TECHNICAL REPORT

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Non-destructive testing — Guidelines for NDT training syllabuses

Essais non destructifs — Lignes directrices pour les 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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.

ISO/TR 25107 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing*, in collaboration with Technical Committee ISO/TC 135, *Non-destructive testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Introduction

With this Technical Report, ISO/TC135 and CEN/TC138 present to the worldwide non-destructive testing (NDT) community their recommendations for the minimum technical knowledge to be required of NDT personnel. These recommendations provide means for evaluating and documenting the competence of personnel whose duties demand the appropriate theoretical and practical knowledge.

As part of the efforts to streamline and harmonize the training and certification of NDT personnel, ISO/TC 135 and CEN/TC 138 have been actively involved in developing guidelines for training syllabuses (this Technical Report) and for NDT training organizations (ISO/TR 27108). These documents are intended to serve those involved in training and to be useful in achieving a uniform level of training material and — consequently — in the competence of personnel.

This document, together with ISO/TR 27108, represents two years of effort for working groups of the two technical committees in the promotion of harmonization and mutual recognition of minimum requirements taken from the different existing certification schemes.

The content of this first edition has been based on the experience of the experts as well as on comments from the end-user industries, as well as the most recent edition of the International Committee for Non-destructive testing (ICNDT) recommended guidelines.

The time allotment for the different topics takes into account the latest developments in each method and, as a consequence, the total duration can be sometimes greater than the minimum duration required by ISO 9712 and EN 473.

This Technical Report is to be revised in the coming years in order to maintain a workable document in line with the development of NDT methods and techniques.

ISO/TC 135 and CEN/TC 138 wish to express their appreciation to all those who contributed to the production of this publication.

Non-destructive testing — Guidelines for NDT training syllabuses

1 Scope

This Technical Report gives guidelines 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, eddy current, leak, magnetic particle, penetrant, radiographic, ultrasonic and visual testing.

NOTE ISO/TR 27108 gives associated guidelines for NDT training organizations intended for the general part of training courses.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 1330 (all parts), *Non-destructive testing — Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330 apply.

4 Introduction to NDT

4.1 Role

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

NDT is the only choice for the testing of an object which may not 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 must be combined, or verified by other test methods.

4.2 Task of NDT personnel

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 must be independent and free from economic influences with regard to his test results, otherwise the results are compromised. The NDT personnel should be aware of the importance of his signature and the consequences of incorrect test results for safety, health and environment. Under legal aspects, the falsification of certificates is an offence and judged according to the national legal regulations. A tester may find himself in a conflicting situation about his findings with his employer, the responsible authorities or legal requirements.

Finally, the NDT personnel is responsible for all interpretations of test results carrying his signature. NDT personnel should never sign test reports beyond their certification.

4.3 History of NDT

The principle of NDT started to be put into practice with visual checks in prehistoric times. In medieval later centuries, test methods such as simple leakage tests and hardness checks were introduced. The breakthrough for NDT came with industrialization in the 19th and 20th centuries: X-ray and ultrasonic testing for inner defects, penetrant and magnetic particle testing for surface cracks. During the last few decades, sophisticated, mostly electronically linked methods, such as eddy current testing, RADAR, computer tomography and thermography have been developed. NDT methods have found application in a wide range of industries — from civil engineering and industrial plants to space and defence technology.

The history of NDT is linked to many famous researchers and inventors, including Röntgen, Becquerel, Curie, Oerstedt, Faraday and even Leonardo da Vinci. They discovered the physical principles and demonstrated early applications. Altogether approximately 5 000 scientists worldwide made contributions to the present state of NDT.

NDT is a global technology. Since NDT tasks and related technical problems are similar in all developed countries, improved solutions and new equipment are spread around the world within a few months. Many international conferences and standards committees contribute to a steady and consensual development of NDT for the benefit of safety, economy and the environment.

4.4 Terminology of NDT

Correct and standardized terminology is a necessity for a particular technology applied worldwide. It is needed for communication between contracting parties, NDT personnel and certifying bodies. Terms like “indication”, “imperfection”, “flaw” and “defect” require a precise and unequivocal definition if confusion and misinterpretation of results is to be avoided. See Clause 3.

4.5 General environmental and safety considerations

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

An essential element of any course training for NDT personnel must 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.

4.5.2 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, local regulations);

— 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).

5 Radiographic testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a **value** indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
5.1 Introduction to, terminology and history of, NDT	**History** Purpose **Terminology:** electromagnetic radiation energy dose dose rate	**E 0,5**	**History** Purpose **Terminology:** wave-length dose dose rate intensity dose rate constant	**E 1,0**	**History** Purpose **Terminology** **Relevant standards:** EN 1330-3	**E 1,0**
5.2 Physical principles of the method and associated knowledge	**Properties of X- and gamma radiation** **Relevant standards:** EN 444: General principles Straight line propagation Effects of radiation Capability of penetration	**E 0,5** **P 0,5**	**Properties of X- and gamma radiation** Photon Process of ionization: photochemical effects; biological effects; fluorescent effects. Energy	**E 1,0**	**Properties of radiation** X-radiography Gamma radiography Neutron radiography Electron radiography Process of ionization: photochemical effects; biological effects; fluorescent effects.	**E 1,0**
	Generation of X-radiation Function of X-ray tubes Tube current I High voltage U: effects on dose rate and energy of radiation.	**E 1,0** **P 0,5**	**Generation of X-radiation** Function of X-ray tubes Spectrum: intensity; max. energy; effective energy; change of spectrum by tube current and tube voltage. Inherent filtering	**E 1,5**	**Generation of X-radiation** Function of X-ray tubes Spectrum: intensity; max. energy; effective energy; change of spectrum by tube current and tube voltage. Characteristic radiation Inherent filtering hardening effect	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Origin of γ-radiation Radio isotope Ir 192, Co 60, Se 75 Activity: half life; characteristics of γ-sources; life time; energy; activity; source size.	**E 1,0** **P 0,5**	**Origin of γ-radiation** Radio nuclide Isotope Ir 192, Co 60, Se 75, Yb 169 Activity A Characteristics of γ-sources: half life; decay curves maximum activity; source size. Characteristic of Gamma ray Dose rate constant Spectrum and effective energy	**E 1,5**	**Origin of γ-radiation** Natural and artificial decay decay series Radio nuclides for NDT Isotope Ir 192, Co 60, Se 75, Yb 169 Activity A Characteristics of γ-sources: half life; decay curves maximum activity; source size. Characteristic of Gamma ray Dose rate constant Spectrum and effective energy	**E 2,0**
	Interaction of radiation with matter Attenuation: absorption; primary radiation; scattered radiation; influence of penetrated thickness. Type of material Energy Half value layer Tenth value layer	**E 1,0**	**Interaction of radiation with matter** Attenuation: photo effect; coherent scattering; Compton scattering; pair production. Attenuation coefficient Scatter radiation Specific contrast Radiation contrast Effects of filtering Beam hardening	**E 3,0** **P 0,5**	**Interaction of radiation with matter** Attenuation vs. energy: photo effect; coherent scattering; Compton scattering; pair production. Attenuation coefficient Scatter radiation Specific contrast Radiation contrast Effects of filtering Beam hardening Klein-Nishina law	**E 6,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Properties of film systems and screens Construction: base, emulsion, silver bromide; grain size and distribution. **Processing** Properties of films: sensitivity; granularity; contrast; optical density; film system class. Film screens: type of film screens; intensifying effect; filtering effect; film to screen contact.	**E 1,0** **P 1,0**	**Properties of film systems and screens** Construction Latent image information origin Photo process Properties of film systems: characteristic curve; film gradient, film contrast, speed; influence of film processing; sensitivity; granularity; detail perceptibility. Classification of film systems according to EN 584-1 Film screens: type of screens; film screen contact; inherent unsharpness; intensifying; effect of filtering; screens for Co 60 and Linac.	**E 2,0** **P 0,5**	**Properties of film systems, screens and digital detection systems** **Additional to level 2** New detectors: storage phosphor imaging plates; flat panels; X-ray intensifier; line detector. Classification of detector system application	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Geometry for radiographic exposures Geometric unsharpness: object to film distance; focus size d; source to object distance. Source film distance	**E 1,0** **P 0,5**	**Geometry for radiographic exposures** Geometric unsharpness: object to film distance; focus size d; source to object distance. Source film distance Determination of the focal spot: size of Gamma sources.	**E 3,0** **P 1,0**	**Geometry for radiographic exposures** **Additional to level 2** Method of focal spot measurement according to EN 12543, EN 12679 Requirements for optimization by Geometric unsharpness, total Unsharpness Focus size, current, voltage Source size, activity	**E 2,0** **P 2,0**
5.3 **Product knowledge and capabilities of the method and its derivate techniques**	**Typical weld discontinuities** Types of discontinuity according to EN ISO 6520	**E 1,0** **P 3,0**	**Typical weld discontinuities** Types of weld seam and weld seam preparation Welding process origin Type of discontinuity according to EN ISO 6520	**E 3,0** **P 1,0**	**Typical weld discontinuities** **Additional to level 2** Introduction to fracture mechanics working load Materials properties Origin of defects Further NDT methods	**E 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Typical defects in castings Types of defect	**E 1,0** **P 1,0**	**Defects in castings** Casting process Types of cast imperfections and their origin Structural indications Beam direction to detectability	**E 3,0** **P 1,0**	**Defects in castings** Casting process Types of cast imperfections and their origin Structural indications Working load Materials properties Production caused defects	**E 2,0** **P 2,0**
	Influence on detectability: type of defect; size; orientation. Imaged thickness range Number of exposures	**E 1,0** **P 0,5**	**Influence on detectability:** beam direction; geometric distortion; increase in wall thickness. Imaged thickness range Thickness ranges for X- and γ-rays Number of exposures	**E 2,0** **P 1,0**	**Influence on detectability:** beam direction; geometric distortion; increase in wall thickness. Imaged thickness range Thickness ranges for X- and γ-rays Number of exposures vs. distortion angle	**E 2,0**
5.4 **Equipment**	**Design and operation of X-ray machines** Stationary systems, mobile unit Tubes: glass- and metal-ceramic tube Design of tubes: standard tube; rod anode tube; short anode tube. Cooling: gas, water, oil	**E 1,5** **P 1,5**	**Design and operation of X-ray machines** **Additional to level 1:** inherent filtering; pre-filtering. Devices for special applications: micro-focus tubes; enlargement technique; radioscopy. Linac	**E 2,0** **P 1,0**	**Design and operation of X-ray machines** **Additional to level 2:** beam opening characteristics; X-ray flash devices; rod anode devices; micro-focus devices; high-voltage devices. Line focus tubes Rotary anode tubes	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Focal spot High voltage, max. current Exposure time Diaphragm Safety circuit Operating instructions		Construction Field of application Typical dates			
	Design and operation of Gamma ray devices: container, shielding; class P/M; type A/B (transportation); source holder and source capsule. Enclosed radioactive material: manipulation device; connections accessory; remote control; collimation; fittings. Operating instructions Reference to national requirements and safety regulations	**E 1,5** **P 1,0**	**Design and operation of Gamma ray devices** **Additional to level 1:** crawler for pipelines; special device for testing of heat exchanger tubes.	**E 2,0**	**Design and operation of Gamma ray devices** **Same as level 2**	**E 2,0**
	Accessories for radiographic testing Equipment: lead tape measure; holding magnets; lead screens shielding;	**E 0,5** **P 0,5**				

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	rubber bands etc.; radiation protection equipment.					
5.5 **Information prior to testing**	**Written procedures given** Information on the test object Object dimensions Test class of standard Equipment to be used Exposure arrangement Extent of testing (20 % inspection) marking	**E 0,5**	**Information about the test object** Identification or designation Material, dimensions, isometrics: number of parts; field of application; kind of manufacture; catalogue of defects. Test conditions: accessibility; infrastructure; particular test conditions. Applicable standards Overview Standards assigned to the test object Preparation of written instructions	**E 2,0**	**Information about the test object and national requirements** Additional to level 2: Selection of standards for specific testing applications European standards: application standards; overview; purpose; technical contents and systematic. Product specific standards for special industrial sectors: for welding; for casting; for pipes; pressurized equipment directive. ISO standards American standards: overview ASME Code overview ASTM standards	**E 4,0**
5.6 **Testing**	**Developing process** Darkroom: design; developer; water bath; fixing bath;	**E 1,5** **P 1,0**	**Developing process** **Additional to Level 1:** Processing equipment, adjustment: checking; storage of unexposed films; darkroom light test;	**E 3,5** **P 1,0**	**Developing process** Principles Processing equipment, adjustment: checking; storage of unexposed films; darkroom light test;	**E 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	final water bath; drying. Preparation and regeneration of baths Use of filmstrips according to EN 584-2: film processing faults		fog test; clearing time; tally sheet. Process-controlling according to EN 584-2		fog test; clearing time; tally sheet. Use of filmstrips according to EN 584-2	
	Examination of welded joints according to EN 1435 Scope Test classes: basic and improved techniques Test arrangements: number of exposures (EN 1435:1997, Annex A) Choice of energy: max. X-ray voltage; penetrated thickness range for gamma rays; special options. Film and screen choice: film system classes, type and thickness of screens Minimum optical density Minimum source-to-object distance	**E 10,5** **P 10,0**	**Examination of welded joints according to EN 1435** Scope Test classes: basic and improved techniques. Test arrangements: number of exposures (EN 1435:1997, Annex A) Choice of energy: max. X-ray voltage; penetrated thickness range for gamma rays; special options. Film and screen choice: film system classes, type and thickness of screens Minimum optical density Minimum source-to-object distance	**E 8,0** **P 4,0**	**Explanation and discussion of EN 1435** Scope basic and improved techniques Test arrangements: number of exposures (EN 1435:1997, Annex A) Choice of energy: max. X-ray voltage; penetrated thickness range for gamma rays; special options. Film and screen choice: film system classes, type and thickness of screens Minimum optical density Minimum source-to-object distance	**E 4,0** **P 8,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Examination of castings according to EN 12681 Scope Test classes: basic and improved techniques Test arrangements: number of exposures Choice of energy: average wall thickness; max. X-ray voltage; penetrated thickness range for gamma ray; special options. Film and screen choice: film system classes, type and thickness of screens. Minimum optical density Minimum source-to-object distance film	**E 6,0** **P 4,0**	**Examination of castings according to EN 12681** Scope for complex shaped objects Test arrangements: number of exposures; special geometries. Choice of energy: average wall thickness; max. X-ray voltage; penetrated thickness range for gamma ray; special options. Use of enlargement: double film technique; wall thickness compensation use of higher energy, hardening. Film and screen choice: film system classes, type and thickness of screens. Minimum optical density Minimum source-to-object distance film	**E 6,0** **P 3,0**	**Explanation and discussion of EN 12681** Scope for complex shaped objects Test arrangements: number of exposures; special geometries. Choice of energy: average wall thickness; max. X-ray voltage; penetrated thickness range for gamma ray; special options. Increase of covered thickness range: double film technique; wall thickness equalization use of higher energy, hardening. Film and screen choice: film system classes, type and thickness of screens Minimum optical density Minimum source-to-object distance film	**E 4,0** **P 6,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Working with exposure charts Definition of exposure value exposure time Correction of exposure time for different: film-focalspot-distance FFD; optical density; relative film exposure factor.	**E 2,0** **P 2,0**	**Special techniques** Stereo technique Round about technique Testing of corrosion damage Enlargement with micro-focus Real-time technique: fluorescent screens; radioscopy; computed radiography; documentation, picture archive.	**E 6,0**	**Direct radiography and radioscopy according to EN 13068** Image detectors: fluoroscope; flat panels; X-ray intensifier; camera and TV-systems. Applications: serial production testing; dynamical testing; special materials. Limits of the method: resolution; dynamic; signal-to-noise-ratio; modulation transfer function. Basic image processing: monitoring; documentation.	**E 2,0** **P 2,0**
					Special techniques Stereo techinique Round about techinique Testing of corrosion damage Enlargement with micro focus Special aspects for radiography of materials with high and low density Low voltage radiography	**E 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
					Radiography of art objects: light alloys; plastics; pre-filtering. High-voltage radiography: concrete testing. Film-screen-systems pre-filtering: intermediate filtering; heavy walled casting; special radiation protection, contamination.	
	Image quality indicators according to EN 462-1, EN 462-2, EN 462-3 Definition of Image quality number design of IQI: IQI position of different exposures; image quality classes; image quality number.	**E 1,0** **P 0,5**	**Image quality indicators according to EN 462-1, EN 462-2, EN 462-3** **Additional to Level 1:** image quality number for other materials according EN 462-4; detection of unsharpness with duplex-indicator according EN 462-5.	**E 2,0**	**Image quality indicators according to EN 462-1, EN 462-2, EN 462-3, EN 462-4, EN 462-5** **Same as Level 2:** relevance of image quality indicators; international image quality indicators.	**E 1,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	System of marking Object to film assignment: permanent marking of the object; zero point, incremental count direction; marker tape; position of markings on the object	**E 1,0** **P 0,5**	**Drafting an NDT instruction for the testing of welding and castings** Organization of simple test procedures Test objects: ambient conditions; reference documents, specifications, standards; choice of radiation source; choice of adequate direction of radiation; film location plan; identification of test piece and radiographs; number of exposures; performance of the test and reporting of test results; viewing of the films; classification of defects; assessment of the results according to applicable codes and standards; list of required accessories.	**E 6,0**	**Drafting an NDT instruction for the testing of welding and castings** Complete organization of test procedures in combination with other NDT methods Integration of internal priorities Choice of testing method: time of testing; radiation protection equipment. Personnel qualification Cost estimation: manpower costs; for equipment; for consumable; for auxiliary attachment second exposures after repair. Selection of specifications for application and evaluation Example of written practice for weld inspection according to ASTM	**E 23,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
5.7 Evaluation and reporting	**Basics of evaluation** Viewing conditions: room condition; viewing time; lapsed time after dazzling; film illuminator, luminance; density measurement.	**E 1,5** **P 1,0**	**Basics of evaluation** **Additional to Level 1:** Mach effect. Film illuminator according to EN 25580: min. luminance; homogeneity factor. Physiological factors: eyesight; adaptation prior to viewing.	**E 2,0**	**Basic of evaluation** Film illuminator according to EN 25580: min. luminance; homogeneity factor. Physiological factors: eyesight; adaptation prior to viewing.	**E 1,0**
	Evaluation of radiographs Verification the image quality Report of simple welding and casting imperfections	**E 2,0** **P 1,0**	**Evaluation of radiographs** Verification of image quality Report of imperfections	**E 3,5**	**Evaluation of radiographs** Verification of image quality Report of imperfections	**E 2,0** **P 2,0**
	Test report: welding according to EN 1435; castings according to EN 12681.	**E 1,0** **P 2,0**	**Check of test report** Does it comply with the examination standard? Conformed to the test quality Achieved test class Achieved image quality class Achieved diagnostic coverage of test object	**E 4,0**	**Feasibility of test report** Confirmation of the radiographic image quality vs. test report	**E 3,0** **P 2,0**
5.8 Assessment			**Classification of imperfections** Type, size, localization, frequency Welding: according to EN ISO 5817; according to EN 12062 or ISO 17635; according EN 12517;	**E 12,5** **P 6,0**	**Classification of imperfections** Type, size, localization, frequency Welding: according to EN ISO 5817; according to EN 12062 or ISO 17635 ; according to EN 12517;	**E 8,0** **P 7,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			according to standard on inspection of pressure vessels (EN 13445-5); casting; according to ASTM. Evaluation catalogue to EN ISO 5817 ASTM catalogue Other national training catalogues Influence of manufacture and material		according to standard on inspection of pressure vessels (EN 13445-5); casting; according to ASTM. Evaluation catalogue to EN ISO 5817 ASTM catalogue Other national training catalogues Influence of manufacture and material	
5.9 **Quality aspects**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification Written instructions Traceability of documents A review of applicable NDT application and product standards	**E 2,0**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification Format of working procedures Traceability of documents Other NDT qualification and certification scheme A review of applicable NDT application and product standards	**E 2,0**
5.10 **Developments**			**Alternative detectors to film** Flat panel detectors	**E 0,5**	**Innovative radiological techniques** 3-dimensional radiology testing: stereo technique; multi angle technique; computed laminography; computed tomography: principle; applications;	**E 4,5**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
					digital image processing; film digitization; image enhancement.	
Total duration		**E 40,5** **P 32,5**		**E 83** **P 20**		**E 91,5** **P 31**

6 Ultrasonic testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
6.1 Introduction to, terminology and history of, NDT	**Task of non-destructive testing — Personnel** **History of NDT** **Terminology of NDT** (EN 1330-1 and EN 1330-2) **History of UT** **Terminology of UT** (EN 1330-4)	**E 1,0**	**Review of level 1 knowledge** **Terminology and definitions of UT**	**E 1,0**	**Terminology and definitions of UT** Overview of standards: ISO, CEN and national (general, and products)	**E 1,5**
6.2 Physical principles of the method and associated knowledge	**Relevant standards:** EN 583-1 to EN 583-6 EN 14127 **Review of mathematical basics** Physical definitions and typical parameters Sinusoidal movement, amplitude, period, frequency, wavelength, propagation velocity **Various types of wave modes** Longitudinal waves Transverse waves Concepts of surface waves or Rayleigh waves and of plate waves or Lamb waves	**E 10,0**	**Physical definitions and typical parameters** **Same as level 1 plus:** acoustic impedance, factors of reflection and transmission (normal beam only); beam propagation. **Various types of wave modes** Same as level 1 plus: extended knowledge of surface waves or Rayleigh waves and of plate waves or Lamb waves; creeping waves.	**E 16,0**	**Same as level 2 plus:** Isotropic and anisotropic materials Phenomena of guided propagation Velocity measurement and dispersion Relation between velocity and elastic properties of material	**E 16,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Reflection and refraction Normal incidence, transmission, and reflection Incidence oblique Snell's law Critical angles, mode conversion		**Reflection and refraction** Same as level 1 plus acoustic pressure			
	Transmission and reception of ultrasonic waves Piezo-electric effect Ferro-electricity or electrostriction **Magnetostriction**		**Transmission and reception of ultrasonic waves** Same as level 1 Ferro-electricity or electrostriction **Magnetostriction**			
	Transducer characteristics Material, dimensions, piezo-electric constants		**Transducer characteristics** Same as level 1 (deeper knowledge)			
	Characteristics of the beam of a circular transducer Influence of transducer frequency and diameter Near field (Fresnel zone) Far field (Fraunhofer zone) Beam divergence		**Characteristics of the beam of a circular transducer** Same as level 1 plus: characteristics of the beam of a rectangular transducer; beam profiling. Beam divergence factor			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
6.3 **Product knowledge and related capability of the method and derived techniques**	**Various defects related to the manufacturing processes and service-induced defects related to the defined sectors** Implementation of the testing techniques according to products and to expected discontinuities Influence of geometry and structure (spurious echoes, sound attenuation)	**E 4,0**	**Same as level 1 plus:** tandem (zones); selection of transducers for required resolution and reduction of noise (type, frequency, size); immersion; TOFD; phased arrays. Influence of the main parameters	**E 8,0**	**Same as level 2 plus:** choice of techniques (contact, immersion, transmission, resonance, etc.); EMAT; multiple probe arrays. A comprehensive understanding and knowledge of the manufacturing processes and associated metallurgy and flaw types etc. A comprehensive understanding and knowledge of the cause and formation of in-service defects including associated metallurgy and flaw types, etc.	**E 8,0**
6.4 **Equipment**	**Various probes (normal, angle, dual):** instruments (analogical and digital); pulse generation; reception and amplification (percentage and dB); range setting; A- scan presentation; B- and C-scan presentation.	**E 8,0** **P 4,0**	**Same as level 1 plus:** detailed knowledge of the different functions of UT test equipment; automatic and semi-automatic systems; B- and C-scan presentation (deeper knowledge); couplant (deeper knowledge); calibration reference and transfer blocks.	**E 8,0** **P 4,0**	**Same as level 2 plus:** systems (manual/semi-automatic, automatic,): speed, incrementation, repeatability, etc.; analog flaw detectors (different circuits); digital flaw detectors (comparison with analog flaw detectors, sampling-rate); special equipment including thickness measurement. Probes: dynamic range; probes for immersion: focused, spherical, cylindrical, Fermat surface;	**E 8,0** **P 4,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Additional functions: couplant.				measurement of pulse length practical mesurement of the near field; shoe (delay, curvature, etc.); connecting cables (sealing, insulation and flexibility; blocks — representativity.	
6.5 **Information prior to testing**	Written instructions (prepared by a level 2 or 3): objectives; requirements.	**E 2,0**	**Same as level 1 (deeper knowledge) plus** contents and requirements of instructions, procedures and standards. Preparation of written instructions	**E 2,0** **P 8,0**	**Same as level 2 plus** Selection of technical parameters: products — geometry, surface quality, accessibility, environment, etc.; UT indication/discontinuity /defect: type, origin, shape,dimension, orientation, tilt/skew, etc.; properties of the equipment. Preparation of written specifications	**E 2,0** **P 8,0**
6.6 **Testing**	**Verification of combined equipment** (according to EN 12668-3) **Standardized calibration blocks** ref: EN 12223 and EN 27963 **Contact technique (straight and angle beam)** Reflection	**E 8,0** **P 16,0**	**Same as level 1 (deeper knowledge) plus:** reference reflectors (laws of distance and size); DGS-method; DAC-curves; distance/amplitude-correction; transfer correction (surface and attenuation);	**E 12,0** **P 16,0**	**Same as level 2 plus:** control and assessment of procedures and instructions for their efficiency.	**E 8,0** **P 8,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Transmission **Immersion techniques (straight and angle beam)** Reflection Transmission **Setting of range and sensitivity** Reference reflectors Transfer correction **Ultrasonic thickness measurement** Equipment Techniques		sizing techniques, principles and limitations; scanning.			
6.7 Evaluation and reporting	**Detecting, locating (trigonometrical rules) and sizing techniques** Recording and evaluation level Acceptance levels Test reports System of coordinates Measurement (probe, reflector) Calculated values	**E 4,0** **P 4,0**	**Same as level 1 (deeper knowledge) plus:** characterization (planar/non-planar according to EN 1713 for welds); interpretation and evaluation of indications.	**E 4,0** **P 8,0**	Use of complementary NDT methods: interpretation of relevant standards and codes; evaluation (conventional approach, validated method); distinction defect/artefact; acceptance criteria; level of significant variation; storage and recording process.	**E 4,0** **P 4,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
6.8 Assessment	**(Not applicable)**		**Evaluation and confirmation of test reports** Application of the acceptance: criteria according to standards, codes and procedures	**E 4,0**	Detailed knowledge of how to classify and assess observations, analyse the results and compare them to codes, standards and design specifications, etc. How to develop codes, standards and design specifications, etc., into clear acceptance criteria to be written into procedures and instructions. Also how to find information/assistance to investigate observations not covered by codes and standards and develop acceptance criteria. The training of levels 1 and 2 for these acceptance criteria.	**E 4,0**
6.9 Quality aspects	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification Written instructions Traceability of documents	**E 1,0** **P 2,0**	**Personnel qualification and responsibility** (according to EN 473 and ISO 9712) Equipment verification Format of working procedures Traceability of documents Other NDT qualification and certification systems A review of applicable NDT applications and product standards	**E 2,0** **P 4,0**
6.10 Developments	**(Not applicable)**		**General information**	**E 1,0**	Newest developments for industrial and scientific applications of UT: e.g. tomography holography, acoustic microscopy.	**E 1,0**
Total duration		**E 38** **P 24**		**E 57** **P 38**		**E 54.5** **P 28**

7 Eddy current testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
7.1 **Introduction to, terminology and history of, NDT**	Generalities on NDT: What is testing? What is the purpose of NDT? At what stage of the life of a "product" is NDT performed? How does it add value? Who may carry out NDT? Main NDT methods. **Eddy current testing** Definition: electromagnetic interaction between a sensor and a test object conducting electricity, providing information on physical characteristics of the test object. History of the method **Terminology** EN 1330-1 and EN 1330-2 EN 1330-5	**E 1,0**	Generalities on NDT: What is testing? What is the purpose of NDT? At what stage of the life of a "product" is NDT performed? How does it add value Who may carry out NDT? Main NDT methods. **Eddy current testing** Definition: electromagnetic interaction between a sensor and a test object conducting electricity, providing information on physical characteristics of the test object. History of the method **Terminology** EN 1330-1 and EN 1330-2 EN 1330- 5	**E 1,0**	Generalities on NDT: What is testing? What is the purpose of NDT? At what stage of the life of a "product" is NDT performed? How does it add value? Who may carry out NDT? Main NDT methods. **Eddy current testing** Definition: electromagnetic interaction between a sensor and a test object conducting electricity, providing information on physical characteristics of the test object. History of the method **Terminology** EN 1330-1 and EN 1330-2 EN 1330- 5	**E 0,5**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
7.2 **Physical principles and associated knowledge** Notions necessary for understanding eddy current testing. The knowledge associated with the physical principles (physics, mathematics) may, as well, be the object of a preliminary course of training.	**Relevant standards:** EN 12084: General principles **Fundamentals** **Electricity — elements** Direct current: current, voltage, resistance, conductance, Ohm's law, resistivity, conductivity. Units, conductivity values for some metals. Alternating current: sinusoidal current and voltage, amplitude, frequency, period, phase. **Magnetism** Magnetism: magnetic field, lines of force, magnetic field strength. Permeability, flux density (induction). Flux. Hysteresis loop. Units.	**E 5,0** **P 2,0**	**Fundamentals** **Electricity** Direct current: current, voltage, resistance, conductance, Ohm's law, resistivity, conductivity. Units, conductivity values for some metals. Alternating current: sinusoidal current and voltage, amplitude, frequency, period, phase. Vector representation. **Magnetism** Magnetism: magnetic field, lines of force, magnetic field strength. Permeability, flux density (induction). Flux. Hysteresis loop. Reluctance. Magneto-motive force. Units. Diamagnetism, paramagnetism, ferromagnetism.	**E 5,0** **P 4,0**	**Fundamentals** **Electricity** Direct current: current, voltage, resistance, conductance, Ohm's law, resistivity, conductivity. Units, conductivity values for some metals. Alternating current: sinusoidal current and voltage, amplitude, frequency, period, phase. Vector representation. Other periodic currents. **Magnetism** Magnetism: magnetic field, lines of force, magnetic field strength. Permeability, flux density (induction). Flux. Hysteresis loop. Reluctance. Magneto-motive force. Units. Diamagnetism, paramagnetism, ferromagnetism.	**E 4,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Electromagnetism Magnetic field created by a current, (wire, coil). Electromagnetic induction phenomenon, inductance, Electromagnetic coupling. Induced currents and secondary field. Lenz's law Eddy current distribution in conducting materials: depth of penetration, amplitude, phase; characteristic frequency. Impedance.		**Electromagnetism** Magnetic field created by a current, (wire, coil). Electromagnetic induction phenomenon, inductance, mutual induction. Electromagnetic coupling. Induced currents and secondary field. Lenz's law Eddy current distribution in conducting materials: planar wave: standard depth of penetration, amplitude, phase; Cylindrical conductors: characteristic frequency. Impedance. Complex plane representation. Impedance plane diagrams.		**Electromagnetism** Magnetic field created by a current, (wire, coil). Electromagnetic induction phenomenon, inductance, mutual induction. Electromagnetic coupling. Induced currents and secondary field. Lenz's law Eddy current distribution in conducting materials: planar wave: standard depth of penetration, amplitude, phase; Cylindrical conductors: characteristic frequency. Impedance. Complex plane representation. Impedance plane diagrams.	
7.3 **Product knowledge and related capability of the method and derived techniques**	Applications of eddy current testing Metal sorting Measurement of a physical parameter: conductivity, ferrite content , thickness of coatings, etc. Detection of local discontinuities (flaws). Capabilities: depth of penetration, conductive materials; non-contact, high-speed, high-temperature, may be mechanized Techniques: single frequency, multifrequency, multiparameter	**E 4,0** **P 4,0**	Manufacturing related discontinuities (typical flaws) Service induced discontinuities (flaws). Material properties influencing eddy current testing: conductivity, permeability. Product characteristics influencing eddy current testing: condition (surface condition, heat treatment, cold working, temperature, etc.), shape, wall thickness, accessibility. Products being tested: semi-finished products, pipes, heat exchanger tubes, mechanical parts (e.g. car, railway and aircraft industry), welds (e.g. offshore)	**E 3,0** **P 3,0**	Manufacturing related discontinuities (typical flaws) Service induced discontinuities (flaws). Material properties influencing eddy current testing: conductivity, permeability. Product characteristics influencing eddy current testing: condition (surface condition, heat treatment, cold working, temperature, etc.), shape, wall thickness, accessibility.	**E 3,0** **P 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Applications of eddy current testing: metal sorting Measurement of a physical parameter: conductivity, ferrite content, thickness of coatings, etc. Detection of local discontinuities (flaws) Capabilities: depth of penetration, conductive materials. Non-contact, high-speed, high-temperature, may be mechanized Techniques: single frequency, multifrequency, multiparameter. Remote field. Codes and standards		Applications of eddy current testing: metal sorting Measurement of a physical parameter: conductivity, thickness of coatings, etc. Detection of local discontinuities (flaws) Capabilities: depth of penetration, conductive materials. Non-contact, high-speed, high-temperature, may be mechanized Techniques: single frequency, multifrequency, multiparameter. Remote field. Codes and standards	
7.4 **Equipment**	**Eddy current testing system:** instrument, probe, reference blocks. **Relevant standards:** EN 13860-1 and EN 13860-2	**E 3,0**	**Eddy current testing system:** instrument, probe, reference blocks. **Relevant standards:** EN 13860-1 and EN 13860-2 General purpose application instrument: essential functions. Specific application instruments. Probe functions: combined or separate transmit- receive. Probe family: surface, coaxial Probe designs.	**E 6,0**	**Eddy current testing system:** instrument, probe, reference blocks. **Relevant standards:** EN 13860-1 and EN 13860-2 General purpose application instrument: essential functions. Specific application instruments. Probe functions: combined or separate transmit- receive. Probe family: surface, coaxial Probe designs.	**E 4,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Measurements: absolute, differential, others. Output and signal display		Measurements: absolute, differential, others. Output and signal display. Reference blocks: material, design, production, storage. Mechanized equipment. Codes and standards.		Measurements: absolute, differential, others. Output and signal display. Reference blocks: material, design, production, storage. Mechanized equipment. Codes and standards.	
7.5 Information prior to testing	Information on the product: grade, metallurgical condition, shape. Type of discontinuities anticipated and location, duty of the product. Extent of examination. Information on test conditions: temperature, humidity, access, availability, unwanted interfering signals, electric and/or magnetic disturbances.	**E 2,0**	Information on the product: grade, metallurgical condition, shape. Type of discontinuities anticipated and location, duty of the product. Extent of examination. Information on test conditions: temperature, humidity, access, availability, unwanted interfering signals, electric and/or magnetic disturbances. Preparation of written instructions	**E 2,0**	Information on the product: grade, metallurgical condition, shape. Type of discontinuities anticipated and location, duty of the product. Extent of examination. Information on test conditions: temperature, humidity, access, availability, unwanted interfering signals, electric and/or magnetic disturbances. Use of other NDT methods. Codes, standards, specifications.	**E 2,0**
7.6 Testing	Reference blocks: design, production, storage. Operating conditions: excitation frequency and, if necessary, auxiliary frequencies; probe speed, probe clearance, probe vibration and centring. Calibration curves Settings: data acquisition procedure/instructions.	**E 2,0** **P 12,0**	Reference blocks: design, production, storage. Probe: selection, as a result of the information in 7.5. Operating conditions as a result of the information in 7.5: excitation frequency and if necessary auxiliary frequencies; probe speed, probe clearance, probe vibration and centring. Calibration curves. Settings: data acquisition procedure	**E 2,0** **P 12,0**	Reference blocks: design, production, storage. Probe: selection or design, as a result of the information in 7.5. Operating conditions as a result of the information in 7.5: excitation frequency and if necessary auxiliary frequencies. probe speed, probe clearance, probe vibration and centring. Calibration curves. Settings: data acquisition procedure.	**E 3,0** **P 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
7.7 Evaluation And Reporting	**(Evaluation not applicable)** **Reporting** Examination report	**E 1,0** **P 1,0**	**Evaluation** Characterisation of the indications: single frequency analysis, multifrequency analysis, data analysis procedure. **Reporting** Reporting level Examination report	**E 2,0** **P 2,0**	**Evaluation** Characterization of the indications: single frequency analysis, multifrequency analysis, data analysis procedure. **Reporting** Reporting level Examination report	**E 3,0** **P 2,0**
7.8 Assessment	**(Not applicable)**	—	Acceptance criteria Codes, standards	**E 2,0**	Acceptance criteria Significance of discontinuities Codes, standards	**E 4,0**
7.9 Quality aspects	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification Written instructions Traceability of documents	**E 1,0** **P 2,0**	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification Format of working procedures Traceability of documents Other NDT qualification and certification systems A review of applicable NDT application and product standards	**E 2,0** **P 4,0**
7.10 Developments	**(Not applicable)**	—	General information	**E 1,0**	Array probes Pulsed eddy currents Non inductive techniques: Magneto-Optical Imaging, SQUID, Giant magneto-resistance Imaging Modelling	**E 4,0** **P 2,0**
Total duration		**E 19,0** **P 19,0**		**E 25,0** **P 23,0**		**E 29,5** **P 14,0**

8 Penetrant testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
8.1 **Introduction to, terminology and history of, NDT**	**History** Purpose **Terminology** Product family EN ISO 12706 Penetrant Developer Remover Reference block example	**E 0,5**	**History** Purpose **Terminology** Product family EN ISO 12706 Sensitivity level Post emulsifiable Dual purpose penetrant Background	**E 1,0**	**History** Purpose **Terminology** Product family EN ISO 12706 Sensitivity level Post emulsifiable Dual purpose penetrant Background	**E 2,0**
8.2 **Physical principles of the method and associated knowledge**	**Relevant standards:** EN 571-1: General principles Viscosity Bleed out Flash point Emulsification of penetrant Development Coloured and fluorescent penetrant	**E 0,5**	**Relevant standards:** EN 571-1: General principles Viscosity Bleed out Capillarity Flash point Emulsification of penetrant	**E 2,0**	**Relevant standards:** EN 571-1: General principles Physical basics of the method Superficial tension Viscosity Contact angle Vapour pressure	**E 2,0**
8.3 **Product knowledge and capabilities of the method and its derivate techniques**	**Typical defects according to the manufacturing process (forgings, castings, rolling, welding, etc.)**	**E 1,0** **P 2,0**	**Typical defects according to the manufacturing process (forgings, castings, rolling, welding, etc.)**	**E 1,5** **P 1,5**	**Typical defects according to the manufacturing process (forgings, castings, rolling, welding, etc.)** Welding process, casting process, process of rolled bars	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
8.4 Equipment	**Design and operation of penetrant installations and units** Aerosol spray cans Dip installations, brushing, light sources, measuring units and reference blocks (EN 3452-3 and EN 3452-4) Viewing condition (EN ISO 3059)	**E 1,0** **P 1,0**	**Design and operation of penetrant installations and units** Electrostatic systems, fluidized bed Aerosol spray cans Dip installations, brushing, light sources, measuring units and reference blocks (EN 3452-3 and EN 3452-4) Viewing condition (EN ISO 3059)	**E 2,0**	**Design and operation of penetrant installations and units** Semi-automatic and automatic systems Electrostatic systems, fluidized bed Aerosol spray cans Dip installations, brushing, light sources, measuring units and reference blocks (EN 3452-3 and EN 3452-4) (According to various standards e.g. EN ISO 3452-4) Viewing condition (EN ISO 3059)	**E 2,0**
8.5 Information prior the test	**Verification that the test object is in suitable condition for testing** Written instructions are given	**E 0,5**	**Information about the test object, prepare written instructions** Identification or designation Material, dimensions, field of application Kind of product family, catalogue of defects Test conditions Applicable standards and codes, assigned to the test object	**E 1,0** **P 1,0**	**Prepare written procedure** Identification or designation Material, dimensions, field of application Kind of product family, catalogue of defects Test conditions Applicable standards and codes, assigned to the test object	**E 4,0**
8.6 Testing	**Performance of the test** According to written instructions	**E 1,0** **P 1,0**	**Preparation and performance of the test** Preparation of written instructions according to EN 1371-1, EN 10228-2, EN 1289	**E 1,0** **P 3,0**	**Preparation of the test** According to EN 571-1	**E 1,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
8.7 Evaluation and reporting	**Test report**	**E 1,0** **P 2,0**	**Check test report**	**E 1,0** **P 0,5**	**Written procedure with check of test reports:**	**E 1,0**
	welding according to EN 571-1; casting according to EN 1371-1; forging according to EN 10228-2; rolled products.		welding according to EN 571-1; casting according to EN 1371-1; forging according to EN 10228-2;		welding according to EN 571-1; casting according to EN 1371-1; forging according to EN 10228-2.	
			Basics of evaluation		**Basics of evaluation**	
	Viewing conditions according to EN ISO 3059	**E 0,5**	Viewing conditions according to EN ISO 3059	**E 1,0**	Viewing conditions according to EN ISO 3059	**E 1,0**
	Reference block No. 2 (according to EN ISO 3452-3)	**P 1,0**	Reference block Nos. 1 and 2 according to EN ISO 3452-3	**P 1,5**	Reference block Nos. 1 and 2 according to EN ISO 3452-3	
	Verification the indication quality		Other used reference blocks		Other used reference blocks	
	Report of simple welding, forging, rolled products and casting imperfections		Calibration of test units batch test report		Calibration of test units	
		E 1,0	**Evaluation**	**E 1,0**	**Evaluation**	**E 0,5**
		P 1,0	Verification the indication quality	**P 1,5**	Verification the indication quality	
			Report of discontinuities according to EN 1289, EN 1371-1, EN 10228-2			
8.8 Assessment	**Assessment of discontinuities**	**E 0,5**	**Assessment of discontinuities**	**E 1,0**	**Assessment of discontinuities**	**E 0,5**
	Depth, width, shape, position, orientation		Influence of manufacture and material		Depth, width, shape, position, orientation	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
8.9 Quality aspects	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification Written instructions Traceability of documents A review of applicable NDT application and product standards	**E 1,0** **P 2,0**	Personnel qualification (according to EN 473 and ISO 9712) Equipment verification Format of working procedures Traceability of documents Other NDT qualification and certification systems A review of applicable NDT application and product standards	**E 2,0** **P 3,0**
8.10 Environmental and safety conditions	**Disposing of chemicals** Penetrants Developer Emulsifier Material of process excess removal Safety data sheet	**E 0,5**	**Disposing of chemicals** Penetrants Developer Emulsifier Material of process excess removal Safety data sheet Active carbon method, ultrafiltration method UV-radiation, electrical hazard **disposal is regulated by national regulations**	**E 2,0**	**Disposing of chemicals** Penetrants, Soluble Remover, developer Safety data sheets UV-radiation, electrical hazard A review of applicable NDT application and product standards	**E 1,5**
8.11 Developments	**(Not applicable)**		Special installations Automotive installations (examples)	**E 0,5**	Creative and innovative special installations Automotive installations (examples) Tube installations	**E 0,5**
Total duration		**E 9** **P 8**		**E 16** **P 11**		**E 20** **P 3**

9 Magnetic particle testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
9.1 Introduction, terminology, purpose and history of NDT	**1. Introduction** 1.1 Presentation of magnetic particle testing 1.2 Applicability and limits 1.3 History 1.4 Terminology (EN 1330-7)	**E 0,5**	**Introduction** 1.1 Presentation of the magnetic particle testing 1.2 Applicability and limits 1.3 History 1.4 Terminology (EN 1330-7)	**E 1,0**	**Introduction** 1.1 Presentation of the magnetic particle testing 1.2 Applicability and limits 1.3 History 1.4 Terminology (EN 1330-7)	**E 1,0**
9.2 Physical principles and associated knowledge	**Basic physical phenomena in terms of general description** 2.1 Electric circuits, typical values, units 2.2 Magnetic circuits, typical values, units 2.3 Magnetic field created by electric circuits 2.4 Passage of the flux from a magnetic medium to a non magnetic media 2.5 Magnetic flux of a magnetic discontinuity 2.6 Influence of depth and orientation of a magnetic discontinuity on its detection 2.7 Magnetic properties of materials 2.8 Nonmagnetic materials 2.9 Magnetic materials. Curie point	**E 3,5**	**Basic physical phenomena** 2.1 Electric circuits, typical values, units 2.2 Magnetic circuits, typical values, units 2.3 Magnetic field created by electric circuits 2.3.1 Indefinite rectilinear conductor 2.3.2 Long magnetic coil 2.3.3 Short or flat magnetizing coil 2.3.4 Passage of the flux of a magnetic in a non magnetic media 2.3.5 Continuity of HT 2.3.6 Continuity of BN 2.3.7 Magnetic flux of a magnetic discontinuity	**E 4,0**	**Basics** 2.1 Diamagnetism – Paramagnetism 2.2 Ferromagnetism – Ferrimagnetism 2.3 Magnetic fields characterization and measurements 2.4 Magnetic field H - magnetic Induction B 2.5 Hysteresis cycle and remarkable points 2.6 Influence of the temperature on the magnetic properties 2.7 Principle of magnetic particle testing 2.8 Influence of the interface between a magnetic medium and a nonmagnetic medium	**E 4,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Relevant standards: EN ISO 9934-1. General principles		2.3.8 Influence of the geometry (depth, thickness and orientation) and of the orientation of a magnetic discontinuity on its detection 2.4 Magnetic properties 2.5 Designation of alloys 2.6 Non magnetic materials 2.7 Magnetic materials 2.7.1 Field of application 2.7.2 Curie Point 2.7.3 Curve of the first magnetization 2.7.4 Hysteresis cycle and remarkable points 2.7.5 Magnetic properties of steels		2.8..1 Continuity of HT 2.8.2 Continuity of BN 2.9 Influence of the orientation of of the discontinuity on magnetic flux 2.10 Behaviour of a magnetic particle in the vicinity of a magnetic flux 2.11 Influence of geometry (depth, thickness and orientation) on detectability 2.12 Magnetic properties of principal ferromagnetic alloys 2.12.1 Magnetic field H, magnetic induction B, relative magnetic permeability μ_r, coercitive force Hc, electrical resistivity ρ. 2.12.2.1 Influence of composition, heat treatments and work hardening of the steel 2.12.2.2 Influence of work hardening. Influence of heat treatment 2.12.2.2 Particular alloys: e.g. Permalloys, Invar, Inconel	
9.3 **Product knowledge and capabilities of method and its derivate techniques**	3.1 Typical discontinuities according to the production process (welds, forgings, castings and roller products 3.2 Testing parameters: Magnetization, detection media and test of detection media indication.	**E 4,0** **P 3,0**	3.1 Typical discontinuities in welds, forgings, castings and roller products and their indications. 3.2 Testing parameters: Magnetization, detection media and test of detection media indication.	**E 6,0** **P 3,0**	3.1 Typical discontinuities in welds, forgings, castings and roller products and their indications. 3.2 Testing parameters: Magnetization, detection media and test of detection media indication.	**E 6,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
9.4 **Equipment**	4.1 Magnetizing equipment	**E 2,0** **P 1,0**	4.1 Various types	**E 3,0** **P 1,0**	4.1 Mobile or fixed equipment using magnetic flow technique or current flow technique	**E 4,0**
	4.2 Viewing condition		4.1.1 Portable electromagnet		4.2 Automatic and robotized with automatic detection (magnetic leakage field) **Relevant standards:** EN ISO 9934-2 and EN ISO 9934-3	
	4.3 Measurement and calibration		4.1.2 Mobile			
	4.4 Demagnetization		4.1.3 Magnetic benches			
	Relevant standards: EN ISO 9934-2 and EN ISO 9934-3		4.1.4 Automatic and robotized with automatic detection (magnetic leakage field)			
			4.2 Sources of light and conditions of illumination			
			4.3 Accessories			
			4.3.1 Flux indicators and products indicators			
			4.3.2 Field strength measuring devices			
			4.3.3 Photometers and radiometers			
			4.4 Considerations on the choice of the equipment (EN ISO 9934-2 and EN ISO 9934-3)			
			4.4.1 Elements to be taken into account, materials and components to be controlled, zones to be controlled, goal of the test, place and environment			
			4.4.2 Choice of the technique type of current Magnetic flow technique (open and closed circuit)			
			4.5 Current flow technique — induced current flow, combined system, multidirectional magnetization and rotating field			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
9.5 **Information prior the test**	5.1 Application of a written instructions	**E 0,5** **P 0,5**	5.1 Identification or designation material: kind of manufacture; catalogue of defects; test condition and application of standard: accessibility infrastructure particular test condition Application standard. Overview Standard and codes assigned to the test objects Acceptance criteria 5.2 Preparation of written instructions 5.3 Documents 5.4 Presentation of the standards, codes and procedures	**E 1,0** **P 0,5**	5.1 Identification or designation material: kind of manufacture catalogue of defects test condition and application of standard: accessibility infrastructure particular test condition application standard. Overview standard and codes assigned to the test objects acceptance criteria 5.2 Preparation of written instructions 5.3 Documents 5.4 Presentation of the standards, codes and procedures	**E 2,0**
9.6 **Testing**	**6 Testing according to the written instructions** 6.1 Surface preparation 6.2 Cleaning, machining 6.3 Use of contrast paint 6.4 Magnetization, types and time of application 6.5 Application of the detection media Recording of discontinuities continuous technique Remanence technique	**E 3,5** **P 1,5**	**6 Testing** 6.1 Surface preparation 6.2 Cleaning, machining 6.3 Use of contrast paint 6.4 Magnetization, types and time of application 6.5 Application of the detection media 6.6 Continuous technique Remanence technique	**E 5,0** **P 2,5**	**6 Testing** 6.1 Preparation of the parts and influence of the surface quality 6.2 Means of magnetization. Values of the parameters. Continuous or simultaneous method. Remanence method. Flux indicators 6.3 Choice of the detection media. products indicators	**E 6,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	6.8 Grid and covering 6.9 Control of conditions of magnetization **6.10 Treatment of components after test** 6.11 Residual field 6.12 Basic principle of demagnetization 6.13 Demagnetization. Industrial methods of demagnetization 6.14 Cleaning of the components		6.8 Grid and covering 6.9 Control of conditions of magnetization **6.11 Treatment of components after test** 6.11 Residual field. Conditions requiring demagnetization. Level of residual field 6.12 Basic principle of demagnetization 6.13 Demagnetization. Industrial methods of demagnetization and influence of terrestrial magnetic field 6.14 Cleaning of the components		**6.4 Treatment of components after test** 6.5 Demagnetization 6.6 Principle, minimal value of the magnetic field of demagnetization, frequency, effect of skin and calculation of magnetizing coil 6.7 Level of residual field according to the later use of material 6.8 Influence of terrestrial magnetic field 6.9 Cleaning of the components	
9.7 **Evaluation and reporting**	**7.1 Classification of the indications:** welding according to EN 1290; casting according to EN 1369; forging according to EN 10228-1; rolled products. Viewing conditions according to reference block; Verification of the indication quality (EN ISO 3059) Report of simple welding, forging, rolled products and casting imperfections	**E 2,5** **P 4,0**	**7.1 Test report** Check test report Basic of evaluation Viewing conditions (EN ISO 3059) according to reference block, other used reference blocks, calibration of test units, batch test report, Evaluation and verification of the indication quality. Report of imperfections according to EN 1290, EN 1369, EN 10228-1.	**E 3,0** **P 3,5**	**7.1 Test report** Written procedure with check of test reports: welding according to EN 1290; casting according to EN 1369; forging according to EN 10228-1. Basics of evaluation, viewing conditions (EN ISO 3059) according to reference block, other used reference blocks, calibration of test units, Evaluation and verification of the indication quality.	**E 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
9.8 **Assessment**	**(Not applicable)**	**E 0,5**	Assessment of discontinuities influence of manufacture and material.	**E 1,0**	Assessment of discontinuities influence of manufacture and material.	**E 1,0**
9.9 **Quality aspects**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	**Personnel qualification** (according to EN 473 and ISO 9712). Equipment verification Written instructions Traceability of documents A review of applicable NDT application and product standards.	**E 1,0** **P 2,0**	**Personnel qualification** (according to EN 473 and ISO 9712). Equipment verification Format of working procedures Traceability of documents Other NDT qualification and certification systems. A review of applicable NDT application and product standards.	**E 2,0** **P 3,0**
9.10 **Environmental and Safety conditions**	10 Health and safety 10.1 Electric risks hazards 10.2 Risks related to the products (magnetic inks) 10.3 Risks related to the ultraviolet radiation 10.4 Disposal of the effluents and environmental conditions (concepts) 10.5 Safety data sheet	**E 0,5**	10 Health and safety 10.1 Electric risks hazards 10.2 Risks related to the products (magnetic inks) 10.3 Risks related to the ultraviolet radiation 10.4 Disposal of the effluents and environmental conditions (concepts) 10.5 Safety data sheet	**E 1,0**	10 Health and safety 10.1 Electric risks hazards 10.2 Risks related to the products (magnetic inks) 10.3 Risks related to the ultraviolet radiation 10.4 Disposal of the effluents and environmental conditions (concepts 10.5 Harmfulness and toxicity of the products 10.6 Treatment and rejection of the effluents, environmental conditions 10.7 Fire hazards 10.8 Risks related to the ultraviolet radiations	**E 1,0**
9.11 **Developments**	**(Not applicable)**	—	Special installation and equipment	**E 1,0**	New techniques Creative and innovative special installations.	**E 1,0**
Total duration		**E 18,5** **P 10,0**		**E 27,0** **P 12,5**		**E 31** **P 3**

10 Leak testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

The letters **EB** and **EC** followed by a value indicate *educational time for pressure method* and *educational time for tracer gas method*.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
10.1 Introduction to, terminology and history of, NDT	**History of Leak testing** **Reasons for leak testing** Material loss prevention Contamination **Fundamental terminology** Leakage terms EN 1330-8 **Leak and leak detection** Fundamentals	**E 1,0**	**History of Leak testing** **Reasons for leak testing** Component system reliability Pressure difference maintenance **Terminology** Leakage terms; Leak tightness Quantitative, semi-quantitative, qualitative **Leak and leak detection** Fundamentals; leakage-finding principles; Choice of method: EN 1779: Guide to method selection	**E 1,0**	**History of Leak testing** **Reasons for leak testing** **Terminology** **Leak and leak detection** Proper selection of leak testing as method choice: differences between leak testing and others methods; complementary roles of leak testing and other methods; factor that qualifies the use of leak testing.	**E 1,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
10.2 **Physical principles and associated knowledge**	**Physical behaviour of gases** Law and fundamentals	**E 2,0**	**Physical behaviour of matter** Structure of matter (fundamental): atomic theory; ionization and ion pairs; state of matter; molecular structure; diatomic and monatomic molecules; molecular weight; Solid-liquid and liquid vapour: state changes. Gas laws and fundamentals: Brownian movements; P-V and P-T diagrams; Pascal's law; Charles, Boyle and Gay Lussac's laws; Dalton's law of partial pressure; perfect gas equation and its application for leakage calculation; mean free-path definition and meaning; gas properties; Kinetic theory of gas (fundamental):	**E 3,0**	**Physical behaviour of matter** Perfect and real gases Vapour pressure and its effects in a vacuum	**E 3,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Avogadro's law; gas mixture and concentration; gas velocity density and viscosity.			
	Pressure Pressure as force on unit area Main pressure units Vapour pressure		**Pressure** Relationship between different measurement units Standard and normal conditions		**Pressure** Definition of pressure from the kinetic theory of gas Relationship between mean free path and pressure. **Perfect gas law** The equation and its use for leakage calculation.	
	Pressure range in vacuum different range		**Pressure range in vacuum**		**Pressure range in vacuum** Relationship between mean free path and vacuum range.	
	Flow in vacuum Definition Leakage as a flow		**Flow in vacuum** Definition Flow parameters: relationship between mean free-path and flow; viscous flow; molecular flow; intermediate flow.		**Flow in vacuum:** flow and kinetic theory; factors affecting gas flow; leak rate versus viscosity; Reynolds number vs. Knudsen number; geometry of a leak path capillary; permeation; capillary.	
	Leakage measurement Units		**Leakage measurement** Units and relationships		**Leakage measurement**	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Conductance in vacuum Definition and meaning Conductance calculation from nomograph or simplified formulas		**Conductance in vacuum** Conductance calculation Flow and conductance	
	Degassing Practical implications		**Degassing** Practical concept and fundamentals		**Degassing** Different gas behaviour Material	
			Pumping speed Definition and meaning		**Pumping speed** Pumping speed calculations	
	Virtual and real leak Concept and difference		**Virtual and real leak** Source of real and virtual leaks pressure vs. time.		**Virtual and real leak** Calculation on virtual leak influence in a pressure change test.	
10.3 **Product knowledge and the capabilities of the method and its derived techniques**	**Type of leak testing** Leak location Leak measurement Pass/fail test Leakage monitoring	**EB 2,0** **EC 3,0**	**Type of leak testing** Specification and sensitivity	**EB 4,0** **EC 6,0**	**Type of leak testing**	**EB 4,0** **EC 6,0**
	Object preparation Object cleanness; Cleaning procedures and effects on leak detection measurements		**Object preparation** Sealed object with or without tracer gas Object inaccessible from one or both sides; Object working above or below the atmospheric pressure		**Object preparation**	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Specifications and method capabilities **Bubble emission method** EN 1593 Principles of bubble emission methods; immersion technique; liquid application technique. **Pressure change methods** EN 13184 Fundamentals of working principles: pressure testing; vacuum testing.		**Specifications and method capabilities** **Bubble emission method** Physical principles involved **Pressure change methods** Principles of detection for the pressure change methods Pressure decay technique Pressure rise technique Bell pressure change technique Flow measurement technique		**Specifications and method capabilities** **Bubble emission method** **Pressure change methods** Difference between the pressure testing and the vacuum testing considering the perfect gas law Terminology related to pressure testing	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Tracer gas method EN 13185 Principles of detection Helium as tracer gas Tracer gas detectors Tracer gas flow into the object (group A techniques) Tracer gas flow out of the object (group B techniques)		**Tracer gas method** **Chemical or physical properties of detectors** **Principles of detection for the tracer gas flow into the object — Group A techniques** a) Local leak: spraying; vacuum technique (local); vacuum technique (partial); bell pressure test. b) Global leak: vacuum technique (total); bell pressure test; pressure rise; flow measurements. **Principles of detection for tracer gas flow out of the object — Group B techniques** a) Local leak: chemical detection with ammonia; vacuum box using internal tracer gas; sniffing test; bubble with vacuum box; pressure technique by accumulation; bell pressure test.		**Tracer gas method**	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			b) Global leak: bubble test — immersion; bubble test foaming; pressure technique by accumulation — global; pressurization-evacuation test (bombing); vacuum chamber technique; bell pressure test; pressure change; flow measurements.			
	Fundamentals of test method choice EN 13625		**Test method — Choice of criteria**		**Test method — Choice of criteria**	
10.4 **Equipment**	**Vacuum gauges**	**E 3,0**	**Vacuum gauges**	**E 5,0**	**Vacuum gauges**	**E 5,0**
	Choice of gauges for different pressures		Absolute and differential gauges			
	Total pressure and partial pressure gauges		Primary and secondary gauges			
			Physical properties involved for the different sensor type			
	Mechanical gauges		**Mechanical gauges**		**Mechanical gauges**	
	Pressure reading techniques for: bourdon gauge; diaphragm gauge; capacitance manometer gauge.		Bourdon gauge: principles and behaviour; influence of atmosphere.		Accuracy for the different sensors.	
			Diaphragm gauge: principles and behaviour; influence of atmosphere.			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Capacitance manometer gauge: principles and behaviour; influence of temperature.			
	U-tube manometers and Mc Leod Pressure reading techniques		**U-tube manometers and Mc Leod** Principles and behaviour		**U-tube manometers and Mc Leod**	
	Pirani and thermocouple gauges Pressure reading techniques Assembly criteria		**Pirani and thermocouple gauges** Principles and behaviour of different gases		**Pirani and thermocouple gauges** Accuracy and calibration for different gases	
	Cold and hot ion gauges Pressure reading techniques Assembly criteria		**Cold and hot ion gauges** Principles and behaviour of different gases		**Cold and hot ion gauges** Accuracy and calibration for different gases	
	Vacuum pumps Types of pump for different vacuum ranges		**Vacuum pumps** Classification and selection of vacuum pumps: pump performance; ultimate pressures; pressure ranges; pumping speed; discharge pressures.		**Vacuum pumps** Physical principle involved.	
	Rotary and piston pumps Performance Maintenance Gas ballast		**Rotary and piston pumps** Pump-down times calculation for different volumes		**Rotary and piston pumps** Physical principle involved Pump-down times calculation for different volumes including conductance influence	
	Roots pump Performance Maintenance		**Roots pump** Size evaluation; Mounting		**Roots pump** Physical principle involved Pump-down times calculation for different volumes including conductance influence	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Diffusion pump		**Diffusion pump**		**Diffusion pump**	
	Performance		Size evaluation for different application		Physical principle involved.	
	Maintenance		Size evaluation for the backing pump			
			Mounting			
	Turbomolecular pump		**Turbomolecular pump**		**Turbomolecular pump**	
	Performance		Size evaluation for different application		Physical principle involved	
	Maintenance		Size evaluation for the backing pump			
			Mounting			
	Valve		**Valve**		**Valve**	
	Type of valves used for leak detection application		Choice of valve for leak testing application			
	Maintenance		Performance			
	Mounting					
	Fittings		**Fittings**		**Fittings**	
	Assembly criteria		Choice of right fittings for leak detection;		Project criteria	
	Maintenance		Diameter and length calculation and influence			
			Material		**Material**	
			Choice for different vacuum ranges			
			Metallic, plastic, glass			
			Oil and grease.			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
10.5 **Information prior to testing**	**Written procedures — Interpretations** Acceptance and rejection criteria Leak interpretation evaluation **Data report module filling**	**EB 1,0** **EC 1,0**	**Existing documentation analysis — Written procedures** Design versus working conditions; Pressure and temperature control Test method and sensitivity required Preparation of leak test specification **Data report module** Preparation of data report modules. **Tracer gas detector/instruments performance factor** Design and use Linearity Calibration Response and recovery time. Preparation of written instructions.	**EB 2,0** **EC 2,0**	**Existing documentation analysis — Written procedures** **Data report module** **Tracer gas detector/instruments performance factor**	**EB 2,0** **EC 2,0**
10.6 **Testing**	**Bubble testing practice and techniques** General requirements: gas, pressure limits, cleaning, etc. Test fluid: test fluids for liquid immersion techniques (preparation and use); test fluids for liquid application techniques (preparation and use).	**EB 10,0** **EC 14,0**	**Bubble testing practice and techniques** Selection of test fluids from the points of view of physical properties selection of techniques for different applications; pipe, nozzle, pad plate, compressor testing; vessel testing; leakage quantitative evaluation.	**EB 18,0** **EC 24,0**	**Bubble testing practice and techniques** Weather effects and lighting.	**EB 12,0** **EC 16,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Immersion technique		**Immersion technique**		**Immersion technique**	
	Pressurization of test specimen		Physical principles involved			
	Knowledge for creating pressure differential					
	Elevated temperature test fluid					
	Vacuum box technique					
	Liquid application technique		**Liquid application technique**		**Liquid application technique**	
	Pressurization of test specimen		Physical principles involved			
	Vacuum technique for non-pressurized objects					
	Pressure change techniques and practice		**Pressure change techniques and practice**		**Pressure change techniques and practice**	
	General requirements		Pressure change method:		Pressure change method	
			physical principles involved;			
			perfect gas law.			
	Pressure decay technique		**Pressure decay technique**		**Pressure decay technique**	
	Temperature and pressure gauges		Apparatus and test set-up		Accuracy of equipment	
	System set up		Choice of pressure and temperature gauges		Gauge calibration accuracy	
					Accuracy of test calculations	
	Reference vessel technique (fundamental)		Effect of temperature change			
			Effect of water vapour pressure			
			Effect of barometric pressure change			
			Calculation of leakage rate			
			Reference vessel technique			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Leakage rate calculation from the perfect gas law			
	Pressure rise technique		**Pressure rise technique**		**Pressure rise technique**	
	Effect of virtual leak		Leakage rate calculation from the perfect gas law		Calibration	
			Choice of vacuum gauges		Evaluation of virtual leak on pressure time relationship	
	System set up		Choice of the system		Accuracy test calculation	
			Effect of virtual leak on pressure-time relationship			
	Bell pressure change technique		**Bell pressure change technique**		**Bell pressure change technique**	
	General requirements		Air flow into the object		Calibration	
			Air flow out of the object		Calculation of leakage rate	
			Choice of gauge		Accuracy test calculation	
			Calculation of leakage rate			
	Flow measurements technique		**Flow measurements technique**		**Flow measurements technique**	
	General requirements		Air flow into the object		Calibration	
			Air flow out of the object		Accuracy test calculation	
			Choice of gauge			
			Calculation of leakage rate			
	Tracer gas practice and techniques		**Tracer gas practice and techniques**		**Tracer gas practice and techniques**	
			Tracer gas method		Tracer gas method	
			Calculation of leakage rate			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			Choice of tracer gas and suitable detector Selection criteria of the technique for different application			
	Mass spectrometers Fundamental principles, MSLD manufacturing aspect: magnetic or quadrupole; direct flow and contraflow; pumping systems, electronic, heads, gauges, etc.; service; calibration leaks; helium mixture.		**Mass spectrometers (helium)** Physical principles involved: e/m equation of mass; mass spectra; magnetic; quadrupole; general and leak testing application. MSLD manufacturing aspect involved and working principles Sensitivity capabilities for the different techniques Calibration Helium mixture and leak rate calculation Maintenance issues		**Mass spectrometers (helium)** Mass spectrometry: qualitative and quantitative; Magnetic or quadrupole.	
	Halogen ion diode Fundamental principles involved Halogen detector leak testing equipment Halogen detector		**Halogen ion diode** Physical principles involved Sensitivity capabilities of the technique Selection criteria of the techniques for different application		**Halogen ion diode**	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Operation		Detector probe “sniffer” speed			
	Cleaning the sensing element replacing the sensing element		Halogen background			
	Detector tube for vacuum application		Properties of refrigerant tracer gas (chemical composition, molecular weight, liquid-gas behaviour)			
	Calibration leaks (maintenance and operation criteria)		Calibration of halogen leak detectors			
	Refrigerant tracer gas (types commonly used)		Halogen mixtures percentage			
	Calibration leak setting for calibration of halogen		Evaluation of test sensitivity			
	Thermal conductivity gauges		**Thermal conductivity gauges**		**Thermal conductivity gauges**	
	Fundamental principles		Physical principles involved		Pirani and thermocouple working principles.	
			Sensitivity capabilities of the techniques with this detector			
			Reactive tracers		**Reactive tracers**	
			Physical principles involved		Radioactive gases	
			Sensitivity capabilities of the technique			
			Gas analysis apparatus (gas chromatography etc.)		**Gas analysis apparatus (gas chromatography etc.)**	
			Physical principles involved			
			Sensitivity capabilities of the technique			

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Tracer gas flows into the objects — Group A techniques		**Tracer gas flows into the objects — Group A techniques**		**Tracer gas flows into the objects — Group A techniques**	
	For all techniques: general requirements; initial set-up and procedure; object preparation.		For all techniques: test sensitivity for different techniques; calilbration; calculation of leakage rate.			
	Vacuum technique — Total and partial		**Vacuum technique — Total and partial**		**Vacuum technique — Total and partial**	
	Vacuum technique — Local (spraying) Object surface scanning		**Vacuum technique — Local (spraying)**		**Vacuum technique — Local (spraying)**	
	Tracer gas flows out of the objects — Group B techniques		**Tracer gas flows out of the objects — Group B techniques**		**Tracer gas flows out of the objects — Group B techniques**	
	For all techniques: general requirements; initial set up and procedure; object preparation.		For all techniques: test sentivity for different techniques; calibration; calculation of leakage rate.			
	Chemical detection with ammonia Reagent application Post test cleaning		**Chemical detection with ammonia** Physical principles involved Type of reagent		**Chemical detection with ammonia**	
	Vacuum box using internal tracer gas		**Vacuum box using internal tracer gas**		**Vacuum box using internal tracer gas**	
	Vacuum box applying the tracer gas in the opposite side		**Vacuum box applying the tracer gas in the opposite side**		**Vacuum box applying the tracer gas in the opposite side**	
	Pressure technique by accumulation		**Pressure technique by accumulation**		**Pressure technique by accumulation**	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Sniffing test Object surface scanning **Fundamental on pressurization-evacuation test (bombing)** **Vacuum chamber technique**		**Sniffing test** Calibration (when applicable) **Pressurization-evacuation test (bombing)** Object preparation Initial set up and procedure Calculation of leakage rate **Vacuum chamber technique**		**Sniffing test** **Pressurization-evacuation test (bombing)** **Vacuum chamber technique**	
10.7 **Evaluation and Reporting**	**Test data report filling**	**EB 0,5** **EC 0,5**	**Results analysis and evaluation on the base of acceptability criteria and applicable proceeding** **Leak test procedures compilation** Reference standards and other documents	**EB 2,0** **EC 2,0**	**Results analysis and evaluation on the base of acceptability criteria and applicable proceeding** **Leak test procedure compilation** Reference standards and other documents technique proceeding and module related to drafting	
10.8 **Assessment**	**(Not applicable)**		**Analysis through alternative techniques or methods**	**EB 2,0** **EC 2,0**	**Acceptability criteria assessment in collaboration with project engineer specialist and manufacturing managers** **Ergonomic analysis through alternative techniques or methods**	**EB 2,5** **EC 2,5**
10.9 **Quality aspects**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification	**E 1,0**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification Written instructions Traceability of documents	**E 1,0** **EB 1,0** **EC 1,0**	**Personnel qualification** (according to EN 473 and ISO 9712) Equipment verification Format of working procedures Traceability of documents	**E 1,0** **EB 1,0** **EC 1,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
			A review of applicable NDT application and product standards		Other NDT qualification and certification systems A review of applicable NDT application and product standards	
10.10 **Developments**	**(Not applicable)**		**Special industrial installation**	**E 1,0**	**New development for industrial and R&D applications**	**E 2,0**
Total duration		**E 7** **EB 13,5** **EC 18,5**		**E 10** **EB 29** **EC 37**		**E 11** **EB 22.5** **EC 28.5**

11 Acoustic emissions testing — Levels 1, 2 and 3

The letters **E** and **P** followed by a value indicate the *educational training time* and *practical training time* respectively, in hours.

NOTE As specified in EN 473, direct access to the level 3 examination requires the total hours shown for level 1 and level 2.

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
11.1 Introduction to, terminology and history of, NDT	**Terminology** EN 1330-9		**Terminology** EN 1330-9		**Terminology** EN 1330-9	
11.2 Physical principles and associated knowledges	**Physical principles of AE sources (mechanism in analogy to earthquakes)**	**E 0,5**		**E 1,0**		**E 0,5**
	Relevant standards: EN 13554: General principles Overview Visual demonstration		Frequency range Source characteristics		Effect of dislocation Effect of stress on the waves Modes of fracture	
	Characteristics of AE Transient emission Continuous emission Amplitude Frequency range Kaiser effect (overview)	**E 1,0**	**Characteristics of AE** Effect of source dimension Effect of source velocity Source propagation Type of loading Kaiser effect in different materials	**E 1,0**	 Effect of repeated loading AE during hold periods Felicity effect Felicity ratio	**E 1,0**
	Sources of AE Metals Composites Other materials Crack growth	**E 1,0**	 Different type of sources Dislocation Plastic deformation Inclusions	**E 1,5**	 AE signatures SCC (stress corrosion cracking) Leak detection Corrosion	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Crack surface friction Leak sources Mechanical friction Loose parts Non detectable sources		Crack growth Critical and sub-critical crack growth Fatigue crack Ductile crack growth Magnitude of AE signals on different materials		Others	
	Wave propagation Types of elastic waves Longitudinal waves Transverse waves Rayleigh waves Wave parameters	**E 1,0**	Wave motion and velocity Mode conversion Reflection and refraction of waves Wave attenuation Lamb waves Wave dispersion Geometric effects Shadowing effects	**E 1,5**	Diffraction Anisotropic propagation Wave propagation in fluids Influence of fluids Attenuation vs. frequency	**E 1,5**
	Source location One sensor location Linear location with delta-t Planar location with delta-t Continuous emission	**E 1,0**	Linear and planar locations Zone location (algorithm knowledge) Thin-walled and thick-walled structures Location uncertainty Guard sensors	**E 2,0**	Algorithm details Cross-correlation Three-dimensional location Neighbourhood relations Accurate locations using analysis	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
11.3 **Product knowledge and capabilities of method and its derivate techniques**	**Possible fields for application of AE** Outline of different structures Outline of different materials	**E 1,0**	Pressure equipment Storage tanks Pipelines and piping systems Leak detection	**E 1,0**	Machines Other components Influences of loading Loading possibilities	**E 1,0**
	Outline of chemical and physical properties Elasticity Ductility Toughness Stiffness Fatigue Wear	**E 2,0**	Creep Welding	**E 1,0**	Fracture mechanics Significant test for materials properties verification	**E 1,0**
	Pressure equipment Normal test performance of pressure equipment	**E 2,0**	Advantages and disadvantages of AE on pressure equipment Differences of the first pressure test and repetition tests	**E 1,0**	Differences between AE and other techniques	**E 2,0**
	Product standards and codes Outline of CEN standards handling with AE (e.g. EN 13445-5:2002, Annex E) Outline of relevant national standards	**E 1,0**	CEN product standards, their influence on AE	**E 2,0**	PED Directives for non-pressurized equipment Relevant national standards Relevant US standards	**E 2,0**

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
11.4	**Relevant standards:**	**E 1,5**	Calibration methods	**E 1,5**	Wave mode response aperture effect	**E 1,5**
Equipment	EN 13477-1 and EN 13477-2		Sensor selection			
	Sensors					
	Piezoelectricity					
	Construction					
	Frequency response		Ground-loop		Reciprocity calibration	
	Wide-band and resonant sensors		Temperature effects		Special sensors	
	Coupling and sensitivity		Acoustic impedance		Shielding	
	Integral electronics		Wave guide		Impedance matching	
	Single ended/differential				Noise susceptibility	
	Connectors				Simulated AE sources	
	Cables					
	Preamplifiers	**E 0,5**	Frequency filter selection	**E 0,5**	Input capacity	**E 0,5**
	Single ended/differential					
	Unit of gain (db scale)		Cable length effects		Filter types	
	Electronic noise		Common mode rejection		Electronic noise	
	Filters		Signal saturation			
	Signal processing	**E 2,0**		**E 1,0**		**E 1,0**
	Continuous signal		AE parameters (EN 1330-9)		Digital vs. analogous signal	
	Transient signal		Energy (true, MARSE, alternative)		System parameter definition and selection	
	Background noise					
	ASL		Acquisition rate		Distribution techniques	
	RMS		Waveform digitization		Spectral analysis	
	Amplitude		Waveform recording		Cascaded hits	
	Threshold				Continuous mode measurement	
	Single- vs. multi-channel system				Industrial dedicated systems	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Source location processing	**E 2,0**		**E 1,0** **P 2,0**		**E 1,0**
	Algorithm overview		Algorithm knowledge		Algorithm details	
	Linear location		Algorithm selection		Wave mode influence	
	Zone location		Location uncertainty		Neighbourhood relations	
	Hit-sequence location		Guard channels		Cross-correlation technique	
	Planar location		Three-dimensional location		Factors affecting errors on location	
	Advanced signal processing	**E 0,5**		**E 0,5**		**E 1,0**
	External parameters		FFT		Pattern recognition	
	Distribution plots		Waveform feature extraction		Signal averaging	
	Correlation plots		Timing considerations		Waveform recording for cross-correlation	
	Equipment calibration	**E 2,0**		**E 1,0** **P 2,0**		**E 0,5**
	Sensor verification in lab		Sensor calibration in lab		Different calibration procedures	
	AE system verification in lab		AE system calibration in lab			
	Knowledge of EN 13477-1 and EN 13477-2		National standards, if applicable			
	Fundamental of informatics	**E 0,5**		**E 0,5**		**E 1,0**
	Knowledge and use of computers		Knowledge of software		Knowledge of the location algorithms	
			Knowledge of data analysis		Knowledge of system limitations	
			Knowledge of data presentation		Knowledge of current state-of-the art	

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
11.5 Information prior to testing	**Determination of the AE test performance**	**E 0,5**		**E 1,0**		**E 1,0**
	EN 13554		Information prior the test Factors influencing the testing instruction		Information about the history of the tested structure	
	Loading procedures Pressure tests (maximum test pressure, loading rate, load holds)	**E 0,5**	Establishment of the loading program Repeated loading Cyclic loading Continuous measurement	**E 1,0**	Determination of the loading procedure Secondary loading effects (e.g. Temperature) Monitoring On-line measurement Influence and other loading possibilities	**E 1,0**
	Source location Single channel location Linear location Zone location Planar location	**E 2,0**	Other location techniques Location accuracy	**E 1,0**	Advanced location techniques	**E 1,0**
	AE testing instructions Working with an AE testing instructions	**E 2,0** **P 2,0**	Writting of an AE testing instruction	**E 2,0** **P 3,0**	Acceptance of an AE testing instruction	**E 2,0**
	AE testing procedure		Implementation of an AE testing procedure into a testing instruction		Writing of an AE testing procedure Interpretation of standards Differences of AE testing procedure and instructions	**E 3,0** **P 4,0**
11.6 Testing	**Equipment set-up** Equipment set-up Sensor placement Equipment verification	**E 2,0** **P 8,0**	Factors affecting the selection of the test equipment	**E 0,5** **P 4,0**		

Content	Level 1	Duration h	Level 2	Duration h	Level 3	Duration h
	Noise identification Velocity and attenuation measurement Location of simulated sources					
	Test performance Loading procedure Actions during the tests	**E 2,0** **P 2,0**		**E 0,5** **P 2;0**		
	Data acquisition and data display during test Data acquisition Significance of the plots for data display (time-based, load-based, location, correlation) Comparison with the verification Comparison with location of simulated source	**E 2,0** **P 8,0**	Establishment of the acceptance criteria Selection of plots, correlation and distributions	**E 1,0** **P 2,0**	On-line evaluation	**E 0,5**
	Necessary actions during the test Stop criteria	**E 1,0** **P 2,0**	Verification of on-line detected AE sources by other NDT methods	**E 1,0**	Interpretation of the relation between the AE source and the result of the adjoining NDT	**E 1,5**
11.7 Evaluation and reporting	**Data display** Time-based plots Load-based plots Parameter-based plots Location plots Distribution plots	**E 2,0** **P 2,0**	AE source correlation	**E 0,5** **P 4,0**	Advanced data display (pattern recognition)	**E 1,0**