TECHNICAL SPECIFICATION

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Non-destructive testing — NDT training syllabuses

Essais non destructifs — Programmes de formation en END

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 7, *Personnel qualification*.

This first edition cancels and replaces ISO/TR 25107:2006.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The body of technical knowledge required of non-destructive testing (NDT) personnel is essential for the development of deliverables concerning NDT methods. No deliverables can be developed appropriately for NDT methods, without sufficient information on the technical background knowledge of the personnel who utilize the methods.

Role of NDT

Non-destructive testing makes an important contribution to the safety, economic and ecological welfare of our society.

NDT is the only choice for the testing of an object which cannot be destroyed, modified or degraded by the testing process. This is generally required for objects which are to be used after testing, for example, safety parts, pipelines, power plants, and also constructions under in-service inspection, but even for unique parts in archaeology and culture.

NDT is based on physical effects at the surface or the inner structure of the object under test. Often, the outcome of the test needs to be interpreted to give a useful result; sometimes different NDT methods are combined or verified by other test methods.

NDT personnel and professional ethics

NDT personnel have a great responsibility, not only with respect to their employers or contractors but also under the rules of good workmanship. The NDT personnel is independent and free from economic influences with regard to his/her test results, otherwise the results are compromised. The NDT personnel is aware of the importance of his/her signature and the consequences of incorrect test results for safety, health and environment.

Finally, the NDT personnel is responsible for all interpretations of test results carrying his/her signature and he/she never signs test reports beyond his/her certification.

Annex B provides standards numbers that can be of interest for the application of the provisions laid out in this document.

Non-destructive testing — NDT training syllabuses

1 Scope

This document gives requirements and recommendations for non-destructive testing (NDT) training syllabuses, with the intention of harmonizing and maintaining the general standard of training of NDT personnel for industrial needs.

It also establishes the minimum requirements for effective structured training of NDT personnel to ensure eligibility for qualification examinations leading to third-party certification according to recognized standards. In addition to non-destructive testing in general, its guidelines for syllabuses cover acoustic emission testing, eddy current testing, leak testing, magnetic testing, penetrant testing, radiographic testing, ultrasonic testing, visual testing, thermographic testing, and strain gauge testing.

ISO/TS 25108 gives requirements and recommendations for NDT training organizations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
adjustment
set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

Note 1 to entry: Types of adjustment of a measuring system include zero adjustment, offset adjustment, and span adjustment (sometimes called gain adjustment).

4 General

4.1 NDT training

Training syllabuses by themselves cannot guarantee competence of the trainees to provide adequate technical knowledge, since it is quite common that some students achieve excellent results whereas others fail in the same class. ISO 9712 provides the minimum training requirements for candidates who possess adequate skills and prior knowledge. If it is not the case, consideration for additional training should include:

a) level 1, 2 and 3 — mathematics;

b) level 1, 2 and 3 — materials and process;

c) level 3 — general knowledge common course applicable to all NDT methods.

As specified in ISO 9712, direct access to the level 2 examination requires the total training time for level 1, level 2 and direct access to level 3 requires the total training time shown for level 1, level 2 and level 3.

ISO 9712 also provides the opportunity for reductions in training duration for candidates seeking certification in more than one method or who have a certain educational degree in an NDT relevant subject. Thus, the training organizations should use discretion when implementing the syllabuses respective of their training environment taking into consideration product/industrial sectors and development or use of common focused courses which pertain to all NDT methods in developing their training curriculum.

4.2 Levels of competence

A three-level scheme, in accordance with ISO 9712, is used to define levels of competence to indicate the required depth of understanding, knowledge and application of material.

Level 1

— Acquire a general knowledge of topic areas.

— Identify equipment and accessories.

— Identify common reference documents.

— Recognize when material is applicable or why it is relevant.

— Demonstrate understanding by performing instructed inspection tasks.

Level 2

— Attain a sound understanding of concepts and principles.

— Develop a sound conceptual and comprehensive technical knowledge.

— Develop a sound working knowledge of procedures.

— Become familiar with common reference documents.

— Become proficient in the application of knowledge to practice.

— Apply concepts and techniques to inspection situations.

— Analyse information to make preliminary conclusions.

Level 3

— Attain an in-depth understanding of concepts and principles.

— Develop in-depth comprehensive technical knowledge of procedures.

— Be proficient in the application of knowledge to practice.

— Be proficient with the use of reference documents.

— Analyse information to form conclusions.

— Apply concepts and techniques to new inspection situations.

NOTE Where topics/subjects/content are listed across multiples levels in Tables 1 through 21, this indicates a more in-depth knowledge is required at the higher level(s).

4.3 General environmental and safety considerations

4.3.1 Non-destructive testing is often applied in conditions where the safety of the operator can be in danger owing to local conditions, or where the application of the particular NDT method or technique itself can compromise the safety of the operator and others in the vicinity.

An essential element of any training for NDT personnel shall therefore be safety. The duration of the training for this subject should be adequate and be provided in addition to the technical training associated with a particular NDT method.

4.3.2 Additional training in radiation safety shall be required prior to radiographic training.

4.3.3 General safety considerations include, but are not necessarily limited to, the following:

— environmental conditions (heat, cold, humidity);

— toxicity (NDT materials, tested products, atmosphere);

— radiation safety (NDT materials, products);

— electrical safety (NDT equipment, lethal voltages, EMC);

— potential for injury to personnel (working at height or in other dangerous environments);

— personal protection equipment (clothing, radiation dosimeters);

— pressure test safety.

5 Radiographic testing (RT) — Levels 1, 2 and 3

The radiographic testing training shall be in accordance with Tables 1 and 2.

Table 1 — General content

		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
5.1	Introduction to terminology and history of radiographic testing (RT)	3	1	1
5.2	Physical principles of the method and associated knowledge	15	10	15
5.3	Product knowledge and capabilities of the method and its derived techniques	15	15	20
5.4	Equipment	25	20	25
5.5	Information prior to testing	5	8	5
5.6	Testing	30	25	2,5
5.7	Evaluation and reporting	5	10	7,5
5.8	Assessment	0	5	10
5.9	Quality aspects	2	5	8
5.10	Developments	0	1	6

NOTE Annex A provides guidance on the training process for advanced radiographic techniques.

Table 2 — Radiographic testing (RT) — Levels 1, 2 and 3

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
5.1 Introduction to terminology and history of radiographic testing (RT)	History		X	X	X	X	X	X	X	X	X
	Purpose of NDT	What is testing?	X	X	X	X	X	X	X	X	X
		What is the purpose of NDT?	X	X	X	X	X	X	X	X	X
		At what stage of life is NDT performed on a “product”?	X	X	X	X	X	X	X	X	X
		How does it add value?	X	X	X	X	X	X	X	X	X
		Who may carry out NDT?	X	X	X	X	X	X	X	X	X
		Main NDT methods	X	X	X	X	X	X	X	X	X
	Purpose of radiographic testing (RT)	Definition	X	X	X	X	X	X	X	X	X
		Applicability and limitations	X	X	X	X	X	X	X	X	X
	Terminology	Electromagnetic radiation	X	X	X	X	X	X	X	X	X
		Energy	X	X	X	X	X	X	X	X	X
		Dose	X	X	X	X	X	X	X	X	X
		Dose rate	X	X	X	X	X	X	X	X	X
		Wavelength	X	X	X		X	X		X	X
		Intensity	X	X	X	X	X	X	X	X	X
		Dose rate constant	X	X	X		X	X		X	X
		Activity	X	X	X	X	X	X			X
	Relevant standards	See Annex B		X	X		X	X		X	X
5.2 Physical principles of the method and associated knowledge Concepts necessary for understanding the physical principles of radiographic testing (physics, mathematics) may be the object of a preliminary course	General	Structure of the atom	X	X	X	X	X	X	X	X	X
		Electromagnetic spectrum	X	X	X	X	X	X	X	X	X
		Sources of radiation and its properties:									
		— X-rays	X	X	X	X	X	X	X	X	X
		— Gamma rays	X	X	X	X	X	X	X	X	X
		— Neutrons			X			X			X
		X-ray and gamma ray spectrum	X	X	X	X	X	X	X	X	X
		Essential radiographic parameters:									
		— Voltage	X	X	X	X	X	X	X	X	X
		— Current	X	X	X	X	X	X	X	X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		— Activity	X	X	X	X	X	X	X	X	X
		Radiation filters		X	X		X	X		X	X
		Focal spot	X	X	X	X	X	X	X	X	X
		Dose	X	X	X	X	X	X	X	X	X
		Dose rate	X	X	X	X	X	X	X	X	X
		Dose rate constant	X	X	X		X	X		X	X
	Attenuation of radiation	General mechanism of interaction:									
		— Photoelectric effect	X	X	X	X	X	X	X	X	X
		— Compton effect	X	X	X	X	X	X	X	X	X
		— Pair production	X	X	X		X	X		X	X
		HVL, TVL and attenuation law	X	X	X	X	X	X	X	X	X
		Hardening of radiation,	X	X	X	X	X	X	X	X	X
		Scattered radiation and build up factor	X	X	X	X	X	X	X	X	X
		Filtering and collimation	X	X	X	X	X	X	X	X	X
		X-ray fluorescence	X	X	X	X		X		X	X
		Attenuation of neutrons and electrons			X			X			X
	Radiation contrast, noise	Contrast, noise, granularity	X	X	X	X	X	X	X	X	X
		Specific contrast		X	X		X	X		X	X
		Scatter influence	X	X	X	X	X	X	X	X	X
		Signal-to-noise ratio (SNR)				X	X	X	X	X	X
		Contrast-to-noise ratio					X	X		X	X
		Unsharpness	X	X	X	X	X	X	X	X	X
		Basic spatial resolution				X	X	X	X	X	X
		Pixel size				X	X	X	X	X	X
		Normalized SNR (SNR_N)				X	X	X		X	X
	Optimization of image quality	Compensation principles:									
		— Contrast vs SNR					X	X		X	X
		— Basic spatial resolution vs SNR					X	X		X	X
		— Local unsharpness vs SNR					X	X		X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		Scatter protection	X	X	X	X	X	X	X	X	X
		Maximum/optimum X-ray voltage		X	X		X	X		X	X
	Geometrical projection conditions	Geometrical and inherent unsharpness	X	X	X	X	X	X	X	X	X
		Geometrical magnification		X	X		X	X	X	X	X
		Effect of magnification		X	X	X	X	X	X	X	X
		Optimum magnification			X		X	X		X	X
		Difference between radiography and radioscopy		X	X		X	X		X	X
		Law of the squared distance	X	X	X	X	X	X	X	X	X
	Image quality indicators	Wire type	X	X	X	X	X	X	X	X	X
		Step hole type	X	X	X	X	X	X	X	X	X
		Plate hole type	X	X	X	X	X	X	X	X	X
		Duplex wire type	X	X	X	X	X	X	X	X	X
		Measurement of basic spatial resolution		X	X		X	X		X	X
		Converging line pairs			X		X	X		X	X
		Line pair gauges (MTF)			X			X			X
5.3 Product knowledge and capabilities of the method and its derived techniques	General defects	Processes overview:									
		— Casting		X	X		X	X		X	X
		— Forging		X	X		X	X			X
		— Welding		X	X		X	X		X	X
		— Tubes and pipes		X	X		X	X			X
		— Wrought products		X	X		X	X			X
		— Composite material		X	X		X	X		X	X
		Types of discontinuities	X	X	X	X	X	X	X	X	X
		Fracture mechanics			X			X			X
		Working load			X			X			X
		Material properties		X	X		X	X		X	X
		Origin of defects		X	X		X	X		X	X
		Evaluation		X	X		X	X		X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
	Influence on detectability	Type of defect	X	X	X	X	X	X	X	X	X
		Size	X	X	X	X	X	X	X	X	X
		Orientation	X	X	X	X	X	X	X	X	X
		Number of exposures		X	X		X	X		X	X
		Beam direction	X	X	X	X	X	X	X	X	X
		Geometric distortion								X	X
		Increase in wall thickness		X	X		X	X		X	X
		Thickness ranges for X- and gamma rays		X	X		X	X		X	X
		Number of exposures vs distortion angle (tubes and pipes)		X	X		X	X		X	X
5.4 Equipment	Radiation sources — X-ray sources	Standard sources:									
		— Types of sources	X	X	X	X	X	X	X	X	X
		— Stationary vs mobile	X	X	X	X	X	X			
		— Construction and function of X-ray tubes	X	X	X	X	X	X	X	X	X
		— Unipolar vs bipolar		X	X		X	X		X	X
		Special sources		X	X		X	X		X	X
		Generation of high voltage		X	X		X	X		X	X
		Cooling	X	X	X	X	X	X	X	X	X
		Handling	X	X	X	X	X	X	X	X	X
		Parameters:									
		— kV	X	X	X	X	X	X	X	X	X
		— mA	X	X	X	X	X	X	X	X	X
		— Spot size	X	X	X	X	X	X	X	X	X
		Measurement of parameters		X	X		X	X		X	X
	Radiation sources — Gamma sources	Container:									
		— Shielding	X	X	X	X	X	X			
		— Classes of containers			X			X			
		Transportation	X	X	X	X	X	X			
		Source holder and capsula:									

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		— Handling and projection	X	X	X	X	X	X			
		— Special design		X	X		X	X			
		— Collimation	X	X	X	X	X	X			
		Parameters:									
		— Isotope type	X	X	X	X	X	X			
		— Spectrum	X	X	X	X	X	X			
		— Energy	X	X	X	X	X	X			
		— Activity	X	X	X	X	X	X			
		— Source size	X	X	X	X	X	X			
		— Half life	X	X	X	X	X	X			
	Film	Construction:	X	X	X			X			
		— Latent image information origin	X	X	X			X			
		— Base, emulsion, silver bromide, grain size, grain form	X	X	X			X			
		— Photo process	X	X	X			X			
		Processing:									
		— Properties of film systems	X	X	X			X			
		— Characteristic curve	X	X	X			X			
		— Film gradient, film contrast, speed	X	X	X			X			
		— Influence of film processing	X	X	X						
		— Sensitivity	X	X	X						
		— Granularity	X	X	X						
		— Detail perceptibility		X	X						
		Classification of film systems	X	X	X						
		Quality assurance with film test strips		X	X						
		Film screens:									
		— Type of screens	X	X	X						
		— Inherent unsharpness	X	X	X						

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		— Intensifying effect	X	X	X						
		— Effect of filtering	X	X	X						
		— Screens for cobalt 60 and Linac	X	X	X						
		Working with exposure charts	X	X	X						
	Film development and dark room conditions	Darkroom design	X	X	X						
		Manual vs machine development	X	X	X						
		Baths:									
		— Different baths	X	X	X						
		— Quality assurance in the dark room	X	X	X						
		Developing process:									
		— Principles	X	X	X						
		— Processing equipment, adjustment	X	X	X						
		— Checking	X	X	X						
		— Storage of unexposed films	X	X	X						
		— Darkroom light test	X	X	X						
		— Fog test	X	X	X						
		— Clearing time	X	X	X						
		— Tally sheet	X	X	X						
		Use of test film strips		X	X						
	Computer-radiography (CR), Imaging plates	Phosphor imaging plates:									
		— Introduction				X	X	X			
		— Design				X	X	X			
		Imaging plate and CR-scanner				X	X	X			
		CR system and classification					X	X			
		Quality assurance (phantom)					X	X			
		Exposure conditions				X	X	X			
		Working with exposure charts				X	X	X			
		Handling				X	X	X			

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		System selection					X	X			
	DDA's	Digital Detector Arrays (DDA):									
		— Introduction				X	X	X	X	X	X
		— Design				X	X	X	X	X	X
		Indirect converting					X	X		X	X
		Direct converting					X	X		X	X
		CCD, amorph. Si, CMOS					X	X		X	X
		Detector adjustment					X	X		X	X
		Quality assurance					X	X		X	X
		Exposure conditions					X	X		X	X
		Handling				X	X	X	X	X	X
		System selection						X			X
	LDA's	Line Detector Arrays (LDA):									
		— Introduction				X	X	X	X	X	X
		— Design					X	X		X	X
		Application areas					X	X		X	X
		Comparison to DDA's					X	X		X	X
		Quality assurance (phantom)					X	X		X	X
		Exposure conditions and Diagrams					X	X		X	X
		Handling					X	X		X	X
		System selection						X			X
	Intensifiers, fluoroscope	Introduction						X	X	X	X
		Design							X	X	X
		Application areas							X	X	X
		Quality assurance (phantom)								X	X
		Exposure conditions and diagrams								X	X
		Handling							X	X	X
		System selection									X
		Comparison to DDA's								X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
	Film digitization	Scanner design:									
		— Camera based		X	X						
		— Line scanners		X	X						
		— Laser scanners		X	X			X			
		Quality assurance (phantom)		X	X			X			
		Handling, archiving		X	X			X			
		System selection			X			X			
		Classification		X	X		X	X			
	Accessories	Equipment:									
		— Lead letters and tape	X	X	X	X	X	X	X	X	X
		— Holding magnets	X	X	X	X	X	X			
		— Lead shielding, collimation, masking	X	X	X	X	X	X	X	X	X
		— Rubber bands	X	X	X	X	X	X			
		— Radiation protection equipment	X	X	X	X	X	X	X	X	X
	Data acquisition, detector adjustment	A/D interface				X	X	X	X	X	X
		Computer structure:									
		— Processor, memory, bus, disk				X	X	X	X	X	X
		— Load and save of digital images				X	X	X	X	X	X
		— Image formats				X	X	X	X	X	X
		Image integration:									
		— On chip integration/ frame time				X	X	X	X	X	X
		— In memory integration/ frame number				X	X	X	X	X	X
		— Optimum gain and latitude settings					X	X		X	X
		— Accumulation vs integration					X	X		X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
5.5 Information prior to testing	Information about the test object	Identification or designation material:									
		— Object to be tested	X	X	X	X	X	X	X	X	X
		— Kind of manufacture	X	X	X	X	X	X	X	X	X
		— Catalogue of defects		X	X		X	X		X	X
		— Extent of test coverage	X	X	X	X	X	X	X	X	X
	Test conditions and application of standard	Accessibility		X	X		X	X		X	X
		Infrastructure		X	X		X	X		X	X
		Particular test conditions		X	X		X	X		X	X
		Application standard		X	X		X	X		X	X
		Stage of manufacture or service life when testing is to be carried out		X	X		X	X		X	X
		Standards assigned to the test object		X	X		X	X		X	X
		Requirements of test personnel		X	X		X	X		X	X
		Acceptance criteria		X	X		X	X		X	X
	Technique and sequence of performing test	Surface condition		X	X		X	X		X	X
		Surface preparation		X	X		X	X		X	X
		Post-test documentation		X	X		X	X		X	X
	Instructions	Preparation of written procedure			X			X			X
		Preparation of written instruction		X	X		X	X		X	X
		Performing inspection in accordance with written instruction	X			X			X		
		Presentation of the standards, codes and procedures			X			X			X
5.6 Testing	Standard practice and evaluation standards	Selection of technique:									
		— Different exposure geometries		X	X		X	X		X	X
		— Interpretation of images		X	X		X	X		X	X
		— Evaluation of flaws		X	X		X	X		X	X
		— Use of catalogues		X	X		X	X		X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		— Measurement of flaw dimensions		X	X		X	X		X	X
5.7 Evaluation and reporting	Basic of evaluation	Viewing conditions:									
		— Room condition	X	X	X	X	X	X	X	X	X
		— Viewing time	X	X	X	X	X	X	X	X	X
		— Lapsed time after dazzling	X	X	X						
		— Luminance		X	X		X	X		X	X
		— Density measurement	X	X	X						
		— Mach effect		X	X						
		Film illuminator:									
		— Introduction	X	X	X						
		— Minimum luminance		X	X						
		— Homogeneity factor		X	X						
	Physical factors	Eye sight		X	X		X	X		X	X
		Adaption prior viewing		X	X						
	Evaluation of radiographs	Verification of the image quality	X	X	X	X	X	X	X	X	X
		Report of imperfections		X	X		X	X		X	X
	Test report	Complies with examination standard		X	X		X	X		X	X
		Conformed to test quality		X	X		X	X		X	X
		Achieved test class	X	X	X	X	X	X	X	X	X
		Achieved diagnostic coverage of test object	X	X	X	X	X	X		X	X
	Digital image processing	Image structure, quantization (bits and Bytes)				X	X	X	X	X	X
		Basic operation:									
		— Picture element (pixel)				X	X	X	X	X	X
		— Grey value				X	X	X	X	X	X
		Point operations:									
		— Contrast				X	X	X	X	X	X
		— Brightness				X	X	X	X	X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
		— Gamma correction				X	X	X	X	X	X
		— Histogram					X	X		X	X
		— Look up table (LUT)					X	X		X	X
		Matrix operations, filters:					X	X		X	X
		— Smoothing, improvement of SNR					X	X		X	X
		— High pass, gradient					X	X		X	X
		— Edge enhancement, line extraction					X	X		X	X
		— median					X	X		X	X
		Measurement tools:									
		— Adjustment					X	X		X	X
		— Line profile					X	X		X	X
		— Measurement of flaw length					X	X		X	X
		— Measurement of areas					X	X		X	X
		— Measurement of depth					X	X		X	X
		Correction of raw data:									
		— Introduction					X	X		X	X
		— Linearization, LUT						X			X
		— Bad pixel interpolation						X			X
	Automated image interpretation	Principles					X	X		X	X
		Binarization						X		X	X
		Measurement of dimensions					X	X		X	X
5.8 Assessment	Classification of imperfections	Type		X	X		X	X		X	X
		Size		X	X		X	X		X	X
		Localization		X	X		X	X		X	X
		Frequency		X	X		X	X		X	X
		Influence of manufacture and material		X	X		X	X		X	X

Table 2 *(continued)*

Content			RT-F (Film)			RT — D (Digital)			RT-S (Radioscopy)		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
5.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X	X	X	X	X	X	X
		Other NDT qualification and certification systems			X			X			X
	Documentation	Format and scope of working procedures			X			X			X
		Qualification of NDT procedures			X			X			X
		Authorizations (NDT instruction, procedures and personnel)			X			X			X
		Developing written instruction		X	X		X	X		X	X
		Working correctly to written instruction	X			X			X		
		Traceability of documents		X	X		X	X		X	X
		Reliability of measurements		X	X		X	X		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X		X	X		X	X
		Use of correct test parameters		X	X		X	X		X	X
		NDT method selection			X			X			X
		Job specific training		X	X		X	X		X	X
		Equipment verification		X	X		X	X		X	X
5.10 Developments	Special techniques	Stereo radiography		X	X		X	X		X	X
		Computed tomography (CT):									
		— Introduction			X		X	X		X	X
		— Inspection geometry					X	X		X	X
		— 2D vs 3D						X			X
		— Reconstruction principles						X			X
		— Filtered back projections						X			X
		— Applications			X		X	X			X
		— Requirements, limitations			X			X			X
		RT-F vs RT-D		X	X		X	X		X	X

6 Ultrasonic testing (UT) — Levels 1, 2 and 3

The ultrasonic testing training shall be in accordance with Tables 3 and 4.

Table 3 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
6.1	Introduction to terminology and history of ultrasonic testing (UT)	1	1	1
6.2	Physical principles of the method and associated knowledge	12	12	22
6.3	Product knowledge and capabilities of the method and its derived techniques	30	24	3
6.4	Equipment	15	8	13
6.5	Information prior to testing	1	11	13
6.6	Testing	30	27	19
6.7	Evaluation and reporting	10	8	11
6.8	Assessment	0	5	6
6.9	Quality aspects	1	4	7
6.10	Developments	0	0	5

Table 4 — Ultrasonic testing (UT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
6.1 Introduction to terminology and history of ultrasonic testing (UT)	Task of NDT personnel		X	X	
	Overview of general and product standards				X
	Terminology		X	X	X
6.2 Physical principles and associated knowledge Concepts necessary for understanding the physical principles of ultrasonic testing (physics, mathematics) may be the object of a preliminary course	Review of mathematical basics	Algebra	X		
		Trigonometry	X		
		Logarithms	X		
	Physical definitions and typical parameters	Sinusoidal movement	X	X	
		Amplitude	X	X	
		Period	X	X	
		Frequency	X	X	
		Velocity	X	X	
		Acoustic impedance	X	X	
		Acoustic pressure	X	X	X
		Factors of reflection and transmission (normal beam only)		X	
		Isotropic materials	X		X
		Anisotropic materials		X	X
	Waves	Sinusoidal movement	X		
		Amplitude	X		
		Frequency	X		
		Wavelength	X		
		Propagation velocity	X		

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
		Longitudinal	X	X	
		Transverse	X	X	
		Rayleigh waves (surface waves)	X	X	X
		Creeping waves		X	X
		Guided waves		X	X
	Transmission and reflection	Effects at interfaces at normal incidence	X	X	
		— Transmission	X	X	
		— Reflection	X	X	
		— Interference		X	
		— Dispersion	X	X	X
		Snell's law	X	X	
		Relation between velocity and elastic properties			X
		Effects at interfaces at oblique incidence	X	X	
		— Transmission	X	X	
		— Reflection	X	X	
		— Refraction	X	X	
		Corner reflectors	X	X	
		— Reflection	X	X	
		— Mode conversion	X	X	
		Electrostriction			X
		Magnetostriction			X
		Electrodynamic generation			X
		Generation by laser			X
		Piezo-electric effect	X	X	
		Reverse piezo-electric effect	X	X	
	Transducer characteristics	Material	X	X	
		Dimensions	X	X	
		Frequency	X	X	
		Piezo-electric constants	X	X	
	Sound fields of disc shaped transducers	Near field (Fresnel zone)	X	X	
		Far field (Fraunhofer zone)	X	X	
		Beam divergence	X	X	
		Influence of transducer frequency and diameter	X	X	
6.3 Product knowledge and related capability of the method and derived techniques	General defects	Casting	X	X	
		Forging	X	X	
		Welding	X	X	
		Tubes and pipes	X	X	
		Wrought products	X	X	
		Composite material	X	X	

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
	Implementation of the testing techniques	According to products	X	X	
		According to expected discontinuities	X	X	
		Standards, specifications and codes		X	
	Overall properties of the specimen	Influence of surface conditions	X	X	
		Geometry (additional echoes due to grazing incidence and radial straight beam incidence	X	X	
		Structure (sound attenuation)	X	X	
		Selection of probe		X	
		— Inspection-oriented design of specimen			X
		Testing technique based on task		X	
		— Simulations			X
6.4 Equipment	Ultrasonic instruments	Digital instruments	X	X	
		— Design	X	X	
		— Function	X	X	
		— Pulse generation	X	X	
		— Reception	X	X	
		— Amplification	X	X	
		— A-scan presentation	X	X	
		— RF-signal	X	X	
		— Rectification	X	X	
		— Peak and flank measurement	X	X	
		Analogue vs digital		X	X
		Ultrasonic thickness gauge	X	X	
		Automated and semi-automated systems		X	X
		Manual			X
		Speed			X
		Incrementation			X
		Repeatability			X
		Sampling rate			X
	Probes	Straight beam	X	X	
		— Design	X	X	
		— Application	X	X	
		Angle beam	X	X	
		— Design	X	X	
		— Effects at interface wedge/ specimen	X	X	
		— Critical angles	X	X	
		— Typical angles for testing of steel	X	X	
		— Sound fields	X	X	
		— Probe index	X	X	

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
		— Beam angle	X	X	
		— Change of probe index and beam angle due to abrasion or probe shoes	X	X	
		— Half and full skip	X	X	
		— Application	X	X	
		Dual-element	X	X	
		— Design	X	X	
		— Deviation error	X	X	
		— Sound field	X	X	
		— Adjustment	X	X	
		— Application	X	X	
		Dynamic range			X
		Immersion probes (focused, spherical, cylindrical, Fermat surface)		X	X
		Measurement of pulse length			X
		Practical measurement of directional characteristics			X
		Shoe (delay, curvature)			X
	Couplant		X	X	
	Connecting cables	Length			X
		Impedance			X
	Adjustment reference and transfer blocks	Adjustment block No. 1	X	X	X
		Adjustment block No. 2	X	X	X
		Reference blocks	X	X	X
		Resolution	X	X	X
		— Near	X	X	X
		— Far	X	X	X
6.5 Information prior to testing	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
	Technique and sequence of performing test	Surface condition	X	X	
		Surface preparation	X	X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
6.6 Testing	Techniques	Pulse echo and transmission	X	X	
		Contact	X	X	
		Tandem technique		X	
		Immersion technique		X	
		TOFD technique		X	
		Phased Array technique		X	
		Techniques for ultrasonic thickness measurement	X	X	
		— Reference reflectors (laws of distance and size)		X	
		Verification of combined equipment	X	X	
		— DGS-techniques		X	
		— Multiple probe arrays			X
		EMAT		X	
		Range setting	X	X	
		— Single point adjustment	X	X	
		— Two point adjustment	X	X	
		Sensitivity setting	X	X	
		— Reference reflectors (BW, SDH, DSR)	X	X	
		— Single reflector technique (reference height)	X	X	
		— Air coupled ultrasonic testing			X
		— Guided waves		X	X
		— Testing at higher temperatures		X	X
		Different sizing techniques		X	
		— Principles		X	
		— Limitations		X	
		— Requirements for reference blocks	X	X	
		— DAC-technique	X	X	
		— Transfer correction	X	X	
		— Recording gain (testing level)	X	X	
		— Errors at echo height evaluation	X	X	
		Laser UT			X
		Verification of procedures and instructions for their efficiency			X

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
6.7 Evaluation and reporting	Interpretation	Relevant standards			X
		Relevant specifications			X
		Relevant codes			X
		Evaluation (conventional or computer aided methods e.g. echo tomography, SAFT)			X
		Data storage process (e.g. ALOK)			X
	Detecting, locating and sizing techniques	Detecting	X	X	
		Distinction between defect and geometry echo	X	X	
		Locating (calculation, trigonometrical rules)	X	X	
		Interpretation		X	
		Evaluation		X	
		A-scan presentation	X	X	X
		B-scan presentation		X	X
		C-scan presentation		X	X
		D-scan presentation			X
		E-scan presentation			X
		F-scan presentation			X
		P-scan presentation			X
		S-scan presentation			X
		Recording results	X	X	
		Classifying results	X	X	
		Acceptance levels	X	X	
		Echo height evaluation with DGS-method		X	
		Sizing and half amplitude technique	X		
		Sizing using the fixed amplitude level technique		X	
		Echo height evaluation with single reflector technique and DAC-method	X	X	
		Reporting	X	X	
		Check content and matching of test reports, instructions and procedures			X
6.8 Assessment	Evaluation and confirmation of test reports	Application of the acceptance criteria according to standards, codes and procedures		X	
6.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems		X	X
	Documentation	Traceability of documents		X	X
		Equipment verification		X	X
		Reliability of measurements		X	X
		Format of working procedures			X

Table 4 *(continued)*

Content			Level 1	Level 2	Level 3
6.10 Developments	Newest developments for industrial and scientific applications of UT	Phased array	X	X	X
		Time of fight diffraction	X	X	X
		Long-range	X	X	X
		Computer modelling			X

7 Eddy current testing (ET) — Levels 1, 2 and 3

The Eddy current testing training shall be in accordance with Tables 5 and 6.

Table 5 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
7.1	Introduction to terminology and history of eddy current testing (ET)	1	1	2
7.2	Physical principles of the method and associated knowledge	15	16	17
7.3	Product knowledge and capabilities of the method and its derived techniques	10	10	15
7.4	Equipment	24	17	15
7.5	Information prior to testing	4	19	26
7.6	Testing	37	19	4
7.7	Evaluation and reporting	5	8	8
7.8	Assessment	0.0	4	4
7.9	Quality aspects	4	4	4
7.10	Developments	0.0	2	5

Table 6 — Eddy current testing (ET) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
7.1 Introduction to terminology and history of eddy current testing (ET)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a “product”?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of eddy current testing (ET)	Definition	X		
		Applicability and limitations	X		

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
7.2 Physical principles and associated knowledge Concepts necessary for understanding the physical principles of eddy current (physics, mathematics) may be the object of a preliminary course	Electricity	Direct current	X	X	X
		— Current	X	X	X
		— Voltage	X	X	X
		— Resistance	X	X	X
		— Conductance	X	X	X
		— Ohm's law	X	X	X
		— Resistivity	X	X	X
		— Conductivity	X	X	X
		Units	X	X	X
		— Conductivity values for some metals	X	X	X
		Alternating current	X	X	X
		— Sinusoidal current	X	X	X
		— Voltage	X	X	X
		— Amplitude	X	X	X
		— Frequency	X	X	X
		— Period	X	X	X
		— Phase	X	X	X
		— Vector representation		X	X
		Other periodic currents			X
	Magnetism	Magnetic field	X	X	X
		Lines of force		X	X
		Magnetic field strength	X	X	X
		Permeability	X	X	X
		Flux density (induction)	X	X	X
		Flux	X	X	X
		Hysteresis loop	X	X	X
		Units	X	X	X
		Diamagnetism		X	X
		Paramagnetism		X	X
		Ferromagnetism		X	X
		Reluctance		X	X
		Magneto-motive force		X	X
	Electromagnetism	Magnetic field created by a current (wire, coil)	X	X	X
		Electromagnetic induction phenomenon	X	X	X
		Inductance	X	X	X
		Mutual inductance		X	X
		Electromagnetic coupling	X	X	X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
		Induced currents	X	X	X
		Secondary field	X	X	X
		Lenz's law	X	X	X
		Distribution in conducting materials	X	X	X
		— Planar wave		X	X
		— Depth of penetration	X		
		— Standard depth of penetration		X	X
		— Amplitude	X	X	X
		— Phase	X	X	X
		Cylindrical conductors		X	X
		— Characteristic frequency	X	X	X
		Real (practical) depth of penetration		X	X
		Impedance	X	X	X
		— Complex plane representation		X	X
		— Impedance plane diagrams		X	X
	Alternative techniques	Pulsed eddy current			X
		Magnetic field sensors			X
		Alternating current field measurement			X
		Remote field eddy currents			X
	Simulation	Analytical calculation of eddy current tests			X
7.3 Product knowledge and related capability of the method and derived techniques	Defectology	Manufacturing related discontinuities		X	X
		Service induced discontinuities		X	X
		Material properties influencing eddy current testing		X	X
		— Conductivity		X	X
		— Permeability		X	X
		Product characteristics influencing eddy current testing		X	X
		— Condition (surface, heat treatment, cold working)		X	X
		— Temperature		X	X
		— Shape		X	X
		— Wall thickness		X	X
		— Accessibility		X	X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
		Products being tested		X	
		— Semi-finished products		X	
		— Pipes		X	
		— Heat exchanger tubes		X	
		— Mechanical parts (e.g. cars, railway and aircraft industry)		X	
		— Welds (e.g. offshore)		X	
		Characteristics of flaws affecting detection		X	
		— Width/depth ratio		X	
	Applications of eddy current testing	Material characterization: conductivity, ferrite content, metal sorting, heat treatment sorting, thickness of thermochemical treatments (case hardening, nitriding….), coating thickness (conductive or non-conductive), and derived information (hardness….)	X	X	X
		Detection of discontinuities: cracks (SCC, fatigue), wall thinning, corrosion, deposits...	X	X	X
	Capabilities	Depth of penetration	X	X	X
		Conductive materials	X	X	X
		Non-contact	X	X	X
		High speed	X	X	X
		High temperature	X	X	X
		Multiplexed arrays	X		
		Mechanized	X	X	X
	Techniques	Single frequency	X	X	X
		Multifrequency	X	X	X
		Multiparameter	X	X	X
		Pulsed current		X	X
		Multiplexed arrays		X	X
		Remote field		X	X
		Similarity rules for surface inspection and tube characteristic/limit frequencies		X	X
	Codes and standards			X	X
7.4 Equipment	Eddy current testing system	Instrument	X	X	X
		General purpose applications — essential functions		X	X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
		Specific applications		X	X
		— Pulsed eddy current			X
		— Magnetic field sensors			X
		— Alternating current field measurement			X
		Mechanized equipment		X	X
		Probes	X	X	X
		— Combined		X	X
		— Separate transmit — receive		X	X
		— Surface		X	X
		— Coaxial		X	X
		— Designs		X	X
		— Array probes (description and operating principles)		X	X
		Measurements	X	X	X
		— Absolute	X	X	X
		— Differential	X	X	X
		— Impedance testing		X	X
	Output and signal display	— Signal-to-noise	X	X	X
		— Distortion/non-linearity	X	X	X
		— Filters	X	X	X
	Reference blocks	Material	X	X	X
		Design		X	X
		Production		X	X
		Storage		X	X
	Codes and standards			X	X
7.5 Information prior to testing	Information about the test object	Written instructions	X		
		Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage		X	X
	Test conditions and application of standard	Accessibility		X	X
		Temperature			X
		Humidity			X
		Availability			X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
		Unwanted interfering signals			X
		Electric and/or magnetic disturbances			X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post-test documentation		X	
		Equipment to be used		X	
		Requirement for recording		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
		Documents			X
		Presentation of the standards, codes and procedures			X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
7.6 Testing	Probe selection as a result of 7.5	Product			
		— Grade		X	X
		— Metallurgical condition		X	X
		— Shape		X	X
		— Type of discontinuity sought		X	X
		— Location		X	X
		— Duty of the product		X	X
		— Extent of examination		X	X
	Operating conditions as a result of 7.5	— Temperature		X	X
		— Humidity		X	X
		— Access		X	X
		— Availability		X	X
		— Interfering signals		X	X
		— Electric and/or magnetic disturbances		X	X
	Parameters	Excitation frequency	X	X	X
		Auxiliary frequencies	X	X	X
		Probe speed	X	X	X
		Probe clearance	X	X	X
		Probe vibration	X	X	X
		Probe centering	X	X	X
	Adjustment curves		X	X	X
	Settings	Data acquisition	X	X	X
		Written procedure		X	X
		Written instruction	X	X	
7.7 Evaluation and reporting	Reporting	Reporting level		X	X
		Examination report	X	X	X
	Evaluation	Characterization of the indications		X	X
		— Single frequency analysis		X	X
		— Multi-frequency analysis		X	X
		— Data analysis		X	X
7.8 Assessment	Evaluation and confirmation of test reports	Acceptance criteria according to standards, codes and procedures		X	X
		Training of level 1 and 2 of the acceptance criteria			X

Table 6 *(continued)*

Content			Level 1	Level 2	Level 3
7.9 Quality aspects	Factors affecting quality of testing	Personnel qualification	X	X	X
		— ISO 9712	X	X	X
		— Other NDT qualification and certification systems			X
		Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instruction	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
7.10 Developments	General information	Non-inductive techniques			X
		— Magneto-optical imaging			X
		— SQUID			X
		— Giant magneto-resistance			X
		Imaging			X
		Modelling			X

8 Penetrant testing (PT) — Levels 1, 2 and 3

The penetrant testing training shall be in accordance with Tables 7 and 8.

Table 7 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
8.1	Introduction to terminology and history of penetrant testing (PT)	3	4	8
8.2	Physical principles of the method and associated knowledge	3	8	9
8.3	Product knowledge and capabilities of the method and its derived techniques	18	13	8
8.4	Equipment	12	8	8
8.5	Information prior to testing	3	8	22
8.6	Testing	12	12	4
8.7	Evaluation and reporting	37	19	10
8.8	Assessment	3	4	2
8.9	Quality aspects	6	12	21
8.10	Environmental and safety conditions	3	8	6

Table 7 *(continued)*

Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
8.11 Developments	0	4	2

Table 8 — Penetrant testing (PT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
8.1 Introduction to terminology and history of penetrant testing (PT)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a "product"?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of penetrant testing (PT)	Definition	X	X	X
		Applicability and limitations	X	X	X
	Terminology		X	X	X
8.2 Physical principles and associated knowledge Concepts necessary for understanding the physical principles of penetrant testing (physics) may be the object of a preliminary course	Penetrant systems	Penetrant types	X	X	X
		— Fluorescent	X	X	X
		— Visible	X	X	X
		Basis of fluorescent and absorption principles used in dye penetrants		X	
		Interactions between different dyes			X
		Penetrant techniques	X	X	X
		— Water washable	X	X	X
		— Post emulsifiable	X	X	X
		— Solvent removeable	X	X	X
		Emulsifiers	X	X	X
		Cleaner	X	X	X
		Developer	X	X	X
		— Wet	X	X	X
		— Dry	X	X	X
	Properties and characteristics	Physical basics of the method	X	X	X
		Penetrant	X	X	X
		— Viscosity	X	X	X
		— Flashpoint	X	X	
		— Bleed out	X	X	
		— Capillarity	X	X	
		— Superficial tension	X	X	X
		— Contact angle	X	X	X
		— Vapour pressure	X	X	X
		Influence of material roughness		X	X

Table 8 *(continued)*

Content			Level 1	Level 2	Level 3
		— Variable values of roughness (Ra + Rz)			X
		— Components with multiple roughness (i.e. foundry with machining)			X
		Signal-to-noise ratio concept	X	X	X
		Residual background noise (over/under washing risks)	X	X	X
		Emulsification of penetrant	X	X	X
		Cleaner	X	X	X
		Developer	X	X	X
8.3 Product knowledge and related capability of the method and derived techniques		Test conditions	X	X	X
		— Lighting in work and surrounding areas		X	
		— Adaption to black light environment		X	
		— Transition between bright and darkened areas		X	
		Viewing conditions	X	X	X
		— Performance of penetrant based on temperature		X	
		— Role of adaptation to darkened environment		X	
		— Cleanliness		X	
		— Modulation (increase) of lighting and adaptation period to darkened environment according to age of inspector			X
		Technique selection		X	X
		Technique application	X	X	X
8.4 Equipment	Design and operation of penetrant installations and units	Aerosol spray cans	X	X	X
		— Compressed gas, liquefied gas, “atomization”			X
		Dip tanks	X	X	X
		Electrostatic systems, fluidized bed		X	X
		Semi-automatic systems		X	X
		Automatic systems		X	X
		Application	X	X	X
		Light sources	X	X	
		— Introduction to actinic blue		X	
		— Physiological human factor knowledge of aspects related to lighting			X
		— Quality of LED products			X
		Measuring units	X	X	

Table 8 *(continued)*

Content			Level 1	Level 2	Level 3
		— Basics of metrology		X	
		— Metrological uncertainties			X
		Reference blocks	X	X	
		— Minimum quality required for a reference photo		X	X
		Viewing conditions	X	X	
8.5 Information prior to test	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		— Actinic blue			X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		— Differences between aqueous alkaline degreaser and water based/solvent		X	
		— Danger of borates and silicate in water based cleaners — soaps			X
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Documents			X
		Presentation of the standards, codes and procedures			X
8.6 Testing	Preparation and performance of the test	Performing inspection in accordance with written instruction	X		
		Supervision of personnel		X	X
	Parameters	Preparation of the parts and influence of the surface quality	X	X	X
		— Surface preparation	X	X	
		— Cleaning	X	X	

Table 8 *(continued)*

Content			Level 1	Level 2	Level 3
		Technique		X	X
		— Selection		X	X
		— Correct use	X	X	X
		Planning of the test		X	
		— Grids		X	
		— Coverage		X	
		Detecting medium	X	X	X
		— Correct use	X	X	
		— Correct selection		X	X
		Viewing conditions	X	X	X
		Observation and indications	X	X	
		Recording of discontinuities	X	X	
		Reporting	X	X	
		Interpretation of indications		X	X
		Labelling and disposition of tested product		X	X
		Cleaning of components	X	X	
8.7 Evaluation and reporting	Test report	Viewing conditions	X	X	X
		Reference block No. 1		X	X
		Reference block No. 2	X	X	X
		— Differences between progressive and non-progressive panels			X
		Statistical aspects of analysed parameters to revalidate penetrant use			X
		Verification of indication quality	X	X	X
		— Use of reference photographs to validate visual conditions		X	
		Report of simple welding, forging rolled products and casting imperfections	X		
		Other reference blocks used		X	X
		Adjustment of test units batch test report		X	X
	Evaluation	Report of discontinuities		X	
8.8 Assessment	Assessment of discontinuities	Influence of manufacture and material		X	X
		Depth		X	X
		Width		X	X
		Shape		X	X
		Position		X	X
		Orientation		X	X
8.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X

Table 8 *(continued)*

Content			Level 1	Level 2	Level 3
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instructions	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
	Relevant standards				
8.10 Environmental and safety conditions	Chemicals	Chemical handling (aerosols/ propellants)	X	X	X
		Disposal	X	X	X
		— Penetrant	X	X	X
		— Developer	X	X	X
		— Emulsifier	X	X	
		— Soluble remover			X
		— Material of process excess removal	X	X	
		— Active carbon method		X	
		— Ultrafiltration method		X	
		Material safety data sheet	X		
		Review of applicable NDT application and product standard			X
	Accessories	Violet and UV radiation hazards	X	X	X
		Dangers of white lights	X	X	X
		Electrical hazards	X	X	X
		UV filters	X	X	
		Vision considerations	X	X	X
		Protective glasses	X	X	X
	Human factors	Extended stay in dark areas			X
		Role of breaks			X
8.11 Developments		Special installations		X	
		Automotive installations		X	
		Creative and innovative special installations			X
		Tube installations			X

9 Magnetic particle testing (MT) — Levels 1, 2 and 3

The magnetic particle testing training shall be in accordance with Tables 9 and 10.

Table 9 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
9.1	Introduction to terminology and history of magnetic particle testing (MT)	3	4	3
9.2	Physical principles of the method and associated knowledge	3	8	13
9.3	Product knowledge and capabilities of the method and its derived techniques	18	13	13
9.4	Equipment	12	8	13
9.5	Information prior to testing	3	8	6
9.6	Testing	12	12	19
9.7	Evaluation and reporting	37	19	9
9.8	Assessment	3	4	3
9.9	Quality aspects	6	12	15
9.10	Environmental and safety conditions	3	8	3
9.11	Developments	0	4	3

Table 10 — Magnetic particle testing (MT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
9.1 Introduction to terminology and history of magnetic particle testing (MT)	History				
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a “product”?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of magnetic particle testing (MT)	Definition	X	X	X
		Applicability and limitations	X	X	X
	Terminology		X	X	X
9.2 Physical principles and associated knowledge Concepts necessary for understanding the physical principles of magnetic particle testing (physics to include electrical theory) may be the object of a preliminary course	Basic physical phenomena	Electric circuits	X	X	X
		— Typical values	X	X	X
		— Units	X	X	X
		Magnetic circuits	X	X	X
		— Typical values	X	X	X
		— Units	X	X	X
		Magnetic field	X	X	X
		— Characterization	X	X	X
		— Measurements	X	X	X
		— Magnetic field (H)	X	X	X
		— Magnetic induction (B)	X	X	X
		— Designation of alloys	X	X	X

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Magnetic field created by electric circuits	X	X	X
		— Indefinite rectilinear conductor	X	X	X
		— Long magnetic coil	X	X	X
		— Short or flat magnetizing coil	X	X	X
		— Influences of the flux of a magnetic field in a non-magnetic media	X	X	X
		— Continuity of H_t	X	X	X
		— Continuity of B_n	X	X	X
		— Passage of flux from a magnetic medium to a non-magnetic medium	X	X	X
		Magnetic flux of a magnetic discontinuity	X	X	X
		— Influence of depth	X	X	X
		— Influence of orientation	X	X	X
	Properties of materials	Non-magnetic materials	X	X	X
		Magnetic materials	X	X	X
		— Influence of temperature on the magnetic properties	X	X	X
		Diamagnetism	X	X	X
		Paramagnetism	X	X	X
		Ferromagnetism	X	X	X
		Ferrimagnetism			X
		Influence of work hardening			X
		Influence of heat treating			X
		Particular alloys		X	X
		— Permalloys		X	X
		— Invar		X	X
		— Inconel		X	X
	Characteristics of magnetic particle testing	Influence of the geometry in detecting a magnetic discontinuity	X	X	X
		— Depth	X	X	X
		— Thickness	X	X	X
		— Orientation	X	X	X
		Magnetic properties	X	X	X
		— Principal ferromagnetic alloys	X	X	X
		Non-magnetic properties	X	X	X
		Magnetic materials	X	X	X
		— Field of application	X	X	X
		— Curie point	X	X	X

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		— Curve of the first magnetization	X	X	X
		— Hysteresis cycle and remarkable points	X	X	X
		— Magnetic properties of steel	X	X	X
		Behaviour of a magnetic particle in the vicinity of a magnetic flux	X	X	X
		— Magnetic field (H)		X	X
		— Magnetic induction (B)		X	X
		— Relative magnetic permeability, μ_r		X	X
		— Coercive force, H_c		X	X
		— Electrical resistivity, ρ		X	X
		Influence of composition	X	X	X
9.3 Product knowledge and related capability of the method and derived techniques	Processing	Test conditions	X	X	X
		Preparation of parts	X	X	X
		Viewing conditions	X	X	X
		— Visual ergonomics			X
		— Modulation (increase) of lighting and adaption period in darkened environment according to age of inspector			X
		Light sources	X	X	X
		— Physiological human factor knowledge of aspects related to lighting			X
		— Quality of light sources products			X
		Application of medium	X	X	X
		Technique selection		X	X
		Factors affecting indications		X	X
		Metrological uncertainties			X
9.4 Equipment	Magnetizing equipment	Permanent magnets	X	X	X
		Portable electromagnets	X	X	X
		Coils	X	X	X
		Threading bars	X	X	X
		Prods	X	X	X
		Magnetic benches	X	X	X
		— Fixed and portable	X	X	X
		— Automatic		X	X
		— Robotized		X	X
		Clamps	X	X	X
		Cable wraps	X	X	X
		Swinging field		X	X

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Mobile		X	X
	Measurement and adjustment	Field indicators	X	X	X
		Hall probe		X	X
	Demagnetization	Accessories	X		
		— Products indicators		X	
		— Field strength measuring devices		X	
		— Flux indicators		X	
	Detection media	Contrast paint	X	X	X
		Particles	X	X	X
	Viewing conditions	Light sources	X	X	X
		— Quality of LED products			X
		Human factors	X	X	X
		— Adaptation to darkened environment		X	X
		— Transition from bright/ darkened lighting conditions		X	X
		— Role of adaptation for darkened environment		X	X
		Conditions of illumination		X	X
		— Photometers and radiometers		X	
9.5 Information prior to test	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Preparation of written instruction		X	
		Documents			X
		Presentation of the standards, codes and procedures			X
9.6 Testing		Performing inspection in accordance with written instruction	X		
		Supervision of testing personnel		X	X
	Parameters	Preparation of the parts and influence of the surface quality	X	X	
		— Surface preparation	X	X	
		Demagnetization	X	X	X
		Cleaning, machining	X	X	
		Magnetization	X	X	
		— Equipment	X	X	
		— Current type	X	X	
		— Type	X	X	
		— Time of application	X	X	
		Control of magnetization conditions	X	X	X
		— Values of the magnetizing parameters		X	
		— Continuous or simultaneous technique		X	X
		— Remanence technique		X	
		— Use of flux indicators and magnetometers		X	
		Technique	X	X	X
		— Correct use	X	X	
		— Selection		X	X
		— Magnetic field strength		X	X
		— Orientation	X	X	X
		Planning of the test	X	X	X
		— Grids		X	X
		— Coverage		X	X
		Detecting medium		X	
		— Correct use	X	X	X
		— Correct selection		X	X
		— Wet medium	X	X	
		— Dry medium	X	X	
		— Contrast paint	X	X	

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Viewing conditions	X	X	X
		— Adaptations to darkened environment		X	
		— Cleanliness		X	
		Observation and indications	X	X	X
		Recording of discontinuities		X	X
		Reporting	X	X	
		Interpretation of indications		X	
		Labelling and disposition of tested product		X	
	Treatment of components	Residual field	X	X	
		— Condition requiring de-magnetization		X	
		— Level of residual		X	
		— Influence on later use of material			X
		Demagnetization	X	X	X
		— Basic principles	X	X	
		— Industrial methods	X	X	
		— Influence of terrestrial magnetic field		X	X
		— Minimal value of the magnetic field of demagnetization principles	X	X	
		— Frequency	X	X	
		— Effect of skin	X	X	
		— Calculation of magnetizing coil		X	X
	Cleaning of components		X	X	X
9.7 Evaluation and reporting	Classification of indications	Welding		X	X
		Casting		X	X
		Forging		X	X
		Fe tubes		X	X
	Inspection conditions	Viewing according to reference block	X	X	X
		Use of other reference blocks		X	X
		Verification of the indication quality (ISO 3059)	X	X	X
		Adjustment of test units		X	X
		Batch test report		X	
	Test report	Basics of evaluation			X
		Test report	X	X	X
		— Check test report		X	
		— In accordance with written procedure			X
		Report of imperfections	X	X	

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Evaluation of the indication quality		X	X
		Preservation of indications		X	
9.8 Assessment	Assessment of indications	Relevant and non-relevant	X		
	Assessment of discontinuities	Influence of manufacture		X	
		Influence of material		X	
		Influence of depth		X	X
		Influence of shape		X	X
		Influence of position		X	X
		Influence of orientation		X	X
9.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instruction	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
		— Medium concentration	X		
		— Medium contamination	X		
		— Ammeter adjustment	X		
		— Lift test	X		
9.10 Environmental and safety conditions	Human Factors	Extended stay in dark areas		X	X
		Role of breaks		X	X
		Role of anti-UV glasses			X
	Chemicals	Proper handling (aerosols/ propellants)	X	X	X
		Disposal of effluents		X	X
		Environmental conditions		X	X
		Treatment and rejection of the effluents			X
		Toxicity of lead contact pads		X	
		Toxicity of products			X

Table 10 *(continued)*

Content			Level 1	Level 2	Level 3
		Risks related to the products	X	X	X
		Material safety data sheet	X	X	
		Review of applicable NDT application and product standard			X
		Fire hazards			X
	Accessories	UV radiation hazards	X	X	X
		Hazards of white light			X
		Electrical hazards	X	X	X
		UV filters	X	X	
		Vision considerations	X	X	X
		— Protective glasses	X	X	X
9.11 Developments		Special installation and equipment		X	
		Actinic blue (alternative wavelengths)		X	X
		New techniques			X
		Creative and innovative special installations			X

10 Leak testing (LT) — Levels 1, 2 and 3

The leak testing training shall be in accordance with Tables 11 and 12.

Table 11 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
10.1	Introduction to terminology and history of leak testing (LT)	5	2	2
10.2	Physical principles of the method and associated knowledge	9	6	8
10.3	Product knowledge and capabilities of the method and its derived techniques	10	12	16
10.4	Equipment	15	14	12
10.5	Information prior to testing	5	4	10
10.6	Testing	49	50	29
10.7	Evaluation and reporting	2	4	8
10.8	Assessment	0	4	7
10.9	Quality aspects	5	2	5
10.10	Developments	0	2	3

Table 12 — Leak testing (LT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
10.1 Introduction to terminology and history of leak testing (LT)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a "product"?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of leak testing (LT)	Definition	X	X	X
		Applicability and limitations	X	X	X
10.2 Physical principles and associated knowledge	Physical behaviour of matter	Structure of matter (fundamental)		X	
		— Atomic theory		X	
		— Ionization		X	
		— State of matter		X	
		— Molecular structure		X	
		— Diatomic and monatomic molecules		X	
		— Molecular weight		X	
		Solid-liquid and liquid vapour		X	
		— State changes		X	
		Gas laws and fundamentals	X	X	
		— Brownian movements		X	
		— P-V and P-T diagrams		X	
		— Pascal's law		X	
		— Charles' law	X	X	
		— Boyle's laws	X	X	
		— Gay Lussac's Law		X	
		— Dalton's law of partial pressure		X	
		— Hagen Poiseuille's law		X	
		— Perfect gas formula and its application for leakage calculation		X	
		— Mean free-path definition and meaning		X	
		— Gas properties		X	
		Kinetic theory of gas (fundamental)		X	
		— Avogadro's law		X	
		— Gas mixture and concentration		X	
		— Gas velocity, density and viscosity		X	
		Perfect and real gases			X
	Pressure	Vapour pressure and its effects in a vacuum			X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		Pressure as force on unit area	X		
		Main pressure units	X		
		Vapour pressure	X		
		Relationship between different measurement units		X	
		Standard and normal conditions		X	
		Definition of pressure from the kinetic theory of gas			X
		Relationship between mean free path and pressure			X
	Perfect gas law	The formula and its use for leakage calculation			X
	Pressure range in a vacuum	Different range	X		
		Relationship between mean free path and vacuum range			X
	Flow in vacuum	Definition	X	X	
		Leakage as a flow	X		
		Flow parameters		X	
		— Relationship between mean free-path and flow		X	
		— Viscous flow		X	
		— Molecular flow		X	
		— Intermediate flow		X	
		— Flow and kinetic theory			X
		— Factors affecting gas flow			X
		— Leak rate versus viscosity			X
		— Reynolds number vs Knudsen number			X
		— Geometry of a leak path capillary			X
		— Permeation			X
		— Capillary			X
	Leakage measurement	Units	X		
		— Relationships		X	
	Conductance in vacuum	Definition and meaning		X	
		Conductance calculation		X	X
		— Nomograph or simplified formulae		X	
		Flow and conductance			X
	Degassing	Practical implications	X		
		Practical concept and fundamentals		X	
		Different gas behaviours			X
		Material			X
	Pumping speed	Definition and meaning		X	
		Pumping speed calculations			X
	Virtual and real leak	Concept	X		

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		Difference	X		
		Source of real and virtual leaks pressure vs time		X	
		Calculation on virtual leak influence in a pressure change test			X
10.3 Product knowledge and related capability of the method and derived techniques	Type of leak testing	Leak location	X		
		Leak measurement	X		
		Pass/fail test	X		
		Leakage monitoring	X		
		Specification		X	
		Sensitivity		X	
	Object preparation	Cleanliness	X		
		— Cleaning procedures and effects on leak detection measurements	X		
		Sealed object with or without tracer gas		X	
		Object inaccessible from one or both sides		X	
		Object working above or below the atmospheric pressure		X	
	Specifications and technique capabilities	Bubble emission technique	X		
		— Principles of bubble emission techniques	X		
		— Immersion technique	X		
		— Liquid application technique	X		
		— Physical principles involved		X	
	Pressure change techniques	Fundamentals of working principles	X		
		— Pressure testing	X		
		— Vacuum testing	X		
		Principles of detection for the pressure change techniques		X	
		— Pressure decay technique		X	
		— Pressure rise technique		X	
		— Bell pressure change technique		X	
		— Flow measurement technique		X	
		Difference between the pressure testing and the vacuum testing considering the perfect gas law			X
		Terminology related to pressure testing			X
	Tracer gas technique	Principles of detection	X		
		Helium as tracer gas	X		
		Tracer gas detectors	X		

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		Tracer gas flow into the object (group A techniques)	X		
		Tracer gas flow out of the object (group B techniques)	X		
	Chemical or physical properties of detectors	Principles of detection for the tracer gas flow into the object — Group A techniques		X	
		Local leak		X	
		— Spraying		X	
		— Vacuum technique (local)		X	
		— Vacuum technique (partial)		X	
		— Bell pressure test		X	
		Global leak		X	
		— Vacuum technique (total)		X	
		— Bell pressure test		X	
		— Pressure rise		X	
		— Flow measurements		X	
		Principles of detection for tracer gas flow out of the object — Group B techniques		X	
		Local leak		X	
		— Chemical detection with ammonia		X	
		— Vacuum box using internal tracer gas		X	
		— Sniffing test		X	
		— Bubble and vacuum box		X	
		— Pressure technique by accumulation		X	
		— Bell pressure test		X	
		Global leak		X	
		— Bubble test — immersion		X	
		— Bubble test foaming		X	
		— Pressure technique by accumulation — global		X	
		— Pressurization-evacuation test (bombing)		X	
		— Vacuum chamber technique		X	
		— Bell pressure test		X	
		— Pressure change		X	
		— Flow measurements		X	
	Test method	Fundamentals	X		
		Choice of criteria		X	X
10.4 Equipment	Vacuum gauges	Choice of gauges for different pressures	X		
		Total pressure and partial pressure gauges	X		

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		Absolute and differential gauges		X	
		Primary and secondary gauges		X	
		Physical properties involved for the different sensor type		X	
	Mechanical gauges	Pressure reading techniques for diaphragm gauge	X		
		Bourdon gauge		X	
		— Principles and behaviour		X	
		— Influence of atmosphere		X	
		Diaphragm gauge		X	
		— Principles and behaviour		X	
		— Influence of atmosphere		X	
		Capacitance manometer gauge		X	
		— Principles and behaviour		X	
		— Influence of temperature		X	
		Accuracy for the different sensors			X
	U-tube manometers and McLeod gauges	Principles and behaviour		X	
	Pirani and thermocouple gauges	Pressure reading techniques	X		
		Assembly criteria	X		
		Principles and behaviour of different gases		X	
		Accuracy and adjustment for different gases			X
	Cold and hot ion gauges	Pressure reading techniques	X		
		Assembly criteria	X		
		Principles and behaviour of different gases		X	
		Accuracy and adjustment for different gases			X
	Vacuum pumps	Physical principle involved			X
		Types of pump for different vacuum ranges	X		
		Classification and selection of vacuum pumps		X	
		— Pump performance		X	
		— Ultimate pressures		X	
		— Pressure ranges		X	
		— Pumping speed		X	
		— Discharge pressures		X	
	Rotary and piston pumps	Physical principle involved			X
		Performance	X		
		Maintenance	X		
		Gas ballast	X		
		Pump-down times calculation for different volumes		X	X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		— Conductance influence			X
	Roots pump	Physical principle involved			X
		Size evaluation		X	
		Mounting		X	
		Performance maintenance		X	
		Pump-down times calculation for different volumes			X
		— Conductance influence			X
	Diffusion pump	Physical principle involved			X
		Size evaluation for different application		X	
		Size evaluation for the backing pump		X	
		Mounting		X	
		Performance maintenance		X	
	Turbomolecular pump	Physical principle involved			X
		Performance	X		
		Maintenance	X		
		Size evaluation for different application		X	
		Size evaluation for the backing pump		X	
		Mounting		X	
	Valve	Type of valves used for leak detection application	X		
		Maintenance	X		
		Mounting	X		
		Choice of valve for leak testing		X	
		Performance		X	
	Fittings	Assembly criteria	X		
		Maintenance	X		
		Choice of right fittings for leak detection		X	
		Diameter and length calculation and influence		X	
		Project criteria			X
	Material	Choice for different vacuum ranges		X	
		— Metallic		X	
		— Plastic		X	
		— Glass		X	
		— Oil		X	
		— Grease		X	
10.5 Information prior to test	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
		Documents			X
		Presentation of the standards, codes and procedures			X
10.6 Testing	Bubble testing practice and techniques	General requirements	X		
		— Gas	X		
		— Pressure limits	X		
		— Cleaning	X		
		Test fluid	X		
		— Test fluids for liquid immersion techniques (preparation and use)	X		
		— Test fluids for liquid application techniques (preparation and use)	X		
		— Selection of test fluids from the point of view of physical properties		X	
		Selection of techniques for different applications		X	
		— Pipe, nozzle, pad plate, compressor testing		X	
		— Vessel testing		X	
		— Leakage quantitative evaluation		X	
		Weather effects			X
		Lighting			X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
	Immersion technique	Physical principles involved		X	
		Pressurization of test specimen	X		
		Knowledge for creating pressure differential	X		
		Elevated temperature test fluid	X		
		Vacuum box technique	X		
	Liquid application technique	Physical principles involved		X	
		Pressurization of test specimen	X		
		Vacuum technique for non-pressurized objects	X		
	Pressure change techniques	General requirements	X		
		Pressure change method			X
		— Physical principles involved		X	
		— Perfect gas law		X	
	Pressure decay technique	Temperature and pressure gauges	X		
		System setup	X		
		Apparatus and test set-up		X	
		Accuracy of equipment		X	X
		— Gauge adjustment accuracy		X	
		— Accuracy of test calculations		X	
		Choice of pressure and temperature		X	
		Effect of temperature change		X	
		Effect of water vapour pressure		X	
		Effect of barometric pressure change		X	
		Calculation of leakage rate		X	
		Reference vessel technique		X	
		Leakage rate calculation from the perfect gas law		X	
		Differential pressure transducer		X	
		Reference vessel technique (fundamental)	X		
	Pressure rise technique	Virtual leak	X		
		— Effect of			
		— Pressure time relationship		X	
		— Evaluation			X
		System setup	X		
		Adjustment			X
		Leakage rate calculation from the perfect gas law		X	
		Choice of vacuum gauges			
		Choice of system		X	
		Accuracy test calculation			X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
	Bell pressure change technique	General requirements	X		
		Adjustment			X
		Air flow into the object		X	
		Air flow out of the object		X	
		Choice of gauge		X	
		Calculation of leakage rate		X	X
		Accuracy of test calculation			X
	Flow measurements technique	General requirements	X		
		Adjustment			X
		Air flow into the object		X	
		Air flow out of the object		X	
		Choice of gauge		X	
		Calculation of leakage rate		X	X
		Accuracy of test calculation			X
	Tracer gas practice and techniques	Tracer gas method		X	X
		Calculation of leakage rate		X	
		Choice of tracer gas and suitable detector		X	
		Selection criteria of the technique for different applications		X	
	Mass spectrometers	Fundamental principles, MSLD manufacturing aspect	X		
		— Magnetic or quadrupole	X		X
		— Direct flow and contraflow	X		
		— Pumping systems, electronic, heads, gauges, etc.	X		
		— Service	X		
		— Adjustment leaks	X		
		— Helium mixture	X		
		Physical principles involved		X	
		— e/m formula of mass		X	
		— Mass spectra		X	
		— Magnetic		X	
		— Quadrupole		X	
		— General and leak testing application		X	
		MSLD manufacturing aspect involved and working principles		X	
		Sensitivity capabilities for the different techniques		X	
		Adjustments		X	
		Helium mixture and leak rate calculation		X	
		Maintenance issues		X	
		Mass spectrometry			X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		— Qualitative			X
		— Quantitative			X
	Halogen ion diode	Fundamental principles involved	X		
		Halogen detector leak testing equipment	X		
		Halogen detector	X		
		Physical principles involved		X	
		Sensitivity capabilities of the technique		X	
		Selection criteria of the techniques for different applications		X	
		Detector probe “sniffer” speed		X	
		Halogen background		X	
		Properties of refrigerant tracer gas		X	
		— Chemical composition		X	
		— Molecular weight		X	
		— Liquid-gas behaviour		X	
		Adjustment of halogen leak detectors		X	
		Halogen mixtures percentage		X	
		Evaluation of test sensitivity		X	
	Thermal conductivity gauges	Fundamental principles	X		
		Physical principles involved		X	
		Sensitivity capabilities of the techniques with this detector		X	
		Pirani and thermocouple working principles			X
	Reactive tracers	Physical principles involved		X	
		Sensitivity capabilities of the technique		X	
		Radioactive gases			X
	Gas analysis apparatus	Physical principles involved		X	
		Sensitivity capabilities of the technique		X	
		Chromatography, etc.			X
	Tracer gas flows into the object — group A techniques	All techniques	X		
		— General requirements	X		
		— Initial set-up and procedure	X		
		— Object preparation	X		
		— Test sensitivity for different techniques		X	
		— Adjustment		X	

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
		— Calculation of leakage rate		X	
	Vacuum technique	Total and partial	X		
		Local (spraying)	X		
		— Object surface preparation	X		
	Tracer gas flows out of the objects — group B techniques	For all techniques	X		
		— General requirements	X		
		— Initial setup and procedure	X		
		— Object preparation	X		
		— Test sensitivity for different techniques		X	
		— Adjustment		X	
		— Calculation of leakage rate		X	
	Chemical detection with ammonia	— Physical principles involved		X	
		— Type of reagent		X	
		— Reagent application		X	
		— Post-test cleaning		X	
	Vacuum box using internal tracer gas				
	Vacuum box applying the tracer gas in the opposite side				
	Pressure technique by accumulation by sniffing test	Object surface scanning	X		
		Adjustment (when applicable)		X	
	Fundamental on pressurization-evacuation test (bombing)	Object preparation		X	
		Initial setup and procedure		X	
		Calculation of leakage rate		X	
	Vacuum chamber technique				
10.7 Evaluation and reporting	Test data report filing		X		
	Results analysis and evaluation on the base of acceptability criteria and applicable proceeding			X	X
	Leak test procedures compilation	Reference standards and other documents		X	X
		Technique proceeding and module related to drafting			X
10.8 Assessment	Analysis through alternative techniques or methods			X	
	Acceptability criteria assessment in collaboration with project engineer specialist and manufacturing managers				X

Table 12 *(continued)*

Content			Level 1	Level 2	Level 3
	Ergonomic analysis through alternative techniques or methods				X
10.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instructions		X	
		Working correctly to written instructions	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
10.10 Developments	Special industrial installation			X	
	New development for industrial and R&D				X

11 Acoustic emission testing (AT) — Levels 1, 2 and 3

The acoustic testing training shall be in accordance with Tables 13 and 14.

Table 13 — General content

General		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
11.1	Introduction to terminology and history of acoustic emission testing (AT)	1	1	2
11.2	Physical principles of the method and associated knowledge	8	12	14
11.3	Product knowledge and capabilities of the method and its derived techniques	11	12	12
11.4	Equipment	14	16	13
11.5	Information prior to testing	11	13	24
11.6	Testing	42	18	4

Table 13 *(continued)*

General		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
11.7	Evaluation and reporting	11	15	8
11.8	Assessment	1	8	10
11.9	Quality aspects	1	2	5
11.10	Developments	0	3	8

NOTE For acoustic emission testing, training hours do not include pressure test safety training.

Table 14 — Acoustic emission testing (AT) — Levels 1,2 and 3

Content			Level 1	Level 2	Level 3
11.1 Introduction to terminology and history of acoustic emission testing (AT)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a "product"?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of acoustic emission testing (AT)	Definition	X	X	X
		Applicability and limitations	X	X	X
	Relevant standards	ISO 12716	X	X	X
11.2 Physical principles and associated knowledge	Physical principles of acoustic emission testing sources (mechanism in analogy to earthquakes)	Relevant standards	X		
		General principles	X		
		Overview	X		
		Visual demonstration	X		
		Frequency range		X	
		Source characteristics		X	
		Effect of dislocation			X
		Effect of stress on the waves			X
		Modes of fracture			X
	Characteristics of Acoustic Emission testing	Transient emission	X		
		Continuous emission	X		
		Amplitude	X		
		Frequency range	X		
		Effect of source dimension		X	
		Effect of source velocity		X	
		Source propagation		X	
		Loading		X	
		— Type of loading		X	
		— Effect of repeated loading			X
		Kaiser effect	X	X	
		— Overview	X		
		— In different materials		X	

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
		Acoustic emission testing during hold periods			X
		Felicity effect			X
		Felicity ratio			X
	Sources of acoustic emission testing	Metals	X	X	X
		Composites	X	X	X
		Other materials	X	X	X
		Dislocation	X	X	X
		Plastic deformation	X	X	X
		Inclusions	X	X	X
		Crack growth	X	X	X
		— Critical and sub-critical crack growth	X	X	X
		— Fatigue crack	X	X	X
		— Ductile crack growth	X	X	X
		Corrosion	X	X	X
		— Stress corrosion cracking	X	X	X
		Crack surface friction	X	X	X
		Leak	X	X	X
		Mechanical friction	X	X	X
		Loose parts	X	X	X
		Non detectable sources	X	X	X
		Others			X
	Wave propagation	Types of elastic waves	X		
		Longitudinal waves	X		
		Transverse waves	X		
		Rayleigh waves	X		
		Lamb waves		X	
		Wave parameters	X		
		Wave motion and velocity		X	
		Mode conversion		X	
		Reflection and refraction		X	
		Wave attenuation		X	
		— Attenuation vs frequency			X
		Wave dispersion		X	
		Diffraction			X
		Geometric effects		X	
		Shadowing effects		X	
		Anisotropic propagation			X
		Wave propagation in fluids			X
		Influence of fluids			X
	Source location	One sensor location	X		
		Linear location with delta-t	X		
		Planar location with delta-t	X		

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
		Continuous emission	X		
		Algorithm details			X
		— Zone location (algorithm knowledge)		X	
		Thin-walled and thick-walled structures		X	
		Location uncertainty		X	
		Three-dimensional location			X
		Guard sensors		X	
		Cross-correlation			X
		Neighbourhood relations			X
		Accurate locations using analysis			X
11.3 Product knowledge and related capability of the method and derived techniques	Fields of application of acoustic emission testing	Outline of different structures	X		
		— Pressure equipment		X	
		— Storage tanks		X	
		— Pipelines and piping systems		X	
		— Machines			X
		— Other components			X
		Outline of different materials	X		
		Leak detection		X	
		Loading possibilities			X
		— Influences of loading			X
	Fundamentals of material sciences and basic knowledge of mechanical properties	Creep		X	
		Welding		X	
		Fracture mechanics			X
		Significant test for materials properties verification			X
	Pressure equipment	Normal test performance of pressure equipment	X		
		Advantages and disadvantages of Acoustic emission testing on pressure equipment		X	
		Differences between acoustic emission testing and other techniques			X
	Product standards and codes	Outline of relevant standards associated with acoustic emission testing	X		
		Product standards, their influence on acoustic emission testing		X	
		Directives for non-pressurized equipment			X
		Relevant standards associated with acoustic emission testing			X

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
11.4 Equipment	Sensors	Piezoelectricity	X		
		Construction	X		
		Frequency response	X		
		Wide-band and resonant sensors	X		
		Coupling and sensitivity	X		
		Integral electronics	X		
		Single ended/differential	X		
		Connectors	X		
		Cables	X		
		Adjustment methods		X	
		Sensor selection		X	
		Ground-loop		X	
		Temperature effects		X	
		Acoustic impedance		X	
		Wave guide		X	
		Wave mode response aperture effect			X
		Reciprocity adjustment (ISO/TR 13115)			X
		Special sensors			X
		Shielding			X
		Impedance matching			X
		Noise susceptibility			X
		Simulated AT sources			X
	Preamplifiers	Single ended/differential	X		
		Unit of gain (dB scale)	X		
		Electronic noise	X		X
		Filters	X		
		— Filter types			X
		— Frequency filter selection		X	
		Cable length effects		X	
		Common mode rejection		X	
		Signal saturation		X	
		Input capacity			X
	Signal processing	Acoustic emission testing parameters (ISO 12716)		X	
		Energy (true, MARSE, alternative)		X	
		Continuous signal	X		
		Transient signal	X		
		Background noise	X		
		ASL	X		
		RMS	X		
		Amplitude	X		

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
		Threshold	X		
		Single- vs multi-channel system	X		
		Acquisition rate		X	
		Waveform digitization		X	
		Waveform recording		X	
		Digital vs analogous signal			X
		System parameter definition and selection			X
		Distribution techniques			X
		Spectral analysis			X
		Cascaded hits			X
		Continuous mode measurement			X
		Industrial dedicated systems			X
	Source location processing	Algorithm	X	X	X
		— Overview	X		
		— Knowledge		X	
		— Details			X
		— Selection		X	
		Linear location	X		
		Zone location	X		
		Hit-sequence location	X		
		Planar location	X		
		Three-dimensional location		X	
		Location uncertainty		X	
		Guard channels		X	
		Wave mode influence			X
		Neighbourhood relations			X
		Cross-correlation technique			X
		Factors affecting errors on location			X
	Advanced signal processing	External parameters	X		
		Distribution plots	X		
		Correlation plots	X		
		FFT		X	
		Waveform feature extraction		X	
		Timing considerations		X	
		Pattern recognition			X
		Signal averaging			X
		Waveform recording for cross-correlation			X
	Equipment adjustments	Sensor verification in lab	X		
		Sensor adjustment in lab		X	
		Acoustic emission testing system verification in lab	X		

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
		Acoustic emission testing system adjustment in lab		X	
		Applicable standards		X	
		Different adjustment procedures			X
	Fundamental of informatics	Knowledge and use of computers	X		
		Knowledge of software		X	
11.5 Information prior to test	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
		Documents			X
		Presentation of the standards, codes and procedures			X
11.6 Testing	Equipment set-up	Sensor placement	X		
		Equipment verification	X		
		Noise identification	X		
		— Noise elimination	X		
		Velocity and attenuation measurement	X		
		Location and simulated sources	X		
		Noise elimination	X		
		Factors affecting the selection of the test equipment		X	

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
		Loading procedure and actions during the tests			X
	Test performance	Loading procedure	X	X	
		Actions during the tests	X	X	
	Data acquisition and data display during test	Data acquisition	X		
		Significance of the plots for data display (time-based, load-based, location, correlation)	X		
		Comparison with the verification	X		
		Comparison with location of simulated source	X		
		Establishment of the acceptance criteria		X	
		Selection of plots, correlation and distributions		X	
		On-line evaluation			X
	Necessary actions during the test	Stop criteria	X		
		Verification of on-line detected Acoustic emission testing sources by other NDT methods		X	
		Interpretation of the relation between the acoustic emission testing source and the result of the adjoining NDT method			X
11.7 Evaluation and reporting	Data display	Time-based plots	X		
		Load-based plots	X		
		Parameter-based plots	X		
		Location plots	X		
		Distribution plots	X		
		Correlation plots	X		
		Acoustic emission testing source correlation		X	
		Advanced data display (pattern recognition)			X
	Data interpretation	Noise and other non-relevant identification	X		
		Acoustic emission testing behaviour vs applied load	X		
		Post processing noise identification and filtering		X	
		Source activity		X	
		Advanced filtering processes			X
	Data evaluation	Source severity		X	
		Source criticality		X	
		Advanced evaluation processes			X
	Documentation and reporting	Documentation of the results	X		
		Report according to relevant standards		X	

Table 14 *(continued)*

Content			Level 1	Level 2	Level 3
11.8 Assessment	Product standards and acceptance criteria	Implementation of the acceptance criteria into the testing instruction		X	
		Implementation of the acceptance criteria into the testing procedure			X
		Interpretation of the acceptance criteria in product standards			X
	Acoustic emission testing source evaluation and test results	Outline for the source validation	X		
		Relations between acoustic emission testing and physical sources		X	
		Interpretation of connection between acoustic emission testing and physical sources			X
		Sophisticated data treatment techniques			X
11.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instruction	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
11.10 Developments	New developments in acoustic emission testing and associated NDT techniques	New developments in the field of NDT (differences)			X

12 Visual testing (VT) — Levels 1, 2 and 3

The visual testing training shall be in accordance with Tables 15 and 16.

Table 15 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
12.1	Introduction to terminology and history of Visual testing (VT)	3	4	8
12.2	Physical principles of the method and associated knowledge	3	12	10
12.3	Product knowledge and capabilities of the method and its derived techniques	18	13	8
12.4	Equipment	12	8	8
12.5	Information prior to testing	3	8	21
12.6	Testing	12	12	5
12.7	Evaluation and reporting	37	19	10
12.8	Assessment	3	4	2
12.9	Quality aspects	6	12	22
12.10	Developments	3	8	6

Table 16 — Visual testing (VT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
12.1 Introduction to terminology and history of visual testing (VT)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a “product”?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT Methods	X	X	X
	Purpose of visual testing (VT)	Definition	X	X	X
		Applicability and limitations	X	X	X
		Extended overview of Visual Testing applications	X	X	
		Use of visual testing as a complement to other NDT methods	X	X	
	Terminology		X	X	X
12.2 Physical principles and associated knowledge	Fundamentals	Goals and principles of visual testing	X	X	
		Comprehensive knowledge and understanding of the physical principles and physics of light	X	X	X
		Optical performance	X	X	
		— Polarization of light	X	X	
		— Stroboscopic principles	X	X	
		— Dispersion	X	X	
		— Refraction and refractive index	X	X	
		— Reflection	X	X	

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
		— Fluorescence	X	X	
		— Advantages and disadvantages of different wavelengths of optical radiation (UV, IR), including colour temperature	X	X	X
	Vision	The eye	X	X	
		— Operation	X	X	
		— Construction	X	X	
		— Vision limitations	X	X	
		— Adaption and accommodation	X	X	
		— Disorders	X	X	
		— Vision ranges	X	X	X
		— Effects of disorders	X	X	X
	Lighting	Transmission	X	X	
		Reflection	X	X	
		Absorption	X	X	
		Physics of light	X	X	
		Electromagnetic radiation	X	X	
		Visible wavelengths	X	X	
		Types of light sources	X	X	X
		— Natural	X	X	X
		— Artificial — including laser	X	X	X
		LED light sources (advantages and disadvantages)			
		— Different wavelengths of optical radiation (UV, IR)			X
		— Colour temperature		X	X
		— LED light sources	X	X	X
		Photometry	X	X	
		Light levels	X	X	
		Light measurement	X	X	
		Luminance	X	X	
		— Lighting levels	X	X	
		— Lighting techniques	X	X	
		— Contrast	X	X	
	Optical principles	Operation of lenses		X	
		Operation of magnifiers		X	
		Image construction		X	
		Virtual images		X	
		Chromatic aberration		X	
		Geometric distortion		X	
		Magnification principles		X	
	Camera and photo sensor operation and principles	Optical filters			X
		Construction of digital images and problems			X

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
		Image processing			X
		Image analysis			X
		Image compression and transmission			X
		Image storage			X
		Resolution			X
		Video monitors			X
		Other monitors			X
		Light meters and photometers			X
	Principles of operation of fibre bundles and lenses	Coherent			X
		Incoherent			X
	Photogrammetry				X
	Visual perception	What the eye sees		X	
		What the mind sees		X	
		What others perceive		X	
		What the designer, engineer, etc., sees		X	
	Material attributes affecting the test	Colour	X	X	
		Surface condition	X	X	
		Surface preparation	X	X	
		Cleanliness	X	X	
		Shape	X	X	
		Size	X	X	
		Temperature	X	X	
		Texture	X	X	
		Type	X	X	
		Surface finish	X	X	
	Environmental and physiological factors	Atmosphere		X	
		Comfort		X	
		Perspective		X	
		Distance		X	
		Accessing		X	
		Fatigue		X	
		Health		X	
		Humidity		X	
		Mental attitude		X	
		Position		X	
		Safety		X	
		Temperature		X	
		Cleanliness		X	
	Direct and remote methods		X	X	
	Vision	Requirements	X	X	
		Employer's responsibility		X	

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
12.3 Product knowledge and related capability of the method and derived techniques		Outline of basic flaws detected with visual testing as necessary to work in a specific sector	X		
		Evaluation of surfaces			X
		Test objects and flaws		X	X
		Basic production and degradation process		X	X
		Terms, origin and nature and appearance of flaws		X	X
		Product technology sectors		X	X
		Basic metallurgy of the process/component		X	X
		Welding/joining methods		X	X
		Cladding and buffering		X	X
		— Wrought product production methods		X	X
		— Cold working processes		X	X
		— Heat treatment processes		X	X
		Roughness and waviness			X
		Definition of shape and geometry of flaws			X
		Material composition		X	X
		— Surface finishing methods		X	X
		— Basic foundry technology		X	X
		— Machining and material removal processes		X	X
		— Polymers/composites		X	X
		In-service aspects		X	X
		— Service induced flaws		X	X
		— Mechanically		X	X
		— Thermally		X	X
		— Tribology		X	X
		— Wear		X	X
		— Chemical		X	X
		— Electrochemical		X	X
	Capability and limitations of visual testing	Overview/awareness	X		
		Detect ability		X	
		— Flaw size		X	
		— Shape		X	
		— Orientation/position		X	
		— Flaw types		X	
		— Surface condition effects		X	
		— Equipment limitations		X	
		— Lighting effects		X	
	Associated techniques	Gauging		X	

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
		Comparators		X	
		Measurement		X	
		Thermographic imaging		X	
		Replication		X	
12.4 Equipment	Introduction and applications	Mirrors	X	X	X
		Magnifiers	X	X	X
		Borescopes	X	X	X
		Fibrescopes	X	X	X
	Photographic and video	Imaging cameras	X	X	
		Video monitors	X	X	
		Light sources and special lighting	X	X	
		Gauges	X	X	
		Templates	X	X	
		Scales	X	X	
		Special tools			X
		Automated systems		X	X
		Computer-enhanced systems		X	X
		Demonstration test piece	X	X	
		Resolution targets	X	X	X
		Graticules		X	X
		Effect on test arrangement			X
		Evaluation of equipment to fulfil a particular task			X
		Development of verification for equipment performance			X
		— Choice/design			X
		— Application of demonstration test pieces			X
	Image recording, transfer and storage equipment	Equipment selection		X	
		Equipment limitations		X	
		Verification of equipment	X	X	
		Procedure for control, maintenance and adjustment of equipment			X
	Sizing of indications	Imaging systems		X	
		Special optical systems		X	
		Special equipment requirements (i.e. underwater, radiation resistant)	X	X	
12.5 Information prior to test	Information about the test object	Identification or designation of material		X	X
		— Object to be tested		X	X
		— Kind of manufacture		X	X
		— Catalogue of defects		X	X

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
		— Extent of test coverage		X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure		X	X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out		X	X
		Standard and codes assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		The illumination (type, level and direction)		X	
		Post-test documentation		X	
		Visual testing equipment to be used		X	
		Demonstration test piece and inspection checkpoints		X	
		Requirement for recorded images		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
		Documents		X	X
		Presentation of the standards, codes and procedures			X
12.6 Testing	Test set-up	Demonstration test pieces	X	X	
		Resolution targets	X	X	
		Adjustment		X	
		Written instruction		X	X
		Written procedure		X	X
12.7 Evaluation and reporting	Reporting results	Reference to test standards	X	X	
		Adjustment status	X	X	
		Reference points for location of indications	X	X	
		Classification of indications	X	X	
		— Instructed acceptance criteria	X	X	
		— Reports and documentation	X	X	

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
		— Reporting verification results	X	X	
	Control and monitoring of test results	Interpretation		X	X
		Evaluation		X	X
		— Objective		X	X
		— Subjective		X	X
		Reporting of results to specifications and standards		X	X
		Completion of adjustment forms		X	X
	Developing report forms	Organization of final forms			X
		Storage of final forms			X
		Distribution of final forms			X
		Investigation of suitable codes and product standards for each application			X
		Acting as a reference point for level 2 advice for interpretation and evaluation			X
12.8 Assessment	Classification and assessment of observations	Acceptance criteria		X	X
		— Codes		X	X
		— Standards		X	X
		— Written instructions		X	X
		— Level 3 reference where no codes or standards exist		X	X
		— Design specifications			X
		By comparison		X	X
		By measurement		X	
		Automated evaluation (e.g. pattern recognition)		X	
		Recording		X	
		Reporting		X	
		Analyse results			X
		Translation of codes, standards and design specifications etc. into clear acceptance criteria to be written into procedures and instructions			X
		Finding information or assistance to investigate observations not covered by codes, standards and develop acceptance criteria			X
		Training of Level 1 and 2 for acceptance criteria			X
12.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X

Table 16 *(continued)*

Content			Level 1	Level 2	Level 3
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instructions	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	X
		NDT method selection			X
		Job specific training			X
		Equipment verification	X	X	X
12.10 Developments	Importance of investigating current and developing technology and method of application				X
	Summary of latest developments				X

13 Thermographic testing (TT) — Levels 1, 2 and 3

The thermographic testing training shall be in accordance with Tables 17 and 18.

Table 17 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
13.1	Introduction to terminology and history of thermographic testing (TT)	1	1	1
13.2	Physical principles of the method and associated knowledge	12	12	23
13.3	Product knowledge and capabilities of the method and its derived techniques	30	24	3
13.4	Equipment	15	9	13
113.5	Information prior to testing	1	11	13
13.6	Testing	30	26	18
13.7	Evaluation and reporting	10	7	11
13.8	Assessment	0	5	6
13.9	Quality aspects	1	4	7
13.10	Developments	0	1	5

Table 18 — Thermographic testing (TT) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
13.1 Introduction to terminology and history of thermographic testing (TT)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a "product"?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of thermographic testing (TT)	Definition	X	X	X
		Applicability and limitations	X	X	X
	Terminology		X	X	X
13.2 Physical principles and associated knowledge	Heat transfer	Heat/temperature/energy	X	X	
		Thermodynamic law	X	X	
		Phase	X	X	
		— Solid	X	X	
		— Liquid	X	X	
		— Gas	X	X	
		Variations of temperature scale	X	X	
		Heat conduction fundamentals	X	X	
		— Fourier's law	X	X	
		Heat convection fundamentals	X	X	
		— Newton's law of cooling	X	X	
		Heat radiation fundamentals	X	X	
		— Plank's law	X	X	
		— Wien's law	X	X	
		— Stefan-Boltzmann law	X	X	
		Evaporation	X	X	
		— Introduction	X		
		— Fundamentals		X	
	Infrared engineering	Electromagnetic spectrum	X		
		— Definition of infrared range	X		
		Terminology	X		
		Emissivity	X		
		Reflectivity	X		
		Transmissivity	X		
		Absorptivity	X		
		Black body/grey body	X		
		— Selective radiator		X	
		Kirchhoff's law	X		
		Cavity radiation effect	X		
		Atmospheric window	X		
		Thermal property of materials	X		

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
		Emissivity of materials	X		
		Steady state/transient condition	X	X	X
		Thermal diffusivity		X	X
		Thermal contact resistance		X	X
		Theoretical temperature estimation/calculation		X	X
		Absorption		X	X
		— Atmospheric		X	X
		— Various gas			X
		Lambert-Beer law		X	X
		Methods for temperature measurement		X	X
		— With or without contact description of principle of different sensors		X	X
		Special emissivity of materials			X
		Photometry			X
		Geometrical optics			X
13.3 Product knowledge and related capability of the method and derived techniques	Principles of thermography	Characteristic of thermography	X	X	
		Technique based on detection	X	X	
		— Adiabatic temperature field	X	X	
		— Delamination/crack	X	X	
		— Self-heating	X	X	
		— Cavity radiation effect	X	X	
		— Active method	X	X	
		— Passive method	X	X	
		— Qualitative thermography	X	X	
		— Quantitative thermography	X	X	
		Selection criteria of technique		X	X
		Other temperature measurement equipment and their measurement principles			X
		Adjustment	X	X	X
	Thermoelastic stress measuring method	Thermoelastic effect		X	X
		Principle of the method		X	X
		Lock-in technique			X
		Temperature difference imaging technique			X
		Thermoelastic property of materials			X
		Stress resolution			X
		Load frequency range			X

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
	Various flaws and their cause	Electricity facilities/ electronic device	X	X	
		Machinery	X	X	
		Plant facility	X	X	
		Buildings and structures	X	X	
		Materials	X	X	
		Design and construction of new materials (CFRP, GFRP, sandwich structures, etc.)			X
		Capability of method, POD			X
		Combination of methods (different thermal loading devices, different NDT methods)			X
13.4 Equipment	Thermographic instrument	Basic components and functions	X		
		Characteristic of sensors	X		
		— Quantum type	X		
		— Thermal type	X		
		Factors affecting emissivity	X		
		Minimum detectable dimension (MDD)	X	X	
		— Spatial resolution	X		
		— Distance	X		
		Minimum detectable temperature difference (MDTD)		X	X
		Minimum resolvable temperature difference (MRTD)		X	X
		Field of view (FOV)	X		
		Knowledge of Image processing	X		
		— Colour palettes	X		
		— Frame averaging	X	X	
		— Pixel correction	X		
		Signal process flow in instruments		X	
		Mechanism and principle of sensors		X	
		Selection criteria of sensors		X	
		— Bolometer		X	
		— Thermocouple		X	
		— Thermopile		X	
		— Pyroelectric sensor		X	
		Scanning method of sensors		X	
		Measurement wavelength band		X	
		— Short wavelength type		X	
		— Long wavelength type		X	

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
		Selection criteria of measurement wavelength band		X	
		Noise equivalent temperature difference (NETD)		X	
		Number of pixels		X	
		Exposure time		X	
		Dynamic range			X
		Standard specimen			X
	Accessories	Filters	X		
		— Varieties and roles of filters	X		
		— Selection criteria of filters		X	
		Varieties and roles of optical lens	X		
		— Selection criteria of optical lens		X	
		— Optics			X
		— Close-up lenses			X
		— Immersion lenses			X
		Varieties and roles of other accessories	X		
		— Emissivity of black paint and tape		X	
		— Selection criteria of infrared mirror		X	
		— Sensor window materials		X	
		— Selection criteria of sensor window including anti-reflection coat			X
		Dual band and dual colour IR-cameras			X
	Thermal loading device	Varieties	X		
		— Contact thermal loading	X		
		— Radiation heating	X		
		— Flash lamp heating/ step heating	X		
		— Electricity heating	X		
		— Other thermal loading devices	X		
		Selection criteria of thermal loading device		X	
		Thermoelastic stress measuring method		X	
		Efficiency			X
		Uniformity			X
		Reproducibility			X
		Safety			X

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
13.5 Information prior to test	Information about the test object	Identification or designation material	X	X	X
		— Object to be tested	X	X	X
		— Kind of manufacture	X	X	X
		— Catalogue of defects		X	X
		— Extent of test coverage	X	X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	
		Performing inspection in accordance with written instruction	X		
		Documents			X
		Presentation of the standards, codes and procedures			X
13.6 Testing	Test condition	Environmental condition	X		
		Recognition of error factor	X		
		Recognition and correction of		X	
		— Atmospheric absorption	X	X	
		— Background radiation	X	X	
		Instructions for transparent objects		X	
		Automated testing in production line scanner			X
		Control and adjustment of production process			X
		FEM simulation for parameter expansion, prediction of results and reconstruction			X
	Operation of infrared instruments	Setting of emissivity	X		
		Knowledge of sensor correction	X		

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
		Understanding of spatial resolution	X		
		Face angle dependence of emissivity		X	
		— Setting of face angle	X		
		Temperature dependence of emissivity		X	
		— Selection of temperature range	X		
		— Setting of temperature span and level	X		
		Setting of frame time	X		
		Instructions for infrared mirror	X		
		Adjustment of focus	X		
		Reference object	X		
		Measurement of emissivity	X	X	
		Wavelength dependence of emissivity	X	X	
		Surface roughness dependence of emissivity	X	X	
		Oxide film thickness dependence of emissivity	X	X	
		Emissivity of quasi-blackbody	X	X	
	Special cases	Thermoelastic stress analysis (TSA)			X
		Testing of semi-transparent materials			X
		High temperature applications			X
		Measurements at high speed			X
		Gas detections			X
	Various flaws and their cause	Electricity facilities	X	X	
		Electronic device	X	X	
		Machinery	X	X	
		Plant facility	X	X	
		Buildings and structures	X	X	
		Materials	X	X	
13.7 Evaluation and reporting	Data processing	Varieties and roles	X		
		Thresholding		X	
		Averaging		X	
		Background subtraction		X	
		Subtraction		X	
		Lock-in		X	
		Motion compensation		X	
		Trend processing		X	
		Selection criteria of data processing flow		X	

Table 18 *(continued)*

Content			Level 1	Level 2	Level 3
	Recording	Requirements	X	X	
	Reporting	Requirements	X	X	
		Characterization		X	
		Interpretation of indications		X	
		Evaluation of indications		X	
	Use of complimentary NDT methods	Interpretation of relevant standards and codes			X
		Evaluation (conventional approach, validated method			X
		Distinction defect/artifact			X
		Acceptance criteria			X
		Level of significant variation			X
		Storage and recording process			X
13.8 Assessment	Evaluation and confirmation of test reports	Application of acceptance		X	
		— Criteria according to standards, codes and procedures		X	
		— Acceptance and classification criteria			X
		— Significance of discontinuities			X
		— With and without codes and standards			X
13.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	
		Working correctly to written instruction	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	
		Use of correct test parameters		X	
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
13.10 Developments	General information			X	
	Newest developments	Industrial applications			X
		Scientific applications			X

14 Strain gauge testing (ST) — Levels 1, 2 and 3

The strain gauge testing training shall be in accordance with Tables 19 and 20.

Table 19 — General content

Content		Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
14.1	Introduction to terminology and history of strain gauge testing (ST)	6	2	2
14.2	Physical principles of the method and associated knowledge	16	18	25
14.3	Product knowledge and capabilities of the method and its derived techniques	12	17	18
14.4	Equipment	13	8	15
14.5	Information prior testing	22	15	5
14.6	Testing	16	13	15
14.7	Evaluation and reporting	13	17	5
14.8	Assessment	0	6	5
14.9	Quality aspect	2	4	5
14.10	Developments	0	0	5

Table 20 — Strain gauge testing (ST) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
14.1 Introduction to terminology and history of strain gauge testing (ST)	History		X	X	X
	Purpose of NDT	What is testing?	X	X	X
		What is the purpose of NDT?	X	X	X
		At what stage of life is NDT performed on a “product”?	X	X	X
		How does it add value?	X	X	X
		Who may carry out NDT?	X	X	X
		Main NDT methods	X	X	X
	Purpose of strain gauge testing (ST)	Definition	X	X	X
		Applicability and limitations	X	X	X
14.2 Physical principles and associated knowledge	Physical principles	Load and deformation	X		
		Stresses and strains on surface	X	X	X
		— Definitions	X	X	
		— Relationships	X	X	
		— Coordinate conversions		X	
		— Mohr’s stress and strain circles		X	
		— Stresses and strain on surface		X	
		— Principle stresses and strains		X	

Table 20 *(continued)*

Content			Level 1	Level 2	Level 3
114.3 Product knowledge and related capability of the method and derived techniques	Product knowledge	Materials testing			X
		Plane stress			X
		Typical fields of stress and strain			X
		Stress and strain in pressure vessel			X
		Thermal stain			X
		Dynamic strain			X
	Electrical circuit	Fundamentals	X	X	
		— DC circuit	X	X	
		— AC circuit		X	
	Strain gauge testing	Characteristics	X	X	X
		Principles	X	X	X
		Structure	X	X	X
14.4 Equipment	Measurement system	Static strain measurement	X	X	
		Dynamic strain measurement	X	X	
		Power supply for bridge circuit	X	X	
	Strain gauges	Various strain gauges	X	X	
		Characteristics	X	X	X
		Properties		X	X
		Categories		X	X
		Gauge lead		X	
		Applicable limit		X	X
		Selection		X	
		Bridge circuit	X	X	X
		— Principles	X	X	X
		— Wire connection	X	X	X
		— Equivalent strain	X	X	
		Strain meter and recorder	X	X	X
		— Static strain meter	X	X	
		— Dynamic strain meter	X	X	
		— Input connector	X	X	
		Recorder	X	X	
		— Categories		X	X
		Response of measurement system		X	X
	Transducer	Characteristics		X	X
		Measurement principle		X	X
		Various		X	X
14.5 Information prior to test	Information about the test object	Identification or designation material		X	X
		— Object to be tested		X	X
		— Kind of manufacture		X	X
		— Catalogue of defects		X	X

Table 20 *(continued)*

Content			Level 1	Level 2	Level 3
		— Extent of test coverage		X	X
	Test conditions and application of standard	Accessibility		X	X
		Infrastructure			X
		Particular test conditions		X	X
		Application standard		X	X
		Stage of manufacture or service life when testing is to be carried out			X
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria			X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Correction of measured values	X	X	
		Correction of gauge factor	X	X	
		Correction including resistance of gauge lead		X	
		Apparent strain caused by temperature change		X	
		— Self-temperature compensated strain gauge		X	
		Temperature compensation by using active-dummy method		X	
		Information of strain gauge		X	X
		— Lead		X	X
		— Gauge terminal		X	X
		— Cement		X	X
		— Confirmation after attachment		X	X
		Damp proofing		X	X
		Testing errors and their solutions		X	X
		— Error due to attaching angle of strain gauge		X	
		— Incompatibility of bridge circuit balance		X	
		— Instability of measurement		X	
		— Noise		X	
		Long-time measurement		X	
		Post-test documentation		X	
	Instructions	Preparation of written procedure			X
		Preparation of written instruction		X	

Table 20 *(continued)*

Content			Level 1	Level 2	Level 3
		Performing inspection in accordance with written instruction	X		
		Documents			X
		Presentation of the standards, codes and procedures			X
14.6 Testing	Preparation	Attachment of strain gauge	X	X	
		— Preparation before attachment	X	X	
		— Attachment	X	X	
		— Confirmation after attachment	X	X	
		Preparation of measurement system		X	
		Damp proofing	X	X	
		Procedure of strain testing (static strain)	X	X	X
		Measuring	X	X	
		— With transducer		X	X
		— Adjustment of transducer		X	X
		— Measurement		X	X
		Procedure of strain testing (dynamic strain)	X	X	
		Connection of equipment	X	X	
	Strain gauge testing in specific conditions and environments	Introduction			X
		Testing of large strain			X
		Testing under low and high temperatures			X
		Testing in water and at high pressure			X
		Testing in magnetic and electrical fields			X
		Testing for rotating components			X
		Testing of impulsive strain			X
		Testing of residual strain			X
14.7 Evaluation and reporting		Recording and reporting of strain data	X	X	
		Evaluation of strain data		X	X
		— Correction of strain data		X	
		Stress analysis from strain data		X	X
		Reporting results		X	X

Table 20 *(continued)*

Content			Level 1	Level 2	Level 3
14.8 Assessment		Criteria for failure and strength		X	X
		— Allowable stress and safety factor		X	X
		— Fatigue			X
		— Fracture mechanics			X
14.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Developing written instruction		X	X
		Working correctly to written instruction	X		X
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	X
		NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
14.10 Developments	Other strain testing methods	Principles and characteristics			X
		Optical method			X
		Infrared method			X
		X-ray stress measuring method			X
		Magnetic method			X
		Ultrasonic method			X
		Coating method			X

15 Developing techniques

The intent of this clause is to provide recommendations on training pertaining to developing techniques. It is recommended that this training has a minimum prerequisite of Level 2 certification in the main method associated with this emerging technology (see Tables 21 to 23).

Table 21 — Ultrasonic time-of-flight diffraction (UT-TOFD) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
15.1.1 Introduction to terminology and history of ultrasonic time-of-flight diffraction (UT-TOFD)	History		X	X	X
	Introduction to ultrasonic time-of-flight diffraction technique	Overview	X	X	X
			X	X	X
15.1.2 Physical principles and associated knowledge	Mathematical and physical basics	Basics of sound beam		X	
		Waves		X	
		— Sinusoidal movement		X	
		— Amplitude		X	
		— Frequency		X	
		— Wavelength		X	
		— Propagation velocity		X	
		— Longitudinal waves		X	
		— Transverse waves		X	
		Principle of wave-diffraction		X	
		Sound-field of UT-TOFD probes		X	
		Visualization of UT-TOFD images		X	
		Probe centre separation (PCS)		X	
15.1.3 Product knowledge and related capability of the method and derived techniques	Various defects related to the manufacturing processes and service-induced defects elated to the defined sectors	Defects related to the manufacturing processes (welding)		X	
		Implementation of UT-TOFD technique according to products and to expected discontinuities (weld defects)		X	
	Overall properties of specimen	Influence of surface conditions		X	
		Geometry		X	
		Attenuation		X	
		Reference reflectors (SDH), notch)		X	
15.1.4 Equipment	Test instrument and combined equipment	UT-TOFD instrument		X	
		UT-TOFD probes		X	
		Adaption of probes to curved scanning surfaces		X	
		Encoders and scanning mechanisms		X	
		Different types of scanners		X	
		Reference blocks		X	
		Different reference blocks		X	
15.1.5 Information prior to test	Items to be defined by specification	Purpose		X	
		Extent of UT-TOFD testing		X	
		Information required by the operator		X	
		Written test instruction or procedure		X	
15.1.6 Testing		Setting of test range and sensitivity		X	

Table 21 *(continued)*

Content			Level 1	Level 2	Level 3
		Setup of probes		X	
		— Scan increment setting		X	
		— Geometry considerations		X	
		— Preparation of scanning surfaces		X	
		— Couplant and coupling techniques		X	
		Range and sensitivity settings		X	
		— Time window		X	
		— Time-to-depth conversion		X	
		— Sensitivity settings		X	
		— Checking of settings		X	
		Reference blocks		X	
		— Material		X	
		— Dimensions		X	
		— Shape		X	
		— Reference reflectors, SDH and notch		X	
		Interpretation and analysis of UT-TOFD images		X	
		— Assessing the quality of the UT-TOFD image		X	
		— Identification and classification of relevant UT-TOFD indications		X	
		— Determination of location and size		X	
15.1.7 Evaluation and reporting		Evaluation according to acceptance criteria		X	
		Test report		X	
		— Information relating to the test object		X	
		— Equipment		X	
		— Test technique		X	
		— Test results		X	
		Storage of data-files		X	
		Generation of reports		X	
		Near surface and opposite surface resolution		X	
		Defect location and length measurement		X	
15.1.8 Assessment		Evaluation and confirmation of test reports		X	
		Application of the acceptance criteria according to standards, codes and procedures		X	
		Offline evaluation using PC software		X	

Table 21 *(continued)*

Content			Level 1	Level 2	Level 3
15.1.9 Quality aspects	Personnel qualification	ISO 9712		X	
		Other NDT qualification and certification systems		X	
15.1.10 Developments	Not applicable				

Table 22 — Ultrasonic phased array testing (UT-PA) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
15.2.1 Introduction to terminology and history of phased array testing (UT-PA)	History				
	Introduction to ultrasonic phased array testing	Overview		X	
		Applicability and limitations			
		Difference between conventional and ultrasonic phased array techniques			
15.2.2 Physical principles and associated knowledge	Mathematical and physical basics	Basics of sound beam		X	
		Waves		X	
		— Sinusoidal movement		X	
		— Amplitude		X	
		— Frequency		X	
		— Wavelength		X	
		— Propagation velocity		X	
		— Longitudinal waves		X	
		— Transverse waves		X	
		Terms relating to sound		X	
		— Side lobes		X	
		— Grating lobes		X	
		— Artifacts spelling		X	
		Terms relating to arrays		X	
		— Active aperture		X	
		— Elementary aperture		X	
		— Primary axis of an array		X	
		— Secondary axis of an array		X	
		Influence of band width		X	
		Electronical beam steering and focusing of sound beams		X	
15.2.3 Product knowledge and related capability of the method and derived techniques	Defects related to the manufacturing processes	Welding		X	
		Forgings		X	
		Castings		X	
	Implementation of ultrasonic phased array techniques according to products and to expected discontinuities			X	

Table 22 *(continued)*

Content			Level 1	Level 2	Level 3
	Overall properties of specimen	Influence of surface conditions			
		Geometry			
		Attenuation			
		Reference reflectors			
		— Backwall			
		— Side drilled holes			
		— Flat bottom holes			
15.2.4 Equipment	Test Instrument and combined equipment	Phased array instrument		X	
		Multi-channel instrument		X	
		Transmitting delay		X	
		Receiving delay		X	
		Delay laws		X	
		Amplitude balancing		X	
		Multi group capability		X	
		Number of focal laws		X	
	Phased array probes	Linear array		X	
		Annular array		X	
		Annular sectorial array		X	
		Acoustic properties of wedge materials that affect phased arrays		X	
		Encircling array		X	
		1,5D array		X	
		Linear array with separate transmitters and receivers		X	
	Multi group capabilities	Number of focal laws		X	
	Encoders	Different types of scanners		X	
	Couplant and coupling techniques			X	
	Adjustment blocks	Block No. 1 according to ISO 2400		X	
		Block No. 2 according to ISO 7963		X	
		Reference block according to ISO 13588		X	
		Different reference blocks		X	
15.2.5 Information prior to test	Applied standards for UT — and ultrasonic phased array testing	Content		X	
		Requirements for procedures		X	
		Developing of test procedures		X	
15.2.6 Testing	Techniques	Linear scanning with 0 deg (forgings and castings)		X	
		Linear scanning with constant angle (welding)		X	
		Sectorial scanning (welding, forging)		X	
		Multigroup scanning		X	

Table 22 *(continued)*

Content			Level 1	Level 2	Level 3
		Range setting		X	
		— Single point adjustment		X	
		— Two point adjustment		X	
		Sensitivity setting		X	
		— Angle corrected gain (ACG)		X	
		— Reference reflectors (BW, SDH, FBH)		X	
		— Single reflector technique (reference height)		X	
		— Requirements for reference blocks		X	
		— DAC-method		X	
		— TCG-method		X	
		— DGS-method		X	
		Typical applications of phased array techniques		X	
15.2.7 Evaluation and reporting	Evaluation of indications	DGS-method		X	
		DAC-method		X	
		TCG-method		X	
		Distinction between defect and geometry echo		X	
		Location of defects		X	
		Interpretation and evaluation of indications		X	
		Sizing of defects		X	
		A-, E-, S-, B- and C-Scan interpretation		X	
	Reporting	Recording		X	
		Classifying of results according to written procedure		X	
		Storage of data-files		X	
		Generation of reports		X	
15.2.8 Assessment		Evaluation and confirmation of test reports		X	
		Application of the acceptance criteria according to standards, codes and procedures		X	
15.2.9 Quality aspects	Personnel qualification	ISO 9712		X	
		Other NDT qualification and certification systems		X	
15.2.10 Developments	Not applicable				

Table 23 — Magnetic flux leakage testing (MFL) — Levels 1, 2 and 3

Content			Level 1	Level 2	Level 3
15.3.1 Introduction to terminology and history of magnetic flux leakage testing (MFL)	Purpose of NDT	What is testing?	X		
		What is the purpose of NDT?	X		
		At what stage of life is NDT performed on a "product"?	X		
		How does it add value?	X		
		Who may carry out NDT?	X		
		Main NDT methods	X		
	Purpose of magnetic flux leakage testing (MFL)	Definition	X		
		Applicability and limitations		X	
15.3.2 Physical principles and associated knowledge	Magnetic fields	Basic principles of testing	X		
		Magnetic field characteristics	X		
		Flux line characteristics	X		
		Flux leakage theory	X	X	X
		Forster and other theories			X
		Finite element methods			X
		Factors that affect flux leakage fields		X	
		— Degree of magnetization		X	
		— Defect geometry		X	
		— Defect location		X	
		— Defect orientation		X	
		— Distance between adjacent defects		X	
	Magnetism by means of electric current	Principles of electricity	X		
		Field around a conductor	X		
		Right-hand rule	X		
		Field in ferromagnetic conductors	X		
		Indirect magnetization	X		
		— Longitudinal fields	X		
		— Transverse fields	X		
		Magnetization variables	X		
		— Current type (AC vs DC)	X		X
		— Hysteresis curve	X		
		— Permeability	X		
		— Factors affecting permeability	X		X
15.3.3 Product knowledge and related capability of the method and derived techniques	Factors affecting choice of sensing elements	Test conditions		X	
		Magnetization characteristics for various magnetic materials		X	
		Magnetization by means of electric fields		X	
		— Circular field		X	
		— Longitudinal field		X	

Table 23 *(continued)*

Content			Level 1	Level 2	Level 3
		— Value of flux density		X	
		Magnetization by means of permanent magnets		X	
		— Permanent magnet relationship and theory		X	
		— Permanent magnet materials		X	
		Selection of proper magnetization method		X	X
		— Type of part			X
		— Type of discontinuity			X
		— Speed of inspection			X
		— Location of discontinuity			X
		— Applications other than discontinuity detections			X
	Applications	Flaw detection		X	
		Sorting for properties related to permeability		X	
		Measurement of magnetic-characteristic values		X	
		Tank floor and side inspection		X	
		Wire rope inspection		X	
		Tube inspection		X	
		Intelligent pigs		X	
		Bar inspection		X	
15.3.4 Equipment	Detectors	Advantages/limitations			X
	Search coils	Rate of change in the normal component of flux leakage	X	X	
		Faraday's law	X	X	
		Factors that affect the output voltage	X	X	
		Advantages/limitations			X
	Hall effect search units	Principles	X	X	
		Factor that affect the output voltage	X	X	
	Instrument design	Read out selection			X
		— Monitor displays			X
		— Strip-chart recorder			X
		— Alarms			X
		— Sorting gates			X
		— Automation			X
		— Computerized data acquisition			X
		— Other			X
		Amplification			X
		Filtering			X
		Sensor configuration			X

Table 23 *(continued)*

Content			Level 1	Level 2	Level 3
15.3.5 Information prior to test	Information about the test object	Identification or designation material			
		— Object to be tested	X	X	
		— Kind of manufacture		X	
		— Catalogue of defects		X	
		— Extent of test coverage	X	X	
		Application standard		X	
		Application of specifications		X	
		Stage of manufacture or service life when testing is to be carried out		X	
		Application of operating procedures		X	
	Technique and sequence of performing test	Surface condition	X	X	
		Surface preparation	X	X	
		Post-test documentation	X	X	
		Presentation of the standards, codes and procedures		X	X
		Preparing written instruction		X	
		Preparing written procedure			X
15.3.6 Testing		Performing inspection to a written instruction	X		
		Supervision of testing personnel		X	X
	Parameters	Surface or subsurface flaw detection			X
		Magnetization			
		— Equipment	X	X	
		— Current type	X	X	
		— Type	X	X	
		Control of magnetization conditions			X
		— Values of the magnetizing parameters			X
		— Continuous vs residual method			X
		— Permeability			X
		— Saturation			X
		Technique		X	X
		— Correct use		X	X
		— Selection		X	X
		— Magnetic field strength		X	
		— Orientation		X	
		Signal-to-noise		X	X
		— Definition		X	
		— Relationship to flux leakage testing		X	

Table 23 *(continued)*

Content			Level 1	Level 2	Level 3
		— Methods of improving signal-to-noise ratio		X	
		— Noise suppression			X
		Response speed			X
		Skin effect			X
		Coupling		X	X
		— Lift off		X	X
		— Fill factor			X
		Signal processing considerations	X	X	X
		— Rectification	X		X
		— Amplification		X	X
		— Filtering	X	X	X
		Readout mechanism	X		X
		— Displays	X		X
		— Strip-chart recorder	X		X
		— Computerized data acquisition	X		X
		Recording of discontinuities	X		
		Reporting	X		
		Interpretation of indications		X	
	Treatment of components	Residual field		X	X
		— Condition requiring demagnetization		X	X
		— Level of residual		X	X
		— Influence on later use of material		X	X
		Demagnetization	X	X	X
		— Basic principles	X		
		— Minimal value of the magnetic field of demagnetization principles			X
15.3.7 Evaluation and reporting	Inspection conditions	Adjustment of test units	X		
		Batch test report	X	X	X
	Test report	Basics of evaluation		X	X
		Report of imperfections	X	X	
15.3.8 Assessment	Assessment of discontinuities	Relevant and non-relevant		X	
		Influence of manufacture		X	X
		Influence of material		X	X
		Characterization		X	X
15.3.9 Quality aspects	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems	X	X	X

Table 23 *(continued)*

Content			Level 1	Level 2	Level 3
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures and personnel)			X
		Written instruction	X	X	
		Traceability of documents			X
		Reliability of measurements			X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	
		NDT method selection			X
		Job specific training		X	X
		Equipment verification	X	X	X
15.3.10 Developments	Not applicable				

Annex A
(informative)

Alternative training hours for advanced radiographic techniques

Table A.1 — Trainings times for RT-training (in hours)

Technique	Required certificate	Level 1 hours	Level 2 hours	Level 3[c] hours
RT-F Film	None	40	80 + RT-F1 training[a,c]	40 + RT-F1,2 training[a,b]
	RT-D 1	32	80	40
	RT-D 2,3	32	40	32
	RT-D 2,3	—	60[c,d]	32
RT-D Digital	None	40	80 + RT-D1 training[a,c]	40 + RT-D1,2 training[a,b]
	RT-F1	32	80	40
	RT-F 2,3	32	40	32
	RT-F 2,3, RT-S 2,3	—	60[c,d]	32
RT-S Radioscopy	None	32	32 + RT-S1 training	32 + RT-S1,2 training[a,b]
	RT-F 2,3		32	32
	RT-D 2,3		32	32

Key

RT: radiographic testing method

RT-F: for film technique

RT-D: for digital technique (film replacement)

RT-S: for radioscopic technique

[a] Level 1 training not required if additional technical qualification can be proven (e.g. university).

[b] Additional basic training and examination by ISO 9712 required and practical examination in level 2.

[c] Direct access, only if additional technical qualification can be proven (e.g. university).

[d] Direct access, only if certified in level 2 or level 3.

NOTE ISO/TS 25108 provides requirements and recommendations for organizations providing training for non-destructive testing.

Enough clean examination test samples need to be available. This includes test samples of different product sectors, step wedges, shielding materials, etc.

If only one type of hardware is available for RT-D training, as DDA- or CR-systems for example, the training with one or both systems may be substituted by a virtual training with PC-based software modelling.

The virtual training software should have the following functionality:

— Input of different test objects (different material/geometry);

— Selection and positioning of image quality indicators (ISO 19232, ASTM E 1025, E 1742);

— Radiation sources: U/kV, I/mA, spectrum, source size, different gamma sources;

— Exposure geometry: distances, radiation angles;

— Detectors: DDA, CR, film basic spatial resolution, pixel size, photon noise, detector noise, efficiency;

— Attenuation law and build up factor;

— Data format: Input CAD files (e.g. *.stl), output 16-bit image data in TIFF, DICONDE or RAW. It is important that data be compatible with the used viewing software;

— Image processing software in accordance with ISO 17636-2:2013, 7.9.

Additionally, the following accessories should be available:

— Different sets of IQIs (ISO 19232) for the used materials.

— Several test samples relevant for the product sector.

— Materials for masking and collimation.

— Pre-filters with different thickness of different materials.

— Step wedges of different materials suitable for generation of exposure graphs.

Annex B
(informative)

Useful references

B.1 Radiographic testing

B.1.1 ISO standards

ISO 3999	ISO 5579	ISO 5580	ISO 10675-1	ISO 10675-2
ISO 11699-1	ISO 11699-2	ISO 14096-1	ISO 14096-2	ISO 15708-1
ISO 15708-2	ISO 16371-1	ISO 16526-1	ISO 16526-2	ISO 16526-3
ISO 17635	ISO 17636-1	ISO 17636-2	ISO 19232-1	ISO 19232-2
ISO 19232-3	ISO 19232-4	ISO 19232-5	ISO 5576	ISO 15708-3
ISO 15708-4	ISO 20769-1	ISO 20769-2		

B.1.2 European standards

EN 12543-1	EN 12543-2	EN 12543-3	EN 12543-4	EN 12543-5
EN 12679	EN 12681	EN 13068-1	EN 13068-2	EN 13068-3
EN 16016-1	EN 16016-2	EN 16016-3	EN 16016-4	

B.1.3 ASTM standards

ASTM E94	ASTM E155	ASTM E186	ASTM E192	ASTM E242
ASTM E272	ASTM E280	ASTM E310	ASTM E390	ASTM E446
ASTM E505	ASTM E689	ASTM E747	ASTM E802	ASTM E1000
ASTM E1025	ASTM E1030	ASTM E1032	ASTM E1114	ASTM E1165
ASTM E1255	ASTM E1316	ASTM E1320	ASTM E1411	ASTM E1416
ASTM E1441	ASTM E1570	ASTM E1648	ASTM E1647	ASTM E1672
ASTM E1695	ASTM E1734	ASTM E1742/ E1742M	ASTM E1814	ASTM E1815
ASTM E1935	ASTM E1936	ASTM E2002	ASTM E2007	ASTM E2033
ASTM E2422	ASTM E2445	ASTM E2446	ASTM E2597/ E2597M	ASTM E2660
ASTM E2663	ASTM E2669	ASTM E2698	ASTM E2699	ASTM E2736
ASTM E2737	ASTM E2738	ASTM E2767	ASTM E2903	

B.1.4 ASME standards

ASME BPVC Section V, Article 2 ASME BPVC Section V, Article 1

B.2 Ultrasonic testing

B.2.1 ISO standards

ISO 2400	ISO 7963	ISO 13588	ISO 16809	ISO 16810
ISO 16811	ISO 16823	ISO 16826	ISO 16827	ISO 16828
ISO 17640	ISO 10863	ISO 18175	ISO 18563-1	ISO 18563-2
ISO 18563-3	ISO 5577	ISO 10375	ISO 16831	

B.2.2 European standards

EN 12668-1 EN 12668-2 EN 12668-3

B.3 Eddy Current testing

ISO 15548-1 ISO 15548-2 ISO 15548-3 ISO 15549

ISO 17643

B.4 Penetrant testing

ISO 3057	ISO 3058	ISO 3059	ISO 3452-1	ISO 3452-2
ISO 3452-3	ISO 3452-4	ISO 3452-5	ISO 3452-6	ISO 23277
ISO 12706	CEN/TR 16638	CEN/TR 17108	CEN/TS 17100	

B.5 Magnetic testing

B.5.1 ISO standards

ISO 3058	ISO 3059	ISO 9934-1	ISO 9934-2	ISO 9934-3
ISO 10893-3	ISO 11960	ISO 17638	ISO 12707	

B.5.2 European standards

EN 1369 EN 10228-1

B.5.3 ASTM standards

ASTM E570 ASTM E1571

B.6 Leak testing

B.6.1 ISO standards

ISO 3530 ISO 20484 ISO 20485 ISO 20486

B.6.2 European standards

EN 1779 EN 13184 EN 13625

B.7 Acoustic Emission testing

B.7.1 ISO standards

ISO 12713 ISO 18249 ISO/TR 13115 ISO 18081 ISO 12714
ISO 12716

B.7.2 European standards

EN 13477-1 EN 13477-2 EN 13554

B.8 Visual testing

B.8.1 ISO standards

ISO 3057 ISO 3058 ISO 5817 ISO 6520-1 ISO 8785
ISO 10042 ISO 17637

B.8.2 European standards

EN 1330-10 EN 1370 EN 1559 EN 10163-1 EN 10163-2
EN 10163-3 EN 13018 EN 13445-5 EN 13480-5 EN 13927

B.8.3 Codes

ASME Code KTA Code

B.9 General

ISO/TS 25108

ICS 19.100

Price based on 97 pages