THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

EEMUA Industry Information Sheet: 1 June 2014

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Technical selection of NDE techniques when evaluating the mechanical integrity of industrial plant

Contents

ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

About EEMUA

The Engineering Equipment and Materials Users Association is usually known by its initials, EEMUA. EEMUA is an Association established by the owners and operators of industrial assets. Any organisation that is a substantial user or substantial purchaser of engineering products is eligible to apply to become a member of EEMUA. Membership is subject to the approval of Council.

EEMUA Aims

EEMUA aims to improve the safety, environmental and operating performance of industrial facilities in the most cost-effective way, pursuing and promoting leadership in industrial asset management by sharing engineering experiences and expertise, and by the active, enlightened promotion of the distinct interests of users of engineering products. These aims are achieved by various means, including:

- Providing the organisation within which networking, information sharing and collaboration among users on non-competitive technical matters can take place
- Influencing the way written regulations are interpreted and applied in practice
- Promoting and presenting members' views, and encouraging the application of good sound engineering practices
- Developing user guides, specifications, training and competency schemes
- Facilitating members' participation in national and international standards making
- Influencing relevant national and European legislation and regulation.

The income and resources of EEMUA are applied solely towards the promotion of the aims of the Association. No profit is transferred by way of dividend, bonus or otherwise to members. The work of the Association is mainly carried out by members' representatives on EEMUA Technical Committees, Working Groups, and Forums, supported by EEMUA staff.

Incorporation, Membership and Other Information

For the purposes of conducting its business, EEMUA is incorporated in England and Wales as a company, limited by guarantee, not having share capital. All usual aspects of company management and business administration are dealt with through the EEMUA Chief Executive, including policy implementation and leadership of the Executive team (the staff).

A list of EEMUA publications for sale is given at the end of this Information Sheet. The full list is also on the Association's website, including details of on-line shopping facilities.

To enquire about corporate Membership, write to enquiries@eemua.org or call +44 (0)20 7488 0801.

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Summary

A key item for hazardous industries to understand is that while non-destructive examination (NDE) is a useful tool in the evaluation of continuing Fitness For Service (FFS), it must be used appropriately. This requires an understanding of the limitations of the techniques used, especially when dealing with geometries, environments, materials and access conditions which differ from previously validated applications.

This Information Sheet provides information that may be considered helpful in evaluating the selection of NDE techniques for specific applications to assess the FFS of industrial assets and lists some relevant (non-exhaustive) source material which may provide further information in this area.

Abbreviations

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	Formerly "American Society for Testing and Materials", now "ASTM International"
BE	British Energy Structural Integrity Assessment (and successors)
BINDT	British Institute of NDT
BS	British Standard
CA	The Competent Authority responsible for CoMAH sites
CoMAH	The Control of Major Accident Hazards, the UK implementation of the European "Seveso" directive (96/82/EC as amended)
DNV	Det Norske Veritas
EEMUA	The Engineering Equipment and Materials Users' Association
ENIQ	European Network for Inspection Qualification
FFS	Fitness For Service
HOIS	Originally "Harwell Offshore Inspections Services", now HOIS2000 JIP
HSE	Health and Safety Executive (British regulatory body)
ISO	International Organization for Standardization
NBIB	US National Board of Boiler and Pressure Vessel Inspectors
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Testing
PoD	Probability of Detection
PoR	Probability of Rejection
RBI	Risk Based Inspection
RR	Research Report (HSE nomenclature)

Introduction

1.1 Why is this document needed?

When using NDE techniques for the evaluation of fitness for service, confidence in the suitability of the methods for the task they are required to perform is essential. Assessing suitability requires sufficient competence, and a knowledge of available literature. EEMUA members have requested a source for identifying available publications that could be of use. Also the British regulator, the Health and Safety Executive (HSE), has reported instances where NDE techniques have been used in the evaluation of continuing fitness for service (FFS) of equipment without an adequate demonstration of their relevant applicability and limitations
In particular there have been cases where the limitations of applying techniques to new situations, in non-ideal conditions and using new operators, and the importance of accuracy, validation and specialist training, have not been properly understood. Using the data from these cases for assessment of FFS may, in potentially high consequence applications, represent a significant risk.

In many cases there is guidance available, but there may be an issue with knowing it is available. The appropriate selection and application of NDT can be a complex technical activity: depending upon the risks involved it may require specialist knowledge.

1.2 What are we trying to achieve?

This Information Sheet provides one possible approach to help select appropriate NDE techniques and to establish the need for further qualification along with supporting references that EEMUA members have found useful in the evaluation of continuing FFS of pressure systems. The references included may also be suitable for more general assessment of the condition of industrial plant.

References include UK, European, US and international standards, recommended practices, and guidance documents. There may be references that are contradictory and this document does not indicate any preference for one particular approach over another.

Note that this document does not consider items such as local health and safety considerations, site access and induction issues, or other operational concerns - it assumes that appropriate procedures are in place. Economic and operational availability considerations are also excluded – in some cases, a decision to replace, rather than undertake an FFS evaluation, may be more expedient.

Areas of reference

1.3 Key principles

There are a number of simple steps that can help determine whether an NDE technique is valid for use in a specific FFS evaluation.

In applying these steps, it is assumed that the types of in-service flaws expected, their most likely location and distribution, and the accept/reject criteria for the inspection have been identified. This may be through a risk based assessment process that develops an inspection plan based on a consideration of the 'risk' associated with the flaws (RBI) or more conventional time-based 'deterministic' inspection intervals.

However the inspection plan is derived, the key principle is to assess whether a specific NDE technique (or combination of different techniques) is capable of achieving the required inspection coverage with sufficient likelihood of detecting unacceptable flaws. This can be done by developing a technical justification for its use.

The step-by-step approach is given in **Figure 1** on page 5.

1.4 Specific inspection application

In developing the technical justification, it should be recognised that the proposed NDE technique is being used for a specific inspection application. The following application-specific factors may be considered relevant:

- The environment in which the technique is to be applied, e.g. temperature/humidity/weather conditions affecting both equipment and operator;
- Whether the area to be inspected has restricted access or complex geometry e.g. that limits the technique's application or the operator's ability to view or manipulate equipment;
- Variation of materials from those for which the technique is typically used or previously qualified;
- Whether the surface conditions limit the application e.g. hot surfaces, badly corroded surfaces.

1.5 Technical justification

The technical justification is considered the main step in validating the selection of an NDE technique for a specific inspection application.

The technical justification is the consideration of all available information that, in the view of the duty holder, is sufficient to give an appropriate level of confidence that the coverage, sensitivity and accuracy can be achieved under the conditions in which the work will be carried out, by the staff who will perform it. This evidence could include a combination of factors, such as:

- The technique is accepted industry practice for this specific application
- There are appropriate standards and/or guidelines for the application of the technique
- There is previous successful experience of the technique in the specific application, either in-house or from external industry experience
- There are results available from relevant qualification trials, either in-house or from external industry experience
- There are results from relevant computer modelling

The depth of information required in a technical justification should be determined by the criticality of the inspection, the novelty of the technique in the specific application and the experience and competency of the NDE operators.

If, after assessing all available factors, it is determined that a selected technique cannot be justified for use in the specific application, it may then be appropriate to undertake additional qualification trials in order to validate its use.

1.6 Validation

Validation of an NDE technique for a specific application is considered the 'end product' of the technical justification.

Validation does not necessarily mean that additional qualification trials of the technique are required if the technical justification can demonstrate it is capable of meeting the requirements for the specific application.

1.7 NDE qualification

If additional qualification is required to validate an NDE technique, this may include a combination of steps such as:

- Relevant computer modelling
- Practical trials using test pieces to represent the specific application elements such as geometry, environment and restricted access
- 'Blind' trials to assess the competency of the intended operators

Several references, such as those provided by ENIQ and DNV, provide information on conducting additional qualification trials.

1.8 Competence and human factors

Duty holders should have a means of verifying operator competence for the particular technique used in the specific application. There should be clear instructions regarding how the technique is to be applied, the type of flaw they are trying to detect and where it is expected to be located, whether they are to report all findings or only 'relevant indications' and whether they

are responsible for interpretation as well as reporting. There should also be a clear route for them to raise concerns regarding access, equipment, data or other operational aspects.

1.9 Evaluation

As well as the results themselves being interpreted, there should be a review of the evaluation process itself, examining how successful it was, and whether it could be improved. The results of this review can then form part of future technical justifications.

1.10 Interpretation

Interpretation of the results from the NDE as an input into the FFS assessment should only be undertaken by someone competent to do so. Use of NDE data will require a degree of knowledge and understanding of the limitations of NDE when used in the FFS assessment including taking account of factors such as sensitivity, accuracy, probability of detection/rejection (PoD/PoR), sizing errors, coverage, and variability of results. For more critical applications, more careful interpretation is appropriate.

EEMUA Guidance

EEMUA has several publications which are relevant. These are listed below and in the Reference section.

EEMUA 193, Recommendations for the Training, Development and Competency Assessment of Inspection Personnel

EEMUA 206, Risk Based Inspection: A Guide to Effective Use of the RBI Process

EEMUA 231, The Mechanical Integrity of Plant Containing Hazardous Substances – A Guide to Periodic Examination and Testing

As well as this, EEMUA Technical Committees provide an opportunity to share good practice between technical experts.

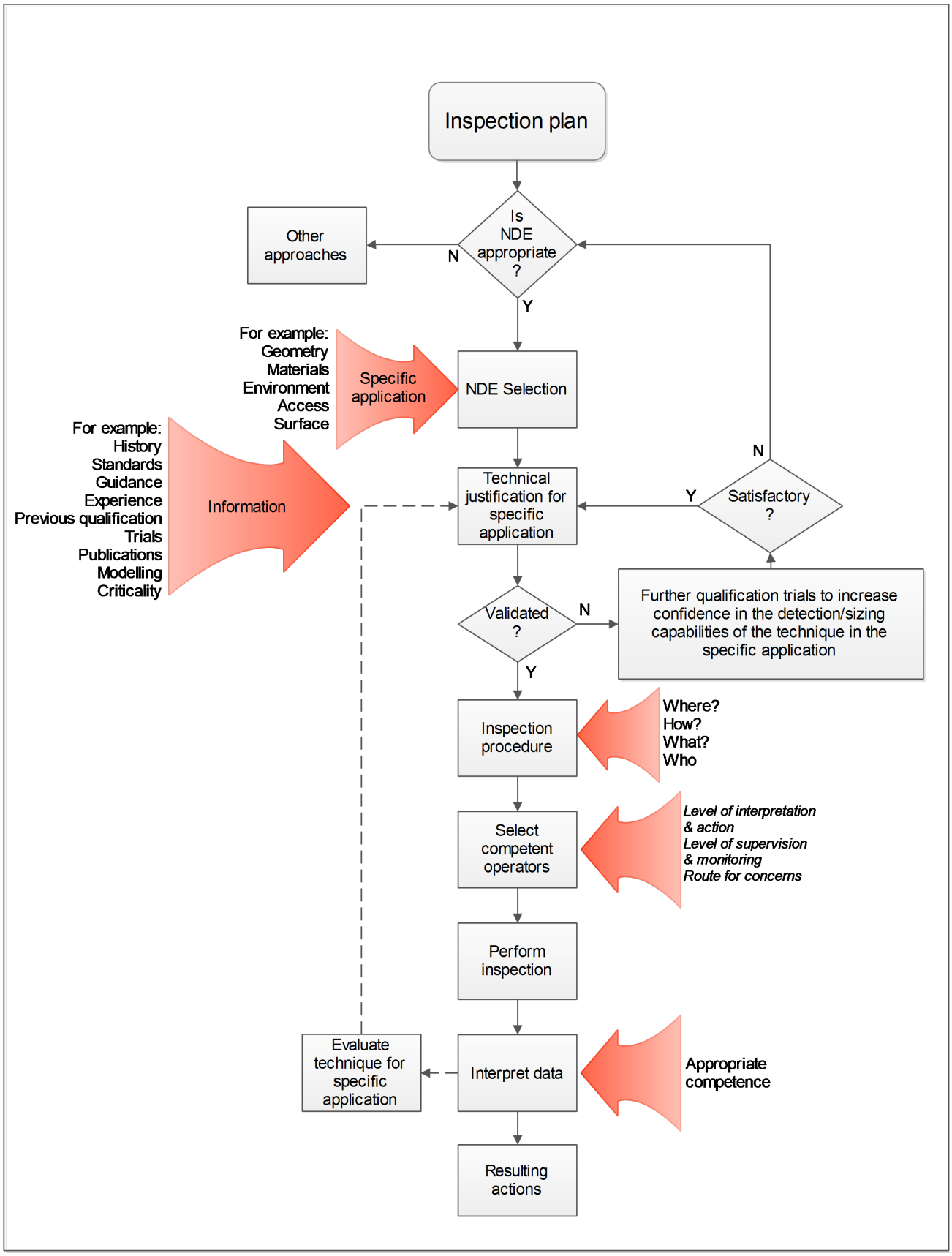

Figure 1 – Selecting, assessing and using NDE techniques for evaluating integrity

References

A list of references which EEMUA members have found useful is given below. It is not intended to be exhaustive, and cannot substitute for the appropriate competence.

1.11 Inspection requirements/planning

American Petroleum Institute (API)

API 510 Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration, Tenth Edition, 2014.
API RP 572 Inspection of Pressure Vessels, Third Edition, 2009.
API 570 Piping Inspection Code: In-service Inspection, Repair, and Alteration of Piping Systems, Third Edition, 2009.
API RP 574 Inspection Practices for Piping System Components, Third Edition, 2009.
API RP 573 Inspection of Fired Boilers and Heaters, Third Edition, 2013.
API 653 Tank Inspection, Repair, Alteration, and Reconstruction, Fourth Edition, 2009 with Addendum 1 (2010), Addendum 2 (2012), Addendum (2013).
API RP 575 Inspection of Existing Atmospheric and Low-pressure Storage Tanks, Third Edition, 2014.
API RP 580 Risk-Based Inspection, Second Edition, 2009.
API RP 581 Risk-Based Inspection Technology, Second Edition, 2008.
API STD 598 Valve Inspection and Testing, Ninth Edition, 2009.

Det Norske Veritas (DNV)

DNV-RP-C302: 2012, Recommended Practice for Risk Based Corrosion Management.
DNV-RP-G101: 2010, Recommended Practice for Risk Based Inspection of Offshore Topsides Static Mechanical Equipment.
DNV-RP-G103: 2011, Recommended Practice for Non-intrusive Inspection.

Engineering Equipment and Materials Users' Association (EEMUA)

EEMUA 159 Users' Guide to the Inspection, Maintenance and Repair of Above Ground Vertical Cylindrical Steel Storage Tanks. ISBN 0 85931 131 7.
EEMUA 206 Risk Based Inspection: A Guide to Effective Use of the RBI Process. ISBN 0 85931 150 3.
EEMUA 231 The Mechanical Integrity of Plant Containing Hazardous Substances – A Guide to Periodic Examination and Testing. ISBN 0 85931 193 9.

British Health and Safety Executive (HSE)

HSE RR16 - Guidelines for use of statistics for analysis of sample inspection of corrosion, 2002. ISBN 0 7176 2554 0.
HSE RR304 - Safety implications of European risk based inspection and maintenance methodology, 2005.
HSE CRR363 - Best practice for risk based inspection as a part of plant integrity management, 2001. ISBN 0 7176 6136 9.
HSE RR509 - Plant ageing: Management of equipment containing hazardous fluids or pressure, 2006.
HSE RR729 - Establishing the requirements for internal examination of high hazard process plant, 2009.
Managing Ageing Plant - A Summary Guide. HSE COMAH Guidance.

Standards Australia

AS/NZS 3788: 2006, Pressure equipment - In-service inspection.

European Network for Inspection Qualification (ENIQ)

ENIQ RP9 - Recommended Practice 9: Verification and validation of structural reliability models and associated software to be used in risk-informed in-service inspection programmes, Issue 1, 2007, ENIQ Report nr. 30 EUR 22228EN.

1.12 NDE Technique selection

American Society of Mechanical Engineers (ASME)

ASME Boiler and Pressure Vessel Code Section V Nondestructive Examination.

American Society for Testing and Materials (ASTM)

ASTM E797 Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method.
ASTM E1067 / E1067M - 11 - Standard Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels.
ASTM E1816 – 12 - Standard Practice for Ultrasonic Testing Using Electromagnetic Acoustic Transducer (EMAT) Techniques.
ASTM E1961 – 11 - Standard Practice for Mechanized Ultrasonic Testing of Girth Welds Using Zonal Discrimination with Focused Search Units.
ASTM E1962 – 09 - Standard Practice for Ultrasonic Surface Testing Using Electromagnetic Acoustic Transducer (EMAT) Techniques.

British Standards (BS)

BS EN ISO 3452-1: 2013, Non-destructive testing. Penetrant testing. General principles.
BS EN 17638: 2009, Non-destructive testing of welds. Magnetic particle testing.
BS EN ISO 17636-1/2:2013, Non-destructive testing of welds. Radiographic testing. X- and gamma-ray techniques. Part 1 film, Part 2 digital.
BS EN ISO 17640: 2010, Techniques, testing levels and assessment for non-destructive and ultrasonic testing of welds.
BS EN ISO 10863: 2011, Non-destructive testing of welds. Ultrasonic testing. Use of Time-Of-Flight Diffraction technique (TOFD).
BS EN ISO 15549: 2010, Non-destructive testing. Eddy current testing. General principles.
BS EN ISO 16407-1: 2014 Non-destructive testing - Radiographic inspection of corrosion and deposits in pipes by X- and gamma rays Part 1 : Tangential radiographic inspection.
BS EN ISO 16407-2: 2014 Non-destructive testing - Radiographic inspection of corrosion and deposits in pipes by X- and gamma rays Part 2 : Double Wall radiographic inspection.

Standards Australia

AS 2452.1: 2004, Non-destructive testing - Determination of thickness. Part 1: Determination of wall thickness.
AS 2452.3: 2005, Non Destructive Testing - Determination of Thickness - Use of Ultrasonic Testing

British Health and Safety Executive (HSE)

HSE RR294 - Recommended practice for the rapid inspection of small bore connectors using radiography 2005.
HSE RR299 - Evaluation of CEN ultrasonic testing standards for in-service inspection 2005.
HSE RR301 - Replacement of Radiography 2005.
HSE RR454 - Probability of Detection (PoD) curves Derivation, applications and limitations 2006.

HSE RR481 - Recommended practice for magnetic flux leakage inspection of atmospheric storage tank floors 2006.
HSE RR617 – Programme for the assessment on NDT in industry, **PANI 3** 2008.
HSE RR 659 - Evaluation of the effectiveness of non-destructive testing screening methods for in-service inspection 2009.
HSE RR729 - Establishing the requirements for internal examination of high hazard process plant 2009.
Information for the procurement and conduct of NDT
Part 1: Manual ultrasonic inspection, 2000.
Part 2: Magnetic particle and dye penetrant inspection, 2002.
Part 3: Radiographic inspection in industry, 2008.
Part 4: Ultrasonic sizing errors and their implication for defect assessment, 2008.

Harwell Offshore Inspection Service (HOIS)

HOIS Recommended Practice for In-Service Computed Radiography of Pipes, 2013.
HOIS Recommended Practice on Weld Corrosion Inspection, 2012.
HOIS Recommended Practice for ISI of Offshore Composite Components, 2012.

1.13 Technical Justification

European Network for Inspection Qualification (ENIQ)

European methodology for qualification of non-destructive testing, Issue 3, 2007, ENIQ Report nr. 31.
ENIQ RP2 - Recommended Practice 2: Recommended contents for a technical justification, Issue 2, 2010, ENIQ Report nr. 4 EUR 24111EN.
ENIQ RP3 - Recommended Practice 3: Strategy document for technical justification, Issue 1, 1998, ENIQ Report nr. 5 EUR 18100EN *(withdrawn, and incorporated in Issue 2 of RP2)*

1.14 NDE Technique Qualification

European Network for Inspection Qualification (ENIQ)

ENIQ Glossary, Issue 2, 1999, ENIQ Report nr. 12 EUR 18102EN.
European methodology for qualification of non-destructive tests, Issue 2, 1997, EUR 17299EN.
A synopsis of the ENIQ 2nd pilot study, 2006, ENIQ Report nr. 27
European methodology for qualification of non-destructive testing, Issue 3, 2007, ENIQ Report nr. 31.
ENIQ RP1 - Recommended Practice 1: Influential / Essential parameters, Issue 2, 2005, ENIQ Report nr. 24 EUR 21751EN.
ENIQ RP4 - Recommended Practice 4: Recommended contents for the qualification dossier, Issue 1, 1999, ENIQ Report nr. 13 EUR 18685EN.
ENIQ RP5 - Recommended Practice 5: Guidelines for the design of test pieces and conduct of test piece trials, Issue 1, 1999, ENIQ Report nr. 14 EUR 18686EN.
ENIQ RP6 - Recommended Practice 6: The use of modelling in inspection qualification, Issue 1, 1999, ENIQ Report nr. 15 EUR 19017EN.
ENIQ RP7 - Recommended Practice 7: Recommended general requirements for a body operating qualification of non-destructive tests, Issue 1, 2002, ENIQ Report nr. 22 EUR 20395EN.
ENIQ RP8 - ENIQ Recommended Practice 8: Qualification Levels and Approaches, Issue 1, 2005, ENIQ Report nr. 25 EUR 21761EN .
ENIQ RP10 - ENIQ Recommended Practice 10: Personnel qualification, 2010, Issue 1, 2010, ENIQ Report 38 EUR 24112EN.
ENIQ RP11 - Recommended Practice 11: Guidance on expert panels in RI-ISI (risk informed in-service inspection), Issue 1, 2008 ENIQ Report 34 EUR 22234EN.

Det Norske Veritas (DNV)

DNV-OS-F101: 2013, Submarine Pipeline Systems.
DNV-RP-F118: 2010, Pipe Girth Weld AUT System Qualification and Project Specific Procedure Validation.

1.15 Personnel Competency

British Institute of Non Destructive Testing (BINDT)

PCN/GEN/2000, General requirements for qualification and certification of personnel engaged in Non-destructive testing.

Engineering Equipment and Materials Users' Association (EEMUA)

EEMUA 193 Recommendations for the Training, Development and Competency Assessment of Inspection Personnel. ISBN 0 85931 190 8.

International Organization for Standardization (ISO)

ISO 9712: 2012, Non-destructive testing - Qualification and certification of NDT personnel.
ISO 17020: 2012, Requirements for the operation of various types of bodies performing inspection.

1.16 Fitness-for-Service Assessment

American Petroleum Institute (API)

API 579-1: 2007, Recommended Practice for Fitness for Service (ASME FFS-1).

British Energy (and successors)

R5: Assessment of the integrity of structures operating at high temperature, Issue 3, 2003
R6: Assessment of the integrity of structures containing defects. Rev. 4, amendment 5, 2007

British Standards (BS)

BS 7910: 2013, Guide to methods for assessing the acceptability of flaws in metallic structures.

Standards Australia

AS/NZS 3788: 2006, Pressure Equipment - In-Service Inspection.

Other sources of guidance

British Institute of Non Destructive Testing (BINDT)
http://www.bindt.org/
Harwell Offshore Inspection Service (HOIS)
http://www.hoispublications.com/
Materials Technology Institute, USA
http://www.mti-global.org/

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Asset and integrity management

231 The Mechanical integrity of plant containing hazardous substances - A guide to periodic examination and testing

206 Risk Based Inspection - A guide to effective use of the RBI process

193 Recommendations for the training, development and competency assessment of inspection personnel

181 A guide to risk based assessments of in-situ large Ex 'e' and Ex 'N' machines

161 Guide to the selection and assessment of silencers and acoustic enclosures

159 Users' guide to the inspection, maintenance and repair of above-ground vertical cylindrical steel storage tanks

148 Reliability specification - Model clauses for inclusion in purchasing specifications for equipment items and packages

Automation and electrical equipment

226 Design and installation of on-line analyser systems - a guide to technical enquiry and bid evaluation

222 Guide to the application of IEC 61511 to Safety Instrumented Systems in the UK process industries

214 Toolbox guide - Electrical installation, inspection and maintenance in potentially explosive atmospheres

201 Process plant control desks utilising Human-Computer Interfaces - A guide to design, operational and human interface issues

191 Alarm systems - A guide to design, management and procurement

189 A guide to fieldbus application for the process industry

187 Analyser systems - A guide to maintenance management

186 A practitioner's Handbook - Electrical installation, inspection and maintenance in potentially explosive atmospheres

178 A design guide for the electrical safety of instruments, instrument / control Panels and control systems

175 Code of practice for calibration and checking process analysers

155 Standard test method for comparative performance of flammable gas detectors against poisoning

138 Design and installation of On-Line Analyser systems

Materials selection, plant design and construction

224 A guide to risk-based procurement - Quality assurance of safety-critical engineering equipment and materials

218 Quality requirements for the manufacture/supply of duplex stainless steels

197 Specification for the fabrication of non-primary structural steelwork for offshore installations

194 Guidelines for materials selection and corrosion control for subsea oil and gas production equipment

185 Guide for hot tapping on piping and other equipment

182 Specification for integral block and bleed valve manifolds for direct connection to pipework

179 A working guide for carbon steel equipment in wet H_2S service

176 Specification for structural castings for use offshore

158 Construction specification for fixed offshore structures in the North Sea

154 Guidance to owners on demolition of vertical cylindrical steel storage tanks and storage spheres

149 Code of practice for the identification and checking of materials of construction in pressure systems in process plants

147 Recommendations for the design and construction of refrigerated liquefied gas storage tanks

146 90/10 Copper nickel alloy piping for offshore applications - Specification: Fittings

145 90/10 Copper nickel alloy piping for offshore applications - Specification: Flanges Composite and Solid

144 90/10 Copper nickel alloy piping for offshore applications - Specification: Tubes seamless and welded

143 Recommendations for tube end welding - Tubular heat transfer equipment, Part 1 - Ferrous materials

141 Guide to the use of noise procedure specification

140 Noise procedure specification

133 Specification for underground armoured cable protected against solvent penetration and corrosive attack

105 Factory stairways, ladders and handrails (incl: Access platforms/ramps)

104 Noise: A guide to information required from equipment vendors

101 Lifting points - A design guide

Pressure equipment

223 Pressure equipment testing after repair, modifications or re-rating: a guide to the pressure test waiver

211 Guidance on the specification of pressure vessels

208 Guide to life-cycle management of pressure relief systems

204 Piping and the European Pressure Equipment Directive - Guidance for plant owners/operators

196 Valve purchasers' guide to the European Pressure Equipment Directive

184 Guide to the isolation of pressure relieving devices

177 Guide to the UK Pressure Systems Safety Regulations (2000)

168 A Guide to the pressure testing of in-service pressurised equipment

149 Code of Practice for the identification and checking of materials of Construction in pressure systems in process plants

Process pipework, valves and machinery

230 Ageing rotating equipment - Guide for maintenance and operation

215 Industrial cooling tower fans and fin fans – Guide for design, maintenance and operation

205 Guide to the production testing of valves for the energy, process, oil and gas industries

204 Piping and the European Pressure Equipment Directive - Guidance for plant owners/operators

200 Guide to the specification, installation and maintenance of spring supports for piping

199 On-line leak sealing of piping - Guide to safety considerations

196 Valve purchasers' guide to the European Pressure Equipment Directive

192 Guide for the Procurement of Valves for Low Temperature (non-cryogenic) Service

188 Guide for establishing operating periods of safety valves

185 Guide for hot tapping on piping and other equipment

182 Specification for integral block and bleed valve manifolds for direct connection to pipework

164 Seal-less centrifugal pumps: Class 1

151 Liquid ring vacuum pumps and compressors

Storage and containment systems

217 Safe and effective operation of storage tanks for oil movements

213 Emission reduction from oil storage tanks and loading operations

207 Double concrete tanks for liquefied gas - Guidelines on design, construction and operation

190 Guide for the design, construction and use of mounded horizontal cylindrical bulk storage vessels for pressurised LPG at ambient temperatures

183 Guide for the prevention of bottom leakage from vertical cylindrical steel storage tanks

180 Frangible roof joints for fixed roof storage tanks - Guide for designers and users

159 Users' guide to the inspection, maintenance and repair of above-ground vertical cylindrical steel storage tanks

154 Guidance to owners on demolition of vertical cylindrical steel storage tanks and storage spheres

147 Recommendations for the design and construction of refrigerated liquefied gas storage tanks