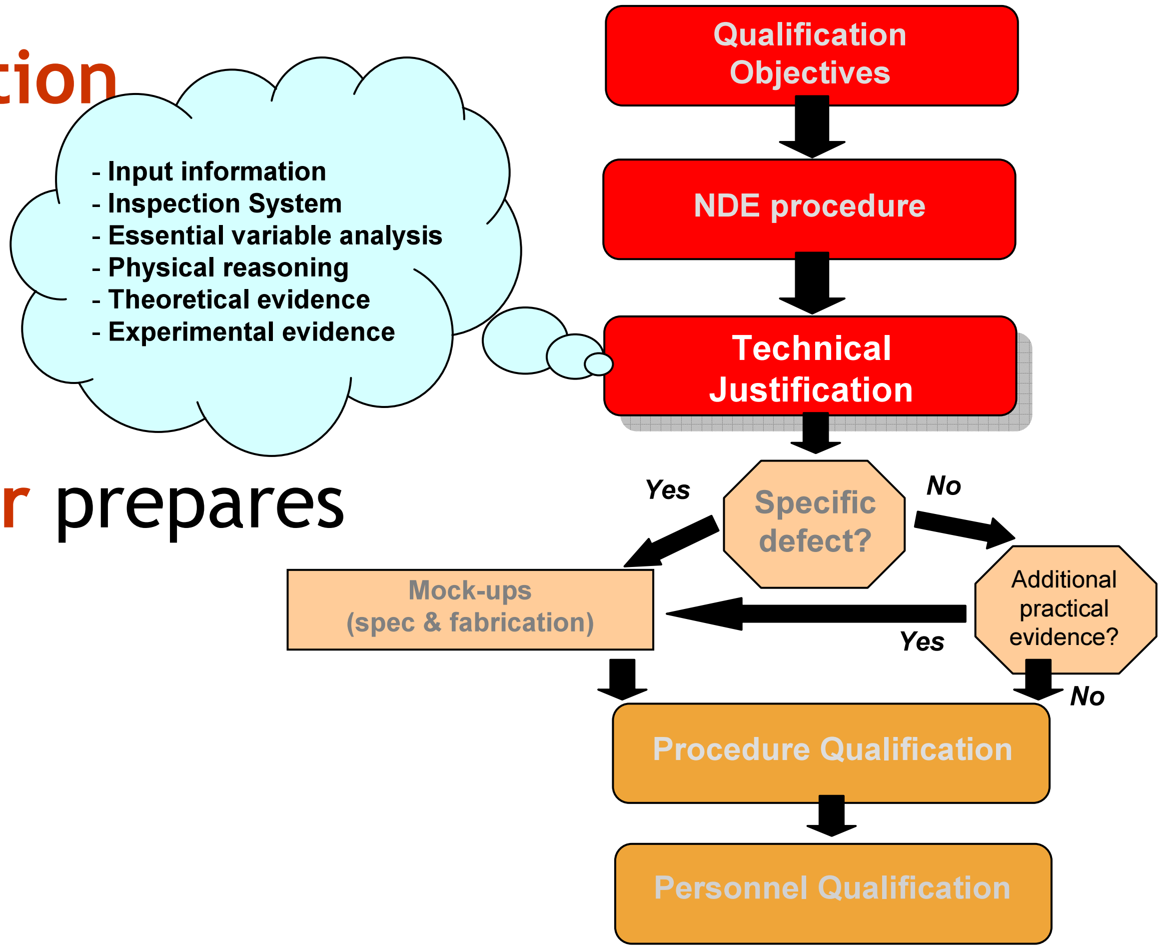
NDE Procedure



- Inspection vendor prepares
- NPP approves
- OIV evaluates

Spanish Qualification process (3/5)

Technical Justification

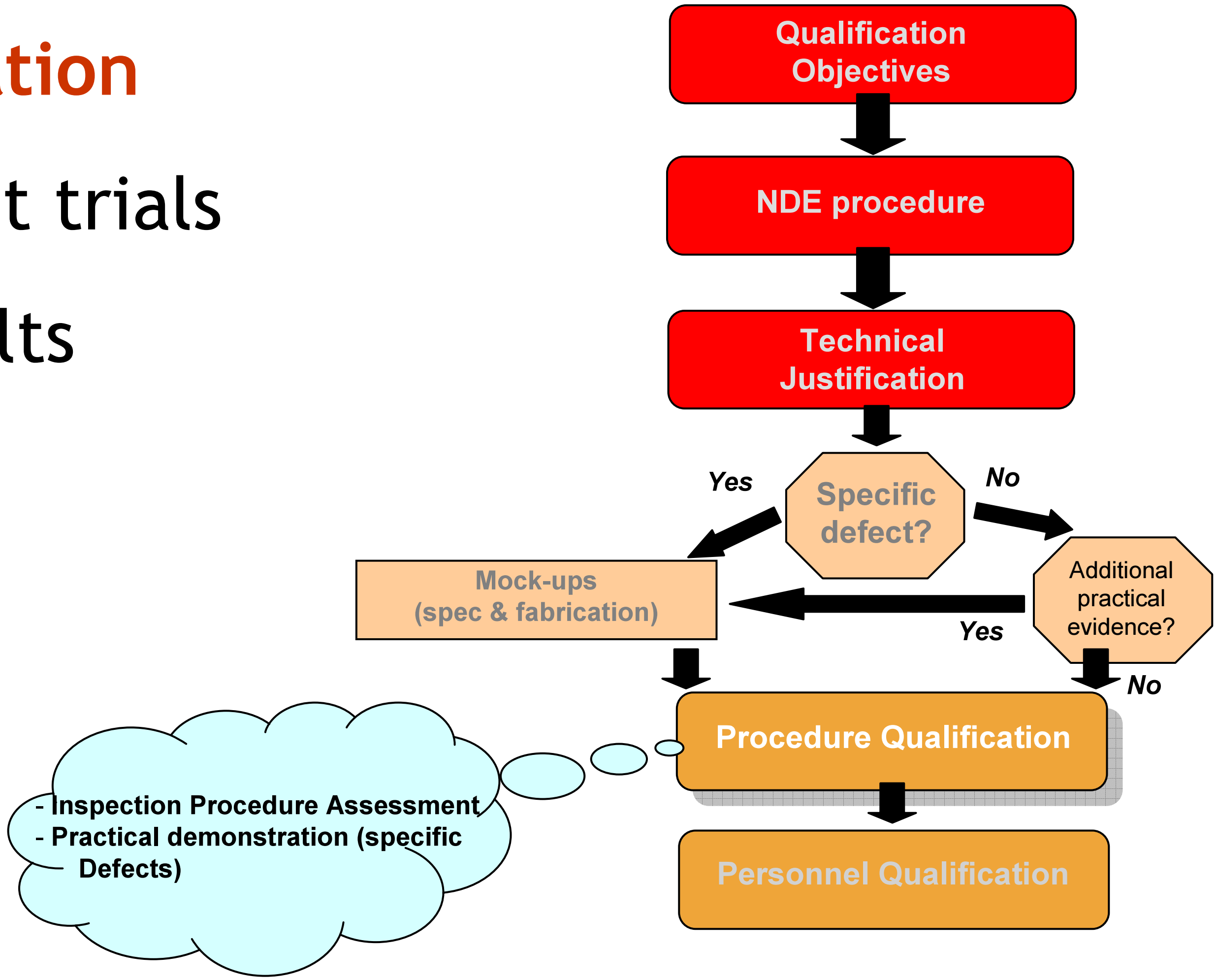


- Inspection vendor prepares
- NPP approves
- OIV evaluates

Spanish Qualification process (4/5)

Procedure qualification

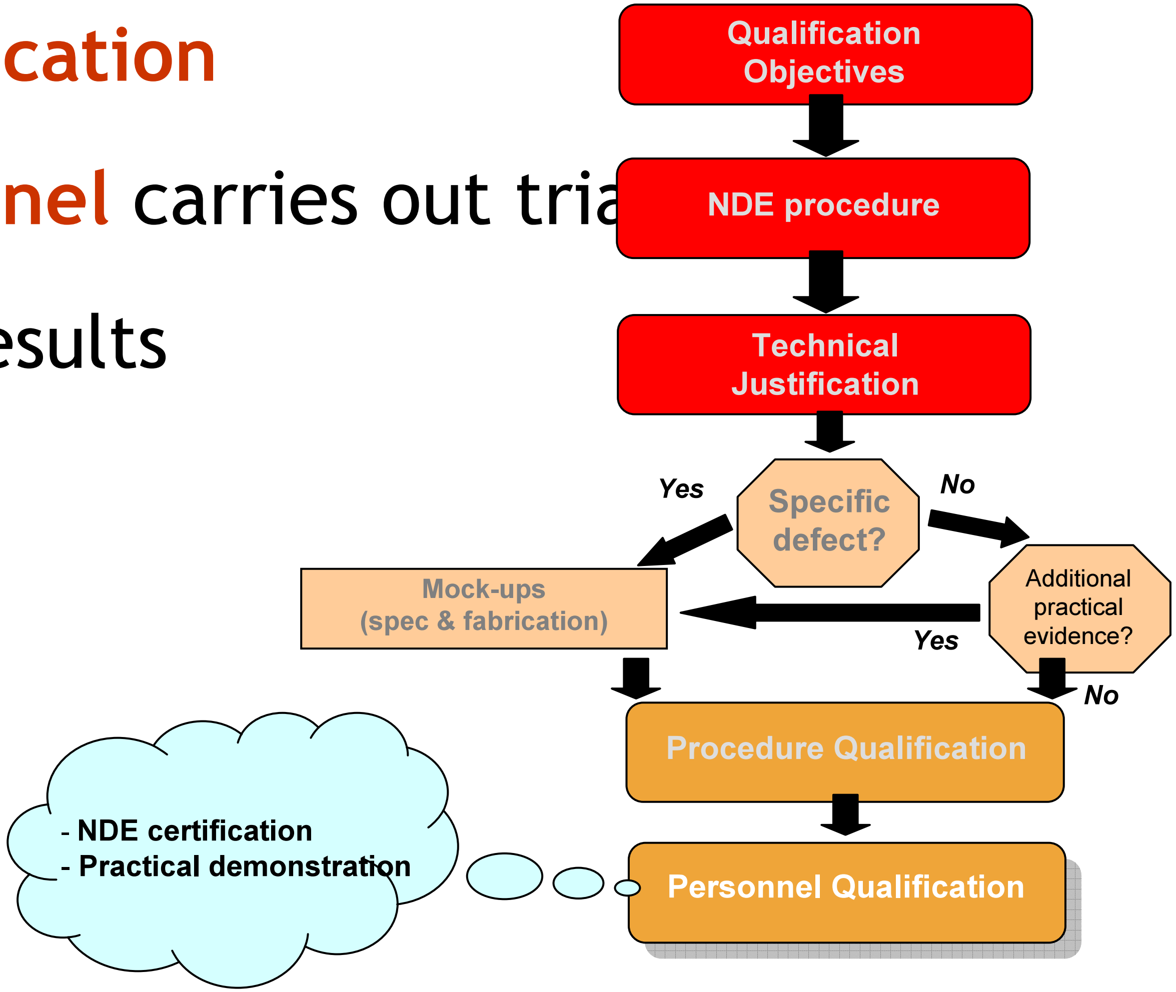
- **Vendor** carries out trials
- **NPP** assesses results
- **OIV** certifies



Spanish Qualification process (5/5)

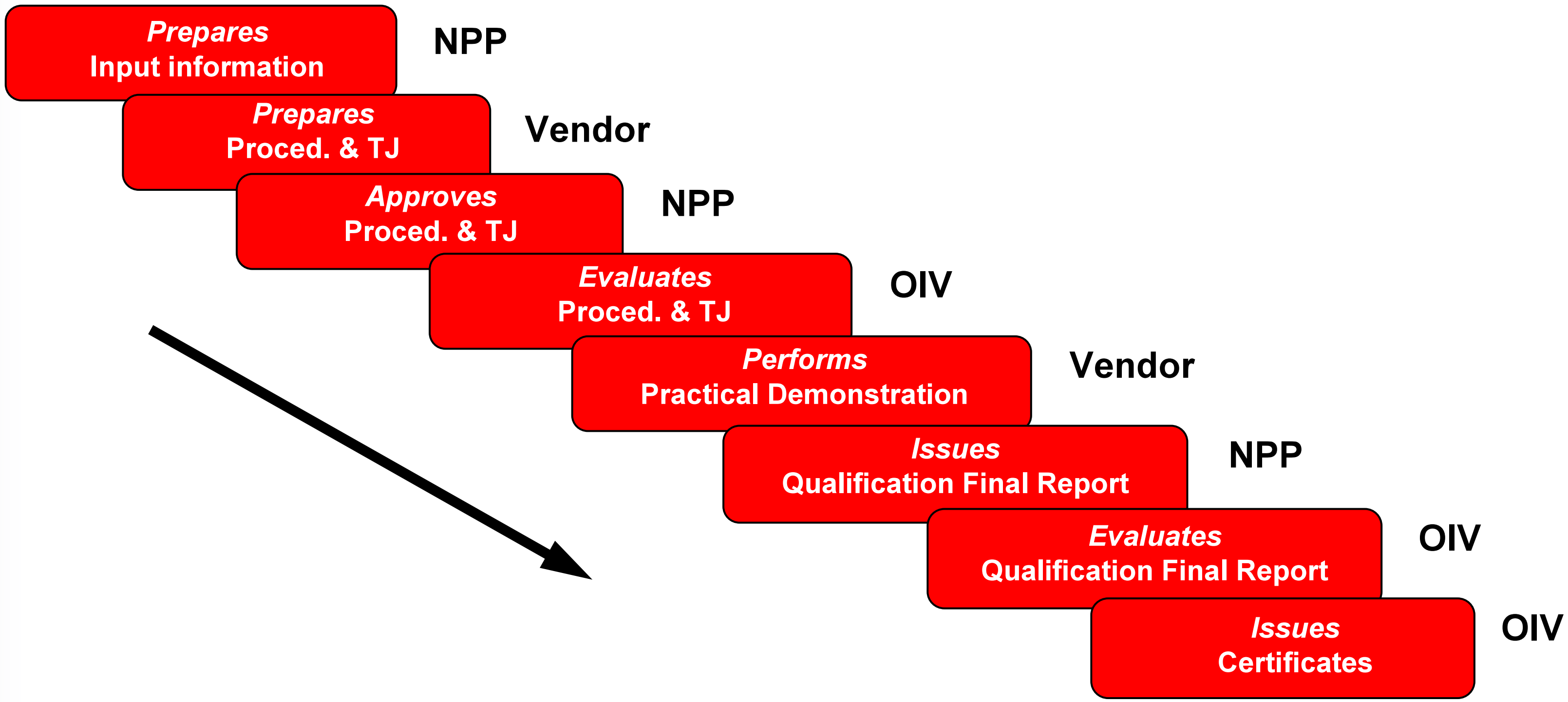
Personnel qualification

- Vendor personnel carries out tria
- NPP assesses results
- OIV certifies



Spanish Qualification process: Organisations

- CSN approves basic requisites of Methodology.



Spanish Qualification process: Scope

- The framework for defining the areas subjected to qualification is:
  - The ISI Programme established according to ASME Code Section XI Appendix VIII.
  - Other Section XI areas not included previously in which exist specific defects.
  - Those required by the CSN.
- 52 Qualification Groups defined.

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)

Spanish Methodology. Progress

- Qualification process:
  - Start: 2004,
  - End: 2008.
- Progress

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

Tecnatom's experience (1/2)

- In different qualification schemes (France, GB, Japan, Spain, Sweden, Swiss, USA, etc.) and technologies (PWR, BWR, WWER, etc.)
- In different components, both required and not required by ISI Codes.

Tecnatom’s experience (2/2)

- RPV full scope (PWR, BWR)
- RPV shroud stainless steel welds
- RPV head penetrations
- RPV bottom penetrations (BMP, ICMH)
- RPV CRDH assembly
- RPV nozzle bimetallic welds
- Primary circuit stainless steel welds (BWR)
- Fuel assembly inspection
- SG collector and tubes (WWER)

Example 1. Qualification objectives report

UNESA-GRUVAL GVL-IT-040, rev. 0

Tabla 1. Variables influyentes del componente. Agrupación de áreas asociadas a las soldaduras de las penetraciones de la tapa de la vasija (PETAVA).

Variable influyente	No.	Valor	Tolerancia	Rango	Observaciones
Geometría del componente	C1	-	-	-	Apartado 5.1
Rugosidad superficial y condiciones superficiales	C2	< 250 micropulgadas	-	-	Apartado 5.2
Espesor de la penetración	C3	15,88 mm	-	-	Apartado 5.1
Diámetro interior de la penetración	C4	69,85 mm	-	-	Apartado 5.1
Diámetro exterior de la penetración	C5	101,6 mm	-	-	Apartado 5.1
Holgura radial (Nota 1)	C6	-	-	3,2 mm	Apartado 5.1
Macroestructura del material base	C6	Nota 2	-	-	Apartado 5.3.1
Accesibilidad al área / componente	C7	Por el interior del tubo o desde el huelgo			
Temperatura ambiente	C8	-			
Humedad relativa	C9	60%			

Notas:

1. Valor nominal de la holgura radial entre la camisa térmica y la
2. Heterogénea y anisótropa.

_PETAVA - 12

UNESA GRUVAL

GRUPO DE VALIDACIÓN END-ISI (GRUVAL)

ID Documento: GVL-IT-040

Título Documento:

INFORME TÉCNICO PARA LA DEFINICIÓN DE LOS OBJETIVOS DE VALIDACIÓN (IOV) DE LA AGRUPACIÓN DE ÁREAS ASOCIADAS A LAS SOLDADURAS DE LAS PENETRACIONES DE LA TAPA DE LA VASIJA (PETAVA)

Revisión: 0

Fecha: Mayo 2006

Aprobado por:	Fecha aprobación:
GRUVAL	04-05-2006

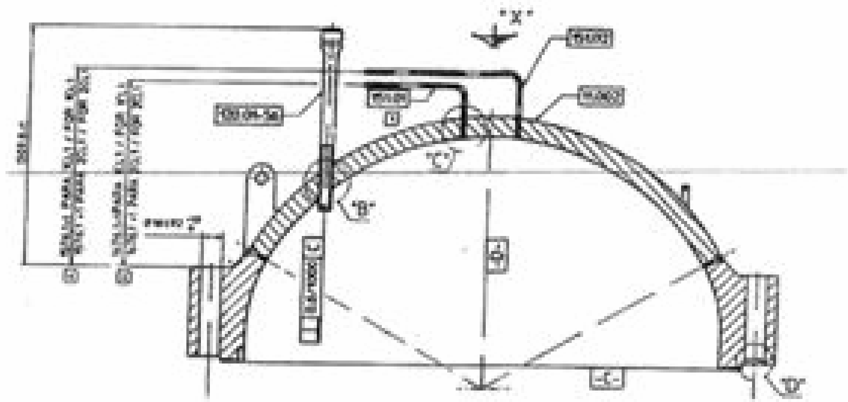
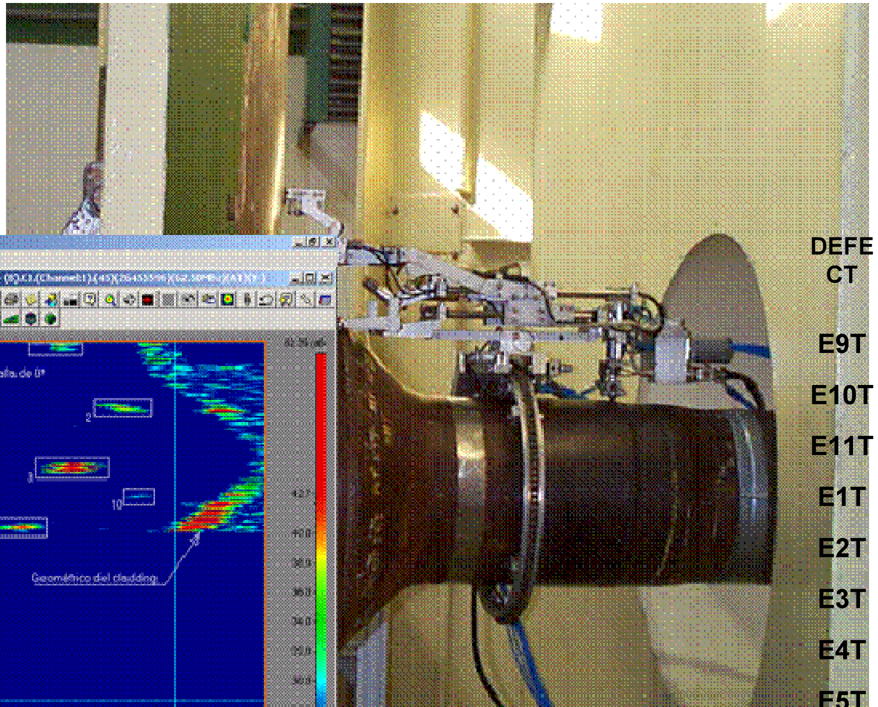
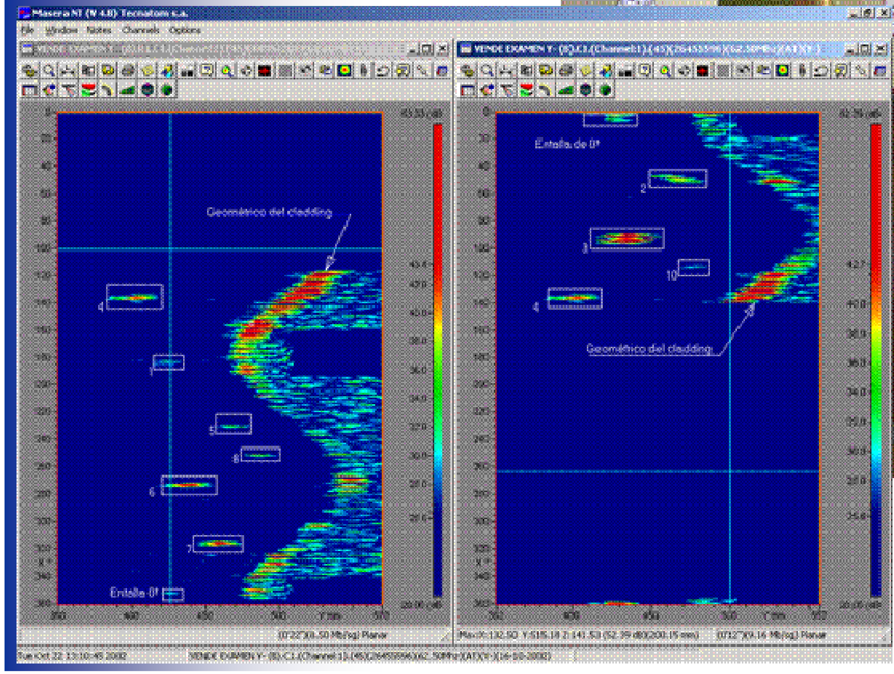


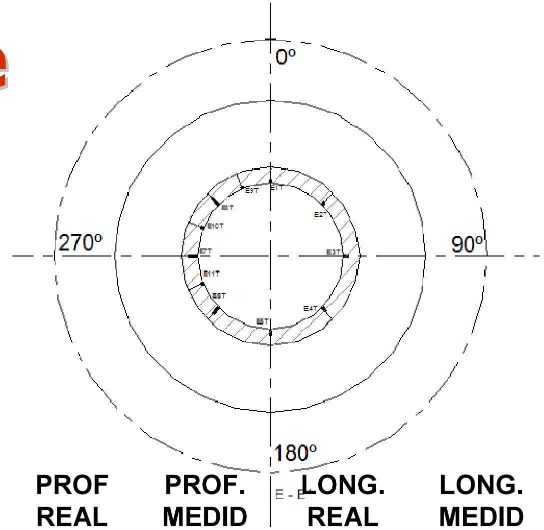
Figura A.I-1. Esquema general de una penetración de la tapa de la vasija [2].

Example 2. Experimental evidence

Nozzle to vessel inspection







DEFECT	PROF REAL mm	PROF. MEDID A mm	LONG. REAL mm	LONG. MEDID A mm
E9T	2,6	--	31,8	NA
E10T	3,6	--	37	NA
E11T	4,5	--	42	NA
E1T	5,3	--	44,8	NA
E2T	7	8	51	NA
E3T	9	8	57,2	NA
E4T	11	10	62,6	NA
E5T	12,6	13	66,4	NA
E6T	15,5	14	72,4	NA
E7T	17	20	75,1	NA
E8T	18,5	18	77,7	NA

Example 3. Procedure

RPV inspection

PROCEDIMIENTO

Clave: UT-123

Nº Páginas: 31

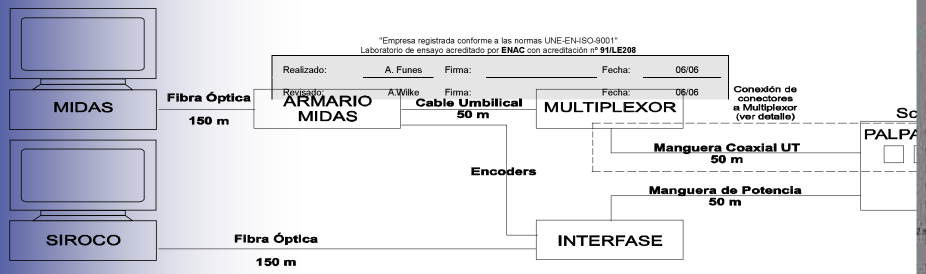
Revisión: 0 (usar letras: A1, ...)

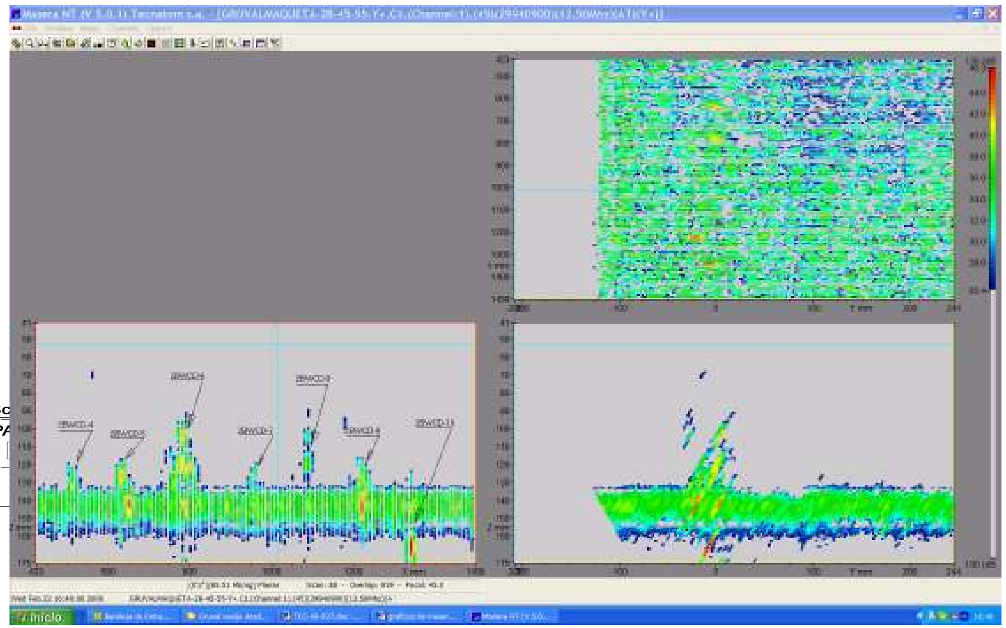
Titulo: PROCEDIMIENTO DE INSPECCIÓN AUTOMÁTICA PARA DETECCIÓN DE DEFECTOS EN SOLDADURAS EN LA PARED DE LA VASIJA DEL REACTOR PWR DESDE EL INTERIOR

"Empresa registrada conforme a las normas UNE-EN-ISO-9001"
Laboratorio de ensayo acreditado por **ENAC** con acreditación nº **91/LE208**

Realizado:	A. Funes	Firma:		Fecha:	06/06
Revisado:	A.Wilke	Firma:		Fecha:	06/06

PALPADORES PARA DETECCIÓN					
PALPADOR	FRECUENCIA	ÁNGULO INCIDENCIA	TIPO DE ONDA	FOCO	TAMAÑO DE CRIST.
45°	1,5 Mhz ± 0,5	45°	Transversal	N.A.	(25x23) mm ±3
55°	1,5 Mhz ± 0,5	55°	Transversal	N.A.	(25x23) mm ±3
70°	2 Mhz ± 0,5	70°	Longitudinal	FD 12 ± 3 mm	2(12x25) mm ±3
0°	2 Mhz ± 0,5	0°	Longitudinal	FD 20 ± 3	2(1/2 Φ 20) mm ±3
0°	2 Mhz ± 0,5	0°	Longitudinal	N.A.	(Φ25) mm ±3



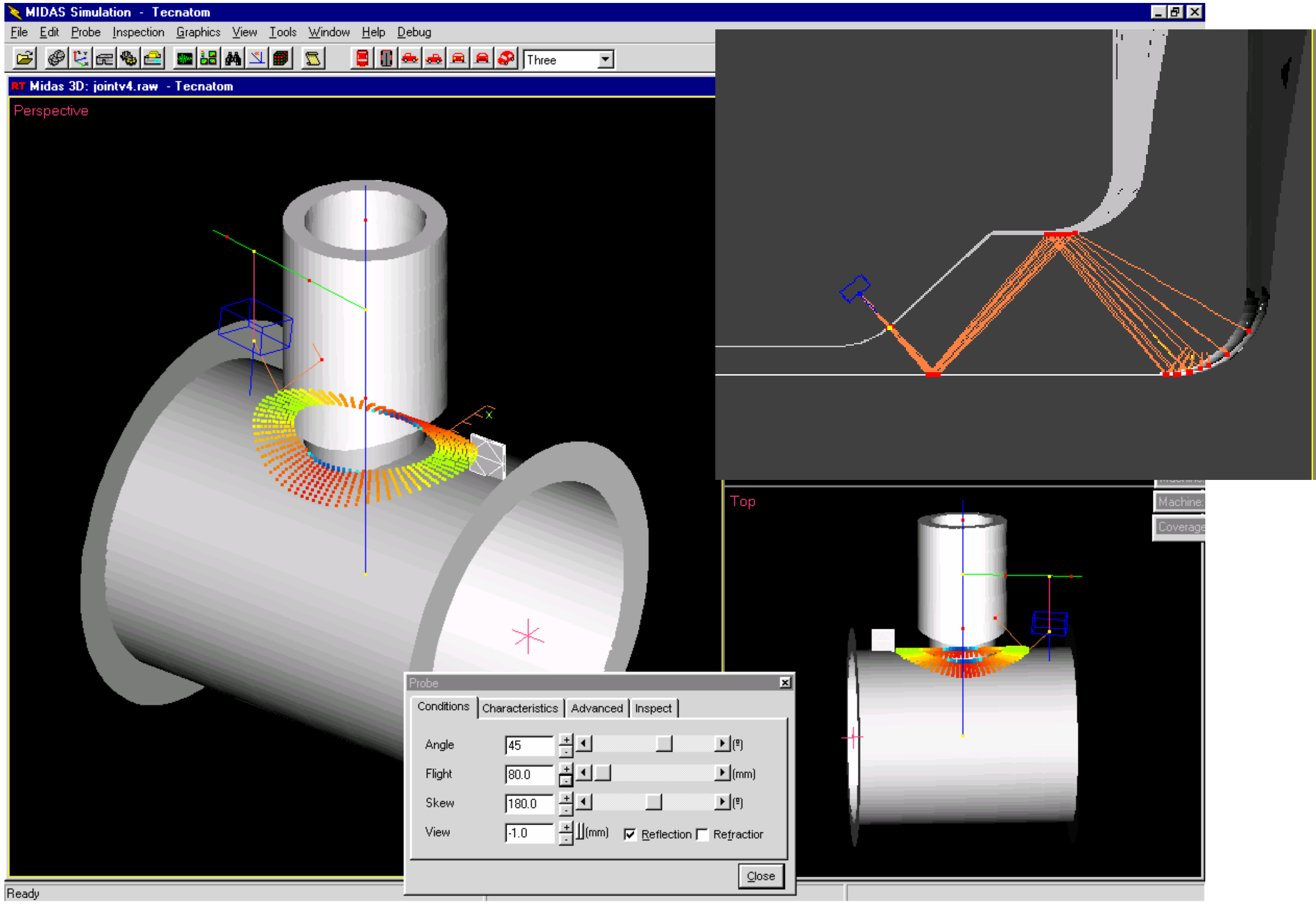


Example 4. Technical Justification

Description	ID	Range	Unit	Toler.	Accredited Procedure		Inspection procedure				JT	Notes
					Initial	Periodic	I	F	Cnc	Id		
Bandwidth	T10	--	> 30% f_0	±20%	MN-20.11	MN-20.11	X			UT-108	Justif.	
Beam angle	T11	--	45°, 60° o 70°	±3°	MN-20.11	MN-20.11		X		UT-108	Justif.	
Central frequency (f_0)	T12	--	2,25 y 5,0 MHz	±20%	MN-20.11	MN-20.11	X			UT-108	Justif.	(1)
Beam exit point	T13	--	Nominal	±3 mm	MN-20.11	MN-20.11		X		UT-108	Infor.	
Manufacturer	T14	--	X	--	--	--	X			UT-108	Infor.	
Shoe – squint angle	T15	--	0°	±1°	Data sheet	--				--	Infor.	
Size of active elements	T16	--	X	±2%	Data 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.	

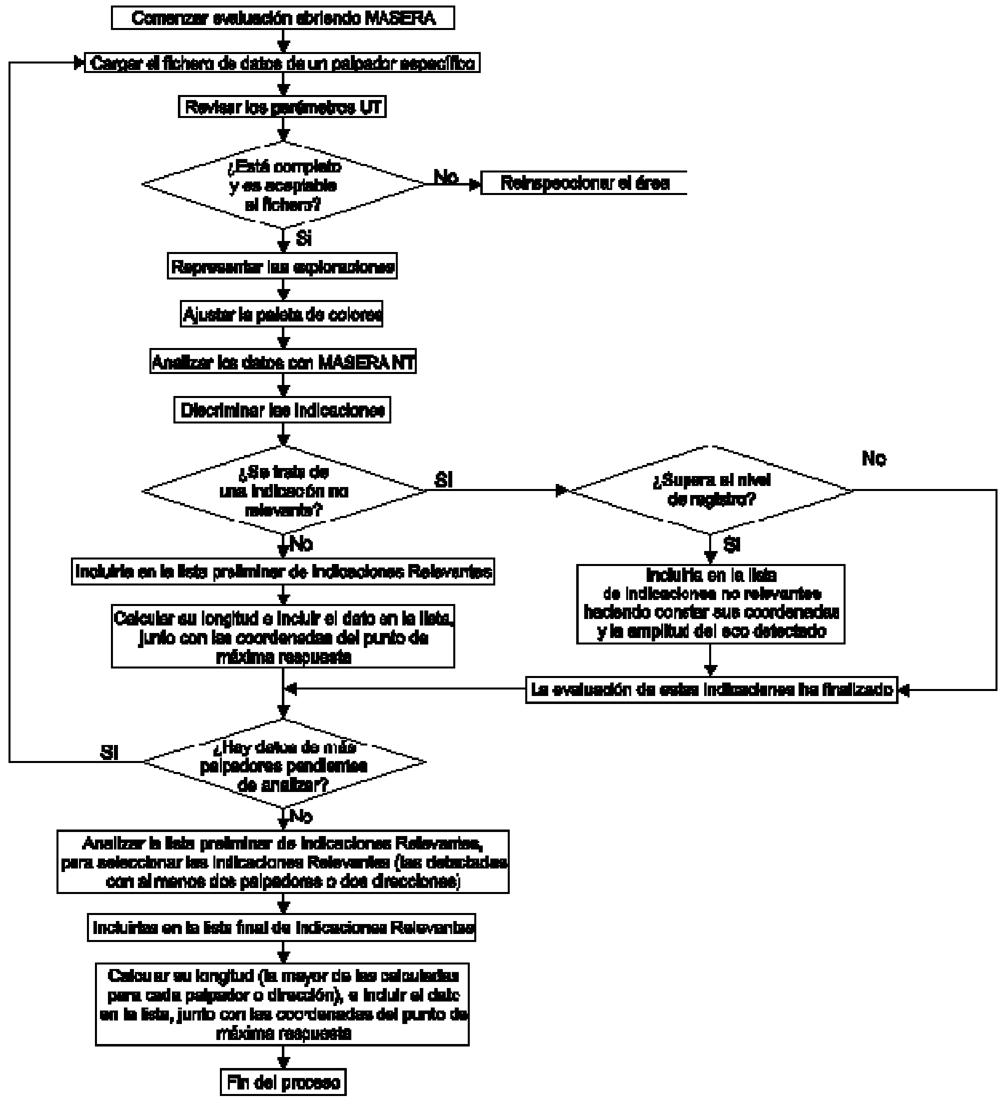
Table of essential variables of detection probes

Example 4. Technical Justification



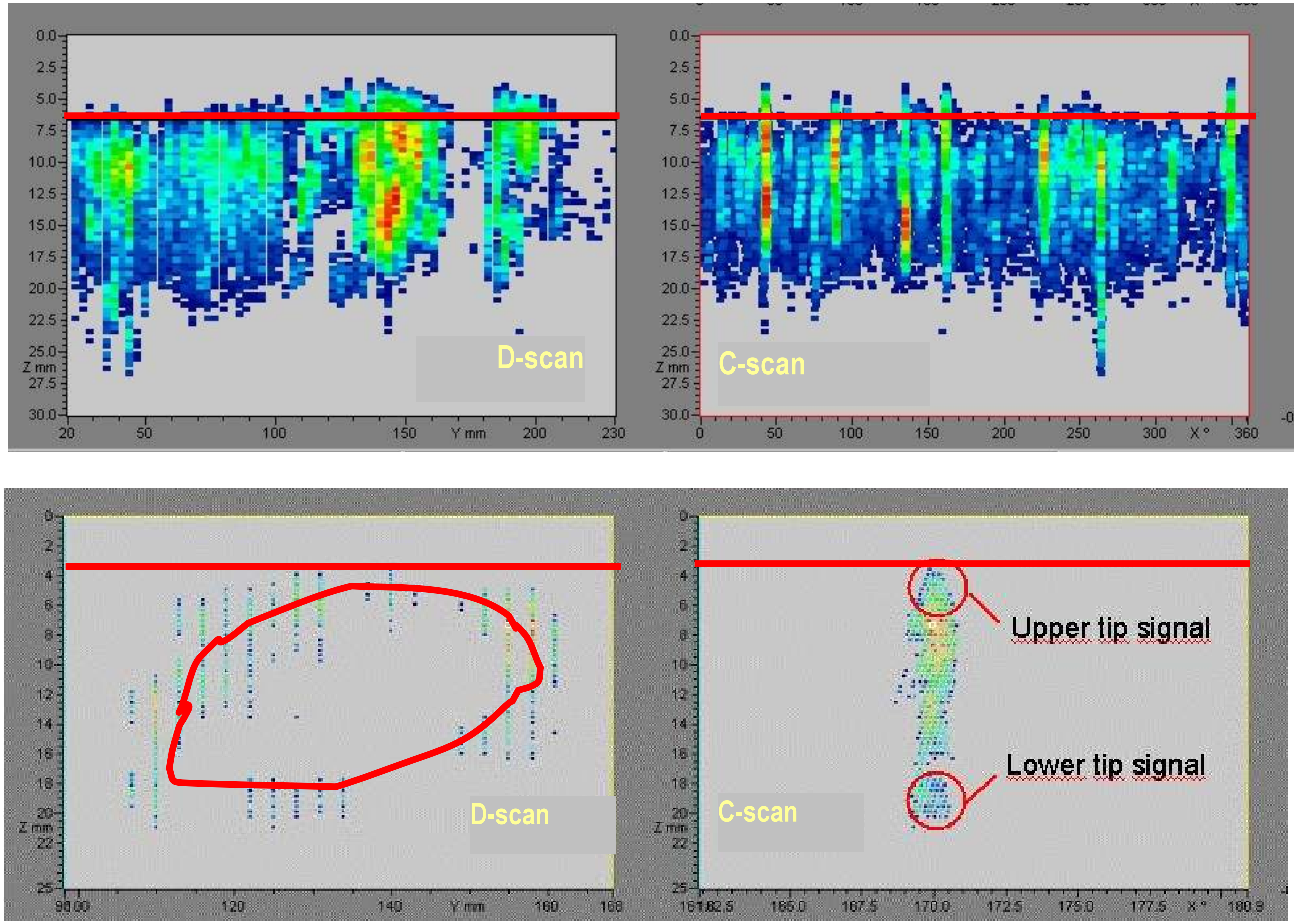
Study of nozzle to vessel weld insonification. Simulation with *Ray Tracing*

Example 4. Technical Justification



Flow chart of data analysis for defect detection

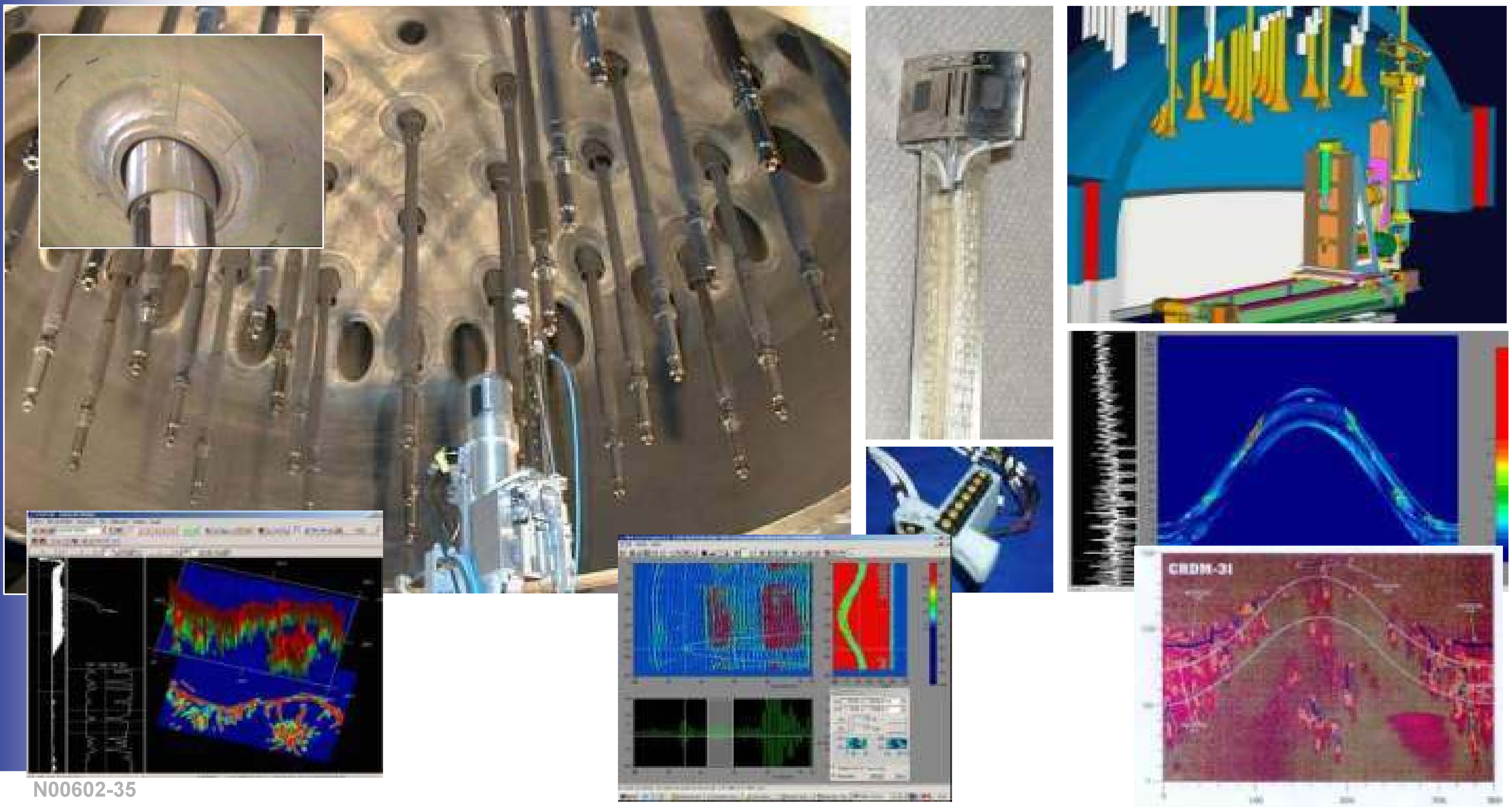
Example 4. Technical Justification



Under cladding crack B-scan and C-scan. Raw data (above) and processed data (below)

ISI and Qualification of critical components

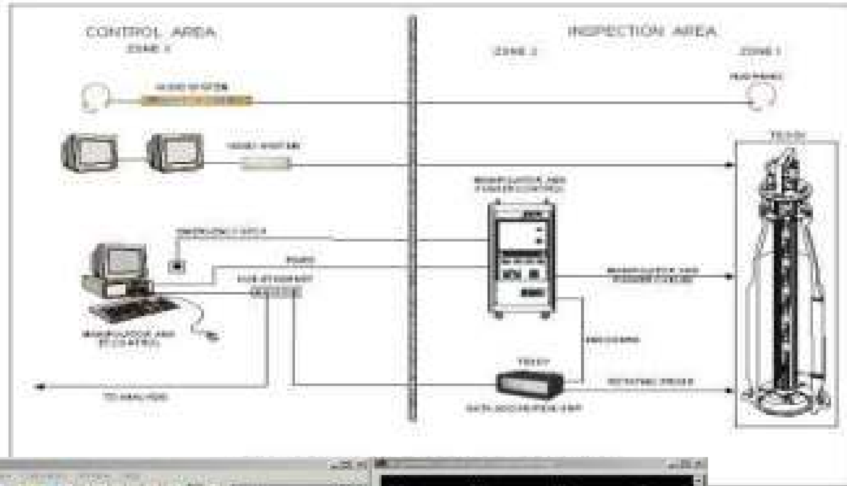
Example: PWR/VVER vessel head inspection tools (eddy current and ultrasonic tests): STAR SYSTEM FAMILY

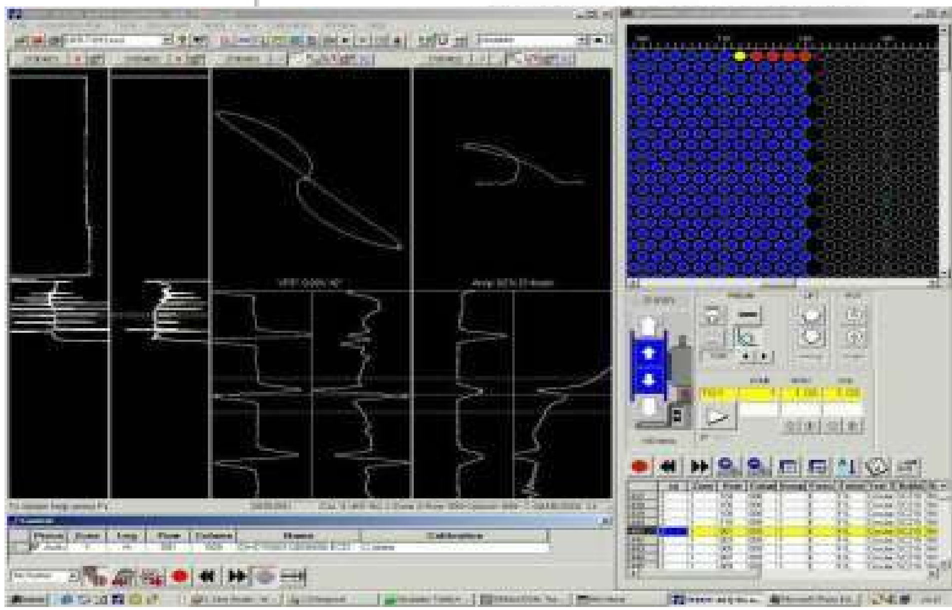


ISI and Qualification of critical components

Example: VVER Steam Generator EC inspection tools (TESGI & TEDDY)

WWER
440/1000





Conclusions (1/2)

- In-service inspection is an important element to determine the integrity of structural materials and a valuable input to Life Management Programmes.
- The necessity of achieving high levels of reliability in ISI has motivated the development of methodologies for inspection qualification.
- Qualification allows:
  - *Systematic approach* to evaluate the increase of reliability.
  - *Optimise* inspection system.
  - *Reduce* number of experimental trials.
  - *Optimise* the training of personnel.

Conclusions (2/2)

- There are several valid approaches and methodologies to qualify inspection systems.
- Spanish NPP utilities have developed their own qualification methodology, based on European Methodology for Qualification of Inspection Systems (ENIQ).
- This Qualification methodology and Tecnatom experience on inspection qualification under different schemes can be of interest to other countries/ organisations facing similar problematic.

Thank you for your attention !