Bundesverband der Deutschen
Luft- und Raumfahrtindustrie e.V.
German Aerospace Industries Association

National Aerospace NDT Board

NANDTB-GERMANY

Syllabuses

Amendment for 2016: RT NonFilm level 1, 2 and 3; PAUT level 2.

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Penetrant testing, level 1 (≥16h)		
Basics of penetrant testing	Basic principles of penetrant testing	
	Basic physical information	Surface tension Wetting Capillarity
	Classification of penetrants by standards	Color contrast penetrants Fluorescent penetrants Fluorescent color contrast penetrants
	Excess penetrant removal processes	Excess penetrant removal with water Excess penetrant removal with lipophilic emulsifier Excess penetrant removal with solvents Excess penetrant removal with hydrophilic emulsifier Excess penetrant removal with water and solvent
	Types of developers	Dry developer Wet developer, water-soluble Wet developer, water suspendable Wet developers, solvent based Wet developer for special applications
Properties of the human eye		Visual acuity Color discrimination capability Contrast sensitivity Brightness-darkness adaptation Astigmatism
Test specimens		Requirements for the test specimen Pre-treatment of the test specimen
Application techniques of penetrant testing		Dye penetrant testing Fluorescent penetrant testing Fluorescent dye penetrant testing Special application techniques Penetration testing
Performance of the test	Penetrant testing procedure	Selection of the testing method Cleaning prior to testing Drying before the penetration procedure Application of penetrant Penetration time Excess penetrant removal Drying after excess penetrant removal Application of developer Developing time Start of inspection Final inspection Description of indications Cleaning after the inspection

Penetrant testing, level 1 (≥16h)		
		Application of surface protection to components Sample indications
Testing equipment and procedure monitoring	Procedure monitoring	Use of reference blocks Use of reference blocks in mobile testing
	Test equipment	Pretreatment areas Drying systems Procedure monitoring on drying furnaces Application area of penetrant Bath systems Dripping station Monitoring of the penetrant Excess penetrant removal Water immersion tank Water spray application unit Emulsification areas Monitoring of the emulsifier Developers Possible application methods for dry developers Wet developers, solvent based Monitoring of developers Working areas Water rinsing unit, temperature and pressure UV-A radiation Illuminance levels Tools Magnifying glasses Endoscopes
Analysis and evaluation		Analysis of test specimens Evaluation of test specimens Documenting a test
Materials science		Material defects generated during manufacture • Inclusions • Pores • Shrinkage cavities • Segregations • Cracks Defects generated during processing • Rolling and forging defects • Turning, grinding defects • Defects caused by hardening Defects caused by operational loads • Cracks • Corrosion

Standards and regulations		Standards Test instructions Internal company regulations
Security regulations		General safety regulations Handling of test media and equipment
Practical exercises		Exercises practicing the handling of aero-nautical parts

Penetrant testing, level 2 (≥16h)		
Basic principles	Basic principles of penetrant testing	
	Test media systems	Penetrants Excess penetrant removal agent Developers Classification of test media
Procedure	Precleaning processes	Precleaning methods
	Mechanical precleaning	Mechanical precleaning Influence of mechanical precleaning Influence on indications after honing Influence on indications after grinding, 180K Influence on indications after grinding, 240K Influence on indications after shot peening Pickling Necessary pickling ablations
	Chemical precleaning	Chemical precleaning Water-based degreasing Decoction degreasing Electrolytic degreasing Rust removal agents Paint removal agents Descaling
	Penetration procedure	The penetration produre Test temperatures based on different rule sets Application of penetrant Wetting Penetration time
	Excess penetrant removal	with water with lipophilic emulsifier with solvents with hydrophilic emulsifier with water and solvent
	Drying	Drying after precleaning Drying after excess penetrant removal
	Development	Development with dry developer Water-soluble wet developer Water suspendable developer Solvent suspendable developer Special developers
Selection of the test system		Test media for standard requirements Test media for increased requirements Test media for maximum requirements Special test systems

Identification of test media properties	Testing as per EN3452	Type testing Batch testing Monitoring by the user
	Properties to be inspected	Density Surface tension; metals, plastics Wetting / contact angle Viscosity Flash point Vapor pressure UV resistance Corrosive components Testing of non-metallic materials Properties of developers Particle size analysis
Verification of the indication range		Reference blocks as per DIN EN ISO 3452-3 Sensitivity levels JIS reference blocks PSM 5 reference blocks Cleaning/storage of the reference blocks
Selection of the surface inspection method		Design of test sequences Safety relevance of specimens to be tested Type of defect to be identified Material of specimen to be tested Shape/surface condition of test specimen Workplace conditions Test temperature range Quantity of specimens to be tested
Equipment and systems		Cleaning systems for precleaning and excess penetrant removal Drying options Developer application systems Inspection systems
Special test conditions		Testing at low temperatures Testing at high temperatures Testing of different surfaces Mobile penetrant testing Testing during maintenance and servicing
Knowledge about the test specimen		Forms of indication and types of defects Testing of non-metallic materials Testing of ceramic materials Testing of plastics
Standards, rules and regulations, specifications		Test engineering guideline Object-based r ules Order agreements, specifications Guideline for a test instruction

Documentation and reports		Significance of documentation Documentation for the customer Documentation for QA Structure of reports/records0 Significance of a coordinate system Documentation tools
Environmental protection and safety regulations		Composition of the test media Disposal of test media Penetrants Excess penetrant removal agent Developers Security regulations Hazardous Substances Ordinance Hazard symbols EU safety data sheets General instructions for handling hazardous materials
Practical exercises		Exercises practicing the handling of aero-nautical parts

Penetrant testing, level 3		
Basic physical information	Basic principles	Basic principles of penetrant testing
	Properties of test media	Density of fluids Surface tension of fluids Surface tension of solids Wetting Contact angle Capillarity Viscosity Flash point Vapor pressure Stability of penetrants Shelf life Testing for corrosive ingredients Sensitivity of penetrants Properties of excess penetrant removal agents Properties of developers
Selection criteria for the application of the penetrant testing method	Delimitation from other surface testing methods	VT visual inspection MT magnetic test methods ET eddy current test methods Special penetrant testing methods Application techniques
Procedure	Preparation of the specimens to be tested	Potential surface contaminations Pre-cleaning methods Influence of mechanical surface treatment Influence of honing used as surface treatment Influence of grinding used as surface treatment Drying after pretreatment Drying temperatures from various rules and standards
	Application of penetrant	Methods for applying the penetrant
	Excess penetrant removal	Particularities of excess penetrant removal Excess penetrant removal processes
	Drying	Drying after excess penetrant removal Drying temperatures from various technical guidelines
	Developer application	Methods for applying the developer Developing time
	Inspection	Inspection
Penetrant testing systems		Design of penetrant testing systems Components of penetrant testing systems Manual systems Semi-automatic systems Fully-automatic systems

Procedure controls		Checks by the user Check of the component Check of the environmental conditions Check of the test equipment system Check of the testing facilities Check of inspector qualifications
Reference blocks for penetrant inspection		Reference block 1 as per DIN EN ISO 3452-3 Reference block 2 as per DIN EN ISO 3452-3 Reference block A as per DIN 54152 T3 Reference block B as per DIN 54152 T3 Reference block as per PSM 5 TAM JIS reference blocks Reference blocks as per ASME V Article 6 Test specimens with natural cracks Test specimens for monitoring removability Cleaning of the reference blocks Storage of the reference blocks
Penetrant test systems		Description as per DIN EN3452-1 Qualification Certification Certification of test equipment systems
Procedure control		General monitoring practices Procedure control steps
Interpretation and analysis of indications		Types of indication Evaluation at various aeronautical parts manufacturers Evaluation as per an engine manufacturer
Rules and standards/ test instructions		General information on rules and standards and test instructions In-house standards and instructions Comparison of national and international rules and regulations
Case studies for test instructions		Requirements for a test instruction Preparation of a test instruction Test instruction for vertical stabilizer shell fitting Test instruction for milled fitting Test instruction as specified

Magnetic testing, level 1 (≥16h)		
Basic physical principles of magnetic inspection	Magnetism	Effects of magnetism Magnetic fields of permanent magnets
	Magnetic fields at and around electrical conductors	Magnetic fields of conductors Magnetic fields of direct currents Magnetic fields of alternating currents
	Matter in a magnetic field	Matter in the magnetic field Magnetic conductivity The hysteresis curve
	Magnetization / demagnetization Properties of the human eye	Necessary magnetization Demagnetization Demagnetization methods Visual acuity Color discrimination capability Contrast sensitivity Brightness-darkness adaptation Astigmatism
Test specimens		Requirements for the test specimen Preparation of the test specimen
Application techniques	Overview	Overview
	Circular magnetization	Self-excitation Separate excitation
	Longitudinal magnetization	Yoke magnetization Coil magnetization Magnetic flow technique
	Combined techniques	Combination of 2 d.c. fields Combination of d.c. and a.c. fields Combination of 2 a.c. fields Phase-shifted a.c. fields
Test performance	General information	General information on performing the test Prerequisites for test specimens and test equipment
	Procedure	Selection of the magnetization method Preparation and clamping of the component Magnetization of the component Chronological sequence of test steps Interpretation and analysis of MP indications Cleaning and application of surface protection after the test

Procedure monitoring	Monitoring of the magnetization devices	Stationary equipment Portable magnetization equpiment Monitoring of the equipment
	Demagnetization equipment	Monitoring of the demagnetization unit Demagnetization coils Demagnetization on static systems Procedure monitoring of demagnetization equipment
	Crack test media	Preparation of crack test media Monitoring of the concentration Monitoring of the indication capability
	Lighting and irradiation	Lighting and irradiation facilities Measurement of UV-A radiation Measurement of white light Procedure monitoring of UV-A irradiation
	Measurement of field strength	Measurement of field strength Tangential field strength measurement Measurements using the Berthold test block
		Remanence meters
Analysis, evaluation, and documentation		Analysis of test specimens Pseudo-defects Pertinent defects Evaluation Documenting in production Documenting in maintenance
Materials science	Material defects generated during manufacture	Inclusions Pores Shrinkage cavities Segregations Cracks
	Defects generated during processing	Rolling and forging defects Turning, grinding defects Defects caused by hardening
	Defects caused by operational loads	Cracks Corrosion
Standards and regulations		Standards Test instructions Internal company regulations
Security regulations		General safety regulations Handling of test equipment and tools
Practical exercises		Exercises practicing the handling of aeronautical parts

Magnetic testing, level 2 (≥16h)		
Basic physical principles of magnetic inspection	Electrical variables	Electric voltage Electric current Frequency Electrical resistance Phase shifting Electrical power Effects of electric currents
	Basic principles of magnetism	Ferromagnetism Magnetic fields Magnetomotive force Magnetic field strength Permeability Magnetic flux density (induction) Magnetic flux Magnetization curves (hysteresis curves) Required field strengths
	Electromagnetic induction	Transformers Skin effect
	Magnetic fields around electrical conductors	Field strength Flux density within and around the conductor
	Ferromagnetic materials in a magnetic field	Magnetic shearing with coil magnetization Particularities of yoke magnetization
	Demonstration of adequate field strengths	Field strength measurement
	Combined methods	Combination of 2 d.c. fields Combination of d.c. and a.c. fields Combination of 2 a.c. fields Phase-shifted a.c. fields
	Demagnetization	Demagnetization methods Proper measurement of residual field strength
	UV-A radiation	UV-A irradiation units Spectral ranges of UV-A radiators Viewing conditions
	Properties of the human eye	Visual acuity Color discrimination capability Contrast sensitivity Brightness-darkness adaptation Astigmatism

Magnetization techniques	Basics of the magnetization technique	General information Yoke magnetization Coil magnetization Self-excitation Separate excitation Magnetic flow technique Combined techniques Other magnetization techniques
Test equipment and auxiliary means	Equipment	Portable equipment Additional equipment Demagnetization coils
	Test media	Fluorescent and colored test media Mixing of test medium suspensions
	Irradiation unit for reference blocks and equipment	UV-A irradiation units Measurement equipment for lighting and irradiation Reference blocks for test media monitoring Reference blocks for equipment monitoring
	Measurement of tangential field strength	Field strength measuring devices Berthold test blocks Test specimens for magnetization checks
Procedure monitoring	Lighting and irradiation measurement	UV-A irradiation measurement White light measurement
	Monitoring of the test system	Monitoring of the test medium concentration Monitoring of the test equipment for proper function Monitoring of tangential field strength
Analysis, evaluation, documentation, test instruction		Analysis Evaluation Test report Structure of a test instruction Test instruction as per ASTM E1444 Case studies
Standards and regulations		Standards Test instructions Internal company regulations
Delimitation from other test methods		Comparison with other surface examination techniques Detectable defect sizes Other NDT methods

Materials science	Material defects generated during manufacture	Inclusions Pores Shrinkage cavities Segregations Cracks
	Defects generated during processing	Rolling and forging defects Turning, grinding defects Defects caused by hardening
	Defects caused by operational loads	Cracks Corrosion
Design concepts		Safe-life Fail-safe Damage Tolerance
Environmental protection and safety regulations		Composition of the test equipment Disposal of test media Penetrants Excess test medium removal agent Developers Safety regulations Hazardous Substances Ordinance Hazard symbols EU safety data sheets General instructions for handling hazardous materials
Practical exercises		Testing of components relevant for aviation Procedure monitoring

Magnetic testing, level 3		
Basic physical principles of magnetic inspection	Electrical variables	Electric voltage Electric current Frequency Electrical resistance Phase shifting Electrical power Effects of electric currents
	Basic principles of magnetism	Ferromagnetism Magnetic fields Magnetomotive force Magnetic field strength Permeability Magnetic flux density (induction) Magnetic flux Magnetization curves (hysteresis curves) Required field strengths
	Electromagnetic induction	Transformers Skin effect
	Magnetic fields around electrical conductors	Magnetic field strength within and around electrical conductors Magnetic flux density within and around electrical conductors
	Ferromagnetic materials in a magnetic field	Magnetic shearing with coil magnetization Particularities of yoke magnetization Demonstration of adequate magnetization
	Comparison of magnetic d.c. and a.c. fields and their superposition	d.c. and a.c. magnetization Combination of d.c. and a.c. fields Combination of phase-shifted fields
	Demagnetization	Demagnetization devices Measurement of residual field strength
	Observation conditions	UV-A radiation UV-A radiator Observation conditions for MP testing
	Properties of the human eye	Visual acuity Color discrimination capability Contrast sensitivity Brightness-darkness adaptation Astigmatism

Application of the method	Current flow techniques	Self-excitation Separate excitation Magnetic flow technique
	Polar magnetization techniques	Coil magnetization Yoke magnetization
	Measurement of magnetization	Field strength measurement with a Hall probe Other field strength indicators Measurement of flux density
Procedure	Preparation of the test specimens	Clamping of the test specimens Definition of adequate magnetization Magnetization / flow Analysis / evaluation
Facilities and test equipment	Magnetic inspection systems	Portable systems Stationary systems
	Lighting and irradiation facility	White light observation Observation under UV-A radiation
Reference blocks		Purpose of reference blocks Reference blocks for control of test media Reference blocks for checking the magnetic direction Reference blocks for checking the overall system
Test equipment		Test medium categories Fluorescent test media Colored test media Base colors High-temperature test media
Interpretation of indications and evaluation		Individual indications Indications with irregular distribution Indications in series
Comparison of rules and regulations		Rules and regulations in general In-house standards Internal instructions Procedures Work instructions Comparison of national and international rules and standards
Case studies for test instructions		Contents of test instructions Requirements as per ASTM E 1444 Example cases Exercises for preparing test instructions
Case studies for test instructions		Test instruction for vertical stabilizer shell fitting Test instruction for milled fitting Test instruction as specified

Eddy current testing, level 1 (≥40h)		
Basic physical information	Eddy current principle	
	Electrical variables	Electric voltage Electric current Frequency Electrical resistance Specific electrical resistance Electrical conductivity Phase shifting Electrical power Resistance in the a.c. circuit
	Magnetism	Basic principles of magnetism Ferromagnetism Matter in a magnetic field Comparison of electrical systems/hydraulic systems and magnetism Properties of ferrites
	Electromagnetic induction	Transformer Self-induction Eddy currents
	Properties of eddy currents	Excitation principle of eddy currents Depth of penetration of eddy currents Propagation interference
	Impedance Impedance graph	Coil impedance Impedance graph
		Structure of the impedance graph Variables influencing impedance changes Conductivity variations Representation of eddy current signals
	Eddy current test system	Function principle of the eddy current test system
	Probes	Probe overview Coil arrangements Electric circuit of test equipment and probe Coil circuits
Application techniques		Measurement of specific electrical conductivity Layer thickness measurement Corrosion test Crack test
Test equipment and auxiliary means	Equipment and tools	Conductivity measuring equipment Layer thickness gages Crack testing devices Corrosion testing devices Universal eddy current devices
Procedure monitoring		Procedure monitoring in general Calibration and reference blocks

Signal interpretation, evaluation, and documentation		Analysis of test specimens Evaluation of test specimens Defect recognition and allowable limits Logging
Material defects generated during manufacture		Inclusions Pores Shrinkage cavities Segregations Cracks Defects generated during processing Rolling and forging defects Turning, grinding defects Defects caused by hardening Defects caused by operational loads Cracks Corrosion
Comparison of NDT methods		ET inspection compared to other methods
Safety regulations		General safety regulations Handling of test equipment and tools
Practical exercises		Exercises practicing the handling of aeronautical parts

Eddy current testing, level 2 (≥40h)		
Basic physical principles of eddy current inspection	Eddy current principle	
	Electrical variables	Electric voltage Electric current Frequency Electrical resistance Specific electrical resistance Electrical conductivity Phase shifting Angular frequency Electrical power Effects of electric currents Resistance in the a.c. circuit
	Basic principles of magnetism	Magnetic fields Excitation Magnetic field strength Permeability Magnetic flux density Magnetic flux Magnetization curves Properties of ferrites
	Electromagnetic induction	Law of induction Transformer Self-induction Skin effect
	Eddy currents	Generation of eddy currents Propagation of eddy currents Depth of penetration of eddy currents Influences on the propagation of eddy currents
	Coil impedance	General information on coil impedance Locuses in the impedance graph Normalized impedance graph Preparation of a normalized impedance graph Influence of conductivity Influence of distance (lift-off) Influence of the test frequency Influence of the component thickness Influence of cracks
	Probes	Probe overview Coil arrangements Types of Circuit Electrical combination of coil and device circuits Function principle of coil systems

Basic physical principles of eddy current inspection **(Continued)**	Design of an eddy-current tester	Alternator Coil system Input stage Demodulator Vector amplifier Zero point compensation Filters Phase adjuster Signal representation
	Filters	General information on filters Low-pass filter High-pass filter Band-pass filter Filter selection and test speed
	Influence of component properties on the eddy current test	High-level and low-level conductivities Ferromagnetic test specimens Anisotropic conductivity, CFRP test specimens
	Static and dynamic testing	Static test Dynamic test Testing using "sliding probes"
Application techniques	Conductivity measurement with screen devices	Equipment and parameter selection Test sequence methodology Representation and analysis of measurement values Typical disturbance variables Alternative methods Positive material identification test
	Layer thickness measurement with screen devices	Equipment and parameter selection Test sequence methodology Representation and analysis of measurement values Alternative methods
	Residual wall thickness measurement Corrosion loss test	Equipment and parameter selection Test sequence methodology Representation and analysis of measurement values
		Influences disturbing the process
	Crack test	Crack type Static crack test using metallic components Categorization of types of cracks Signal processing, distinguishing of disturbance variables Test engineering Influences disturbing the process Determination of crack lengths Crack test with rotating probes Sample defects found when inspecting holes
	Use of computers	Determination of probe characteristics Automated equipment settings Measurement data collection Scanners

Test equipment and auxiliary means		Conductivity measuring equipment Layer thickness gages Crack testing devices Corrosion testing devices Universal eddy current devices
Analysis, evaluation, documentation	Analysis, evaluation, documentation	Analysis of test specimens Evaluation of test specimens Defect recognition and reliability thresholds Logging
	Basic concepts of statistical evaluation	Statistics terminology POD curves
Standards and regulations	Standards	National standards International standards
	Test instructions	Requirements for a test instruction Preparation of test instructions
	Case studies	Example for a test instruction
Capabilities of the method		General information on eddy current testing Limits of the method Other NDT methods
Material defects and quality assurance	Generation of irregularities in metallic work pieces	General information Irregularities generated during production Irregularities generated during further processing Material failure during operation Corrosion and types of corrosion
	Design concepts	Safe-life Fail-safe Damage Tolerance
Accident prevention and environmental protection		Safety regulations and advisories
Practical exercises		Practical exercises using aeronautical components Preparation of a case study Preparation of a test instruction

Eddy current testing, level 3		
Eddy current test principle		
Basic physical principles of eddy current inspection	Electrical variables	Electric voltage Electric current Frequency Electrical resistance Specific electrical resistance Electrical conductivity Phase shifting Angular frequency Electrical power Effects of electric currents Resistance in the a.c. circuit
	Basic principles of magnetism	Magnetic fields Excitation Magnetic field strength Permeability Magnetic flux density Magnetic flux Magnetization curves Properties of ferrites
	Electromagnetic induction	Law of induction Transformer Self-induction Skin effect
	Eddy currents	Generation of eddy currents Propagation of eddy currents Depth of penetration of eddy currents Influences on the propagation of eddy currents
	Coil impedance	General information on coil impedance Locuses in the impedance graph
	Standartized impedance graph	Influence of conductivity Influence of distance (lift-off) Influence of the test frequency Influence of the component thickness Influence of cracks
	Probes	Probe overview Coil arrangements Types circuit Electrical combination of coil and device circuits Function principle of coil systems

Basic physical principles of eddy current inspection **(Continued)**	Design of an eddy-current tester	Alternator Coil system Input stage Demodulator Vector amplifier Zero point compensation Filters Phase adjuster Signal representation
	Filters	General information on filters Low-pass filter High-pass filter Band-pass filter Filter selection and test speed
	Influence of component properties on the eddy current test	High-level and low-level conductivities Ferromagnetic test specimens Anisotropic conductivity, CFRP test specimens
	Static and dynamic testing	Static test Dynamic test Testing using "sliding probes"
Test methods	Conductivity measurement	General information on conductivity measurement Purpose of conductivity measurement Measuring principle Variables Measurement inaccuracies / calibration blocks Implementation Standards and regulations pertaining to conductivity measurements Conductivity measuring equipment Calibration blocks for conductivity measurements
	Layer thickness measurement	Layer thickness measurement using eddy currents Layer thickness measurement using magnetic induction methods Variables Measurement inaccuracies / calibration blocks Standards and regulations pertaining to layer thickness measurements Layer thickness gages
	Corrosion testing	Residual thickness measurement Measuring the elimination of surface corrosion Layer corrosion
	Static crack testing	General information Types of causes for cracks Categorization of types of cracks Determination of the crack length

Test methods **(Continued)**	Surface crack testing	General information Magneto-optic instrument (MOI) NTM specification Comparison of standards for crack testing Test equipment for surface crack testing
	Crack tests for detecting subsurface cracks	Signal processing, distinguishing of disturbance variables Test method Influences disturbing the process Pulsed eddy current testing Universal eddy current devices Example for a test instruction
	Tube testing	General information Comparison of standards for tube testing
	Dynamic crack test with rotating probes	Sample defects for inspecting drilled holes Calibration blocks for inspecting drilled holes Standards and regulations pertaining to inspections of drilled holes Comparison of standards and regulations Devices for testing with rotating probes
	Use of computers	Determination of probe characteristics Automated equipment set-up Measurement data collection Scanners Automatic testing using the ONMAN system
Eddy current testing compared to other NDT methods		General information Other NDT methods Limits of the method Comparison with different surface crack testing methods Comparison with test methods for subsurface cracks Comparison with corrosion test methods
Rules and standards/ test instruction		General information on standards Analysis Evaluation National and international standards and regulations Process instruction Structure of a test instruction Examples of a test instruction
Practical exercises	Case study	Development of a test problem

Radiographic inspection Film, level 1 (≥40h)		
Physical and technological concept of radiographic inspections	Electromagnetic waves	Spectrum of electromagnetic waves
	Structure of matter	Bohr atom
	Isotopes	Radioactive series
	Dose and dose rate	Energy dose / dose rate Ion dose / dose rate Dose equivalent / equivalent dose rate
	X-radiation	Generation principle for X-radiation
	Components of the X-ray tube	Cathode Anode and focal spot The vacuum inside the X-ray tube Cooling Tube shield Ray exit window
	Types of tubes	Monopolar tubes Bipolar tubes Fine focus tubes Micro-focus tubes
	Power supply of the tubes	Direct current systems Full-wave systems Alternating current systems Half-wave system
	X-ray spectrum	
	Propagation of radiation	Inverse square law
	Penetration and attenuation	Influence of thickness Influence of density Influence of the radiation quality
	Attenuation mechanisms	Photoabsorption Compton effect Pair production
	Testing for radiation	Ionization Density of photographic layers Fluorescence Operating principle of radiation measure-ment devices Ionization chamber
	Structure of radiographic films	Structure of radiographic films Mode of action of the photographic layer Intensification screens
	Film procedure	Developing Soaking Fixation Final soaking step Drying

(Continued)	Sensitometry	Optical density Sensitometric curves Conversion factors, types of films and optical density
	Screens	
	Imaging techniques	Radiation pattern and radiograph Geometric factors Intensity distribution of the radiation beam
	Image quality	Contrast Geometric unsharpness Movement unsharpness Inherent unsharpness Graininess Optimum image quality Observation of the image quality
Performance of the radiographic test	Radiation diagram	Adjustment of the material Adjustment of the optical density Adjustment of the distance Adjustment of the film type Combined adjustment
	Inspection as per EN 444	
	Inspection as per EN 1435	Definitions Classification of radiographic techniques Position of the weld on the radiograph Identification of radiographs Marking Overlapping films Types and positions of image quality indicators Evaluation of the image quality Minimum image quality values Personnel qualification Recommended number of exposures based on radiograph Particularities of the elliptic technique Selection of the tube voltage Selection of the film system category Reduction of scattered radiation Determining the minimum distance Film density Minimum number of images
Imaging technology	Basic information on the performance of an X-ray photography	Selection of the X-ray system Specification of radiography parameters Preparation of the test specimen Film identification
	Testing of aeronautical parts	

Evaluation and documentation	Viewing equipment	Check of the viewing equipment
	Analysis of films	Check list for film analysis
	Documentation	Test report
	Properties of the human eye	Visual acuity Color discrimination capability Contrast sensitivity Accommodation ability Astigmatism
Standards and regulations	Standards	DIN EN 444 DIN EN 1435 DIN EN 462 ASTM E1025
Materials science	Material defects generated during manufacture	Inclusions Pores Shrinkage cavities Segregations Cracks
	Defects generated during processing	Rolling and forging defects Turning, grinding defects Defects caused by hardening
	Defects caused by operational loads	Cracks Corrosion
General Safety Regulations		
Exercises with aeronautical parts		

Radiographic inspection Film, level 2 (≥40h)		
Physical and technological concept of radiographic inspections	Structure of matter	Substance, atom, molecule Structure of an atom Structure of the electron shells of the atom
	Generation of X-ray radiation	Generation of free electrons Acceleration of the electrons Deceleration at the anode
	Radioactivity and radioactive radiation	Radioactive elements Radioactive radiation Decay law
	Attenuation and hardness increase	General law of attenuation Attenuation mechanisms Attenuation and hardness increase in matter
	Neutron radiography	Neutron radiography principle Equipment for neutron radiography
	Interactions between radiation and matter	Secondary radiation Ionization Fluorescence Density of photographic layers Radiation effects on the organism
	Testing for and measurement of radiation	Radiological units of measure Radiographic films and sensitometry Image converter Xeroradiography Radiation measurement equipment
	Properties of the human eye	Visual acuity Color discrimination capability Contrast sensitivity Accommodation ability Astigmatism
Application techniques of radiographic testing	One-dimensional radiographic testing	Thickness measurement Fill level verification
	Two-dimensional radiographic testing	Detection of material defects Check for foreign objects Inspection of electronic components
	Three-dimensional radiographic testing	Stereo-radiography Computer tomography
	Fine structure examinations	

Testing equipment, tools, and procedure monitoring	Radiographic systems	Range of applications for radiographic systems Radiation emission High-voltage connection Number of focal spots Vacuum system High-voltage generator layout Pre-filtering High voltage generation Multiple-section accelerators
	Radioactive radiators	Isotopes used Design and operation of gamma devices
	Radiation shelters	Sample plant and equipment Positioning devices
	Radiographic films	General information on radiographic films Intensification screens X-ray paper Polaroid method Cartridges and types of packaging Film storage
	Developer systems and dark room facilities	Dark room facilities Processing of an irradiated film Automated film processing
	Accessories for film analysis	Film viewing equipment Density measurement devices Magnifying glasses
	Image intensifiers and accessories for video analysis	General information Image converters Image intensifiers Radiographic video transmission
	Other detectors	Counter tubes Scintillation detectors
	Image quality indicators	Image quality indicator (IQI) as per DIN EN 462 I.Q.I. as per ASTM 1025 and E1742, AMS2635
	Procedure monitoring	General information on monitoring Procedure monitoring of X-ray tubes Procedure monitoring of radioactive radiators Procedure monitoring of radiographic films and developers Procedure monitoring of X-ray tubes Procedure monitoring of film viewing devices Procedure monitoring of image intensifier systems Procedure monitoring of radiation measurement devices

Image quality and detail recognizability	Factors determining image quality	
	Quality of the radiation relief image	Regularity of the radiation contrast Scatter ratio k Scatter radiation reduction and contrast improvement with foils Specific contrast Geometric unsharpness Movement unsharpness
	Quality of film imaging	Inherent unsharpness of the film Influence of the intensification screens on the inherent unsharpness Linking of inherent and geometric unsharpness Film graininess <-> detail recognizability Gradation and overall contrast ratio Influence of the film development
	Optimization of image quality	
	Detail recognizability	Effects of defect dimensions on the contrast
	Image quality check with metallic materials	General information on image quality checks Wire penetrameter IQI as per DIN EN 462-1 IQI as per DIN EN 462-2 Image quality classes as per DIN EN 462-3 Image quality indicators per DIN EN 462-5 Image quality check as per ASTM E1025
	Image quality check with fiber composites	Determining the linear attenuation coefficient Manufacturing of image quality indicators Definition of the max. permissible energy of X-radiation
Imaging technology	Selection of X-ray system	Geometry of the ray exit window Focal spot size Inherent filtration value Radiation angle and emittable range Intensity distribution (heel effect)
	Radiation diagram	General information on the radiation diagram Preparation of a radiograph Consideration of the maximum energy Radiation diagram for isotopes
	Use of the radiation diagram	Conversions for other materials Modification of film density Variation of SFD
	Selection of SFD and OFD	
	Selection of the imaging set-up	Particularities of the elliptic technique
	Use of IQIs	Arrangement of IQIs per EN 462-2 para.5.2 Arrangement of IQIs per EN 1435 para. 5.7 Arrangement of IQIs per ASTM E142

	Consideration of wall thickness differences	General information Multiple film technique Thickness compensation Contrast reduction
Imaging technology **(Continued)**	Determining the flaw depth	General information Parallax method Stereo-radiography
	Testing of fiber composites	General information Radiographic testing of honeycomb parts Use of contrast medium
Analysis, evaluation, documentation	Analysis, evaluation, documentation	Analysis Evaluation Documentation and reports
Safety regulations and radiation protection	Safety regulations and radiation protection	Influence of the type of radiation Distribution of the dose over time Total body irradiation and partial body exposure Somatic damage Genetic damage Main factors of radiation protection
	Measurands, units of measure	Dose Dose rate Sample exercises Dose rate for X-ray and gamma radiation
Materials science and design concepts	Material defects generated during manufacture	Inclusions Pores Shrinkage cavities Segregations Cracks
	Defects generated during processing	Rolling and forging defects Turning, grinding defects Defects caused by hardening
	Defects caused by operational loads	Cracks Corrosion
	Design concepts	Safe-life Fail-safe Damage Tolerance
Expressions		
Standards and regulations		
Practical exercises with aeronautical parts		

Radiographic inspection Film, level 3		
Physical and technological concept of radiographic inspections	Structure of matter	Substance, atom, molecule Structure of an atom Structure of the electron shells of the atom
	Generation of X-ray radiation	Generation of free electrons Acceleration of the electrons Deceleration at the anode
	Radioactivity and radioactive radiation	Radioactive elements Radioactive radiation Decay law
	Attenuation and hardness increase	General law of attenuation Attenuation mechanisms Attenuation and hardness increase in matter
	Neutron radiography	Neutron radiography principle Equipment for neutron radiography
	Interactions between radiation and matter	Secondary radiation Ionization Fluorescence Density of photographic layers Radiation effects on the organism
	Testing for and measurement of radiation	Radiological units of measure Radiographic films and sensitometry Image converters Xeroradiography Radiation measurement equipment
	Properties of the human eye	Visual acuity Color discrimination capability Contrast sensitivity Accommodation ability Astigmatism
Application techniques of radiographic testing	One-dimensional radiographic testing	Thickness measurement Fill level verification
	Two-dimensional radiographic testing	Detection of material defects Check for foreign objects Inspection of electronic components
	Three-dimensional radiographic testing	Stereo-radiography Computer tomography
	Fine structure examinations	

Testing equipment, tools, and procedure monitoring	Radiographic systems	Applications for radiographic systems Radiation emission High-voltage connection Number of focal spots Vacuum system High-voltage generator layout Pre-filtering High voltage generation Multiple-section accelerators
	Radioactive radiators	Isotopes used Design and operation of gamma devices
	Radiation shelters	Sample plant and equipment Positioning devices
	Radiographic films	General information on radiographic films Intensification screens X-ray paper Polaroid method Cartridges and types of packaging Film storage
	Developer systems and dark room facilities	Dark room facilities Processing of an irradiated film Automated film processing
	Accessories for film analysis	Film viewing equipment Density measurement devices Magnifying glasses
	Image intensifiers and accessories for video analysis	General information Image converters Image intensifiers Radiographic video transmission
	Other detectors	Counter tubes Scintillation detectors
	Image quality indicators	Image quality indicator (IQI) as per DIN EN 462 I.Q.I. as per ASTM 1025 and E1742, I.Q.I. as per AMS 2635
	Procedure monitoring	General information on monitoring Procedure monitoring of X-ray tubes Procedure monitoring of radioactive radiators Procedure monitoring of radiographic films and developers Procedure monitoring of X-ray tubes Procedure monitoring of film viewing devices Procedure monitoring of image intensifier systems Procedure monitoring of radiation measurement devices

Image quality and detail recognizability	Factors determining image quality	
	Quality of the radiation relief image	Regularity of the radiation contrast Scatter ratio k Scatter radiation reduction and contrast improvement with foils Specific contrast Geometric unsharpness Movement unsharpness
	Quality of film imaging	Inherent unsharpness of the film Influence of the intensification screens on the inherent unsharpness Linking of inherent and geometric unsharpness Film graininess <-> detail recognizability Gradation and overall contrast ratio Influence of the film development
	Optimization of image quality	
	Detail recognizability	Effects of defect dimensions on the contrast
	Image quality check with metallic materials	General information on image quality checks Wire penetrameter IQI as per DIN EN 462-1 IQI as per DIN EN 462-2 Image quality classes as per DIN EN 462-3 Image quality indicators per DIN EN 462-5 Image quality check as per ASTM E1025
	Image quality check with fiber composites	Determining the linear attenuation coefficient Manufacturing of image quality indicators Definition of the max. permissible energy of X-radiation
Imaging technology	Selection of X-ray system	Geometry of the ray exit window Focal spot size Inherent filtration value Radiation angle and emittable range Intensity distribution (heel effect)
	Radiation diagram	General information on the radiation diagram Preparation of a radiograph Consideration of the maximum energy Radiation diagram for isotopes
	Use of the radiation diagram	Conversions for other materials Modification of film density Variation of SFD
	Selection of SFD and OFD	

Imaging technology **(Continued)**	Selection of the imaging set-up	Particularities of the elliptic technique
	Use of IQIs	Arrangement of IQIs per EN 462-2 para.5.2 Arrangement of IQIs per EN 1435 para. 5.7 Arrangement of IQIs per ASTM E142
	Consideration of wall thickness differences	General information Multiple film technique Thickness compensation Contrast reduction
	Determining the flaw depth	General information Parallax method Stereo-radiography
	Testing of fiber composites	General information Radiographic testing of honeycomb parts Use of contrast medium
Analysis, evaluation, documentation	Analysis, evaluation, documentation	Analysis Evaluation Documentation and reports
Test instructions	Test instruction	General information on test instructions Requirements as per ASTME1030 Sample test instruction as per ASTM 1030
Radiation protection	Mechanisms of radiation exposure	Influence of the type of radiation Distribution of the dose over time Total body irradiation and partial body exposure Somatic damage Genetic damage Main factors of radiation protection
	Measurands, units of measure	Dose Dose rate Sample exercises Dose rate for X-ray and gamma radiation
Standards and regulations		Terminology Qualification and certification of test personnel Specifications for radiographic inspections Comparison of standards
Practical exercises		Preparation of test instructions

Radiographic inspection NonFilm, level 1 (≥40h)		
Introduction		History
Concept	Physical concept	
	Structure of an atom	Atom Elements
	Generation of X-ray radiation	Electron source target X-ray spectrum Retardation radiation Characteristic radiation
	Properties of X-ray radiation	Wave length and related unit Intensity Dose Energy dose and Energy dose constant
	Interactions of matter	Photoeffect Coherent scattering Incoherent scattering Pair formation effect Attenuation coefficient
	Scattering	Inner scattering Sideways scattering Back scattering (record films) Detector scatter (DDA, image intensifier)
	Geometric concept	Geometric unsharpness Picture distortion Inverse square law
	The human eye	Anatomy Function of sight Colour discrimination capability Contrast sensivity Brightness-darkness adaption ametropia
X-ray tubes	Structure	Cathode Filament Anode Focal spot Ray exit window Filter Electrical supply Cooling

Digital X-ray detectors	Image itensifiers	
		Structure and functionality
	Properties image itensifiers	Linearity and measuring/dynamic range
	Phosphor record films (CR; Computed Radiography)	
	Structure and functionality	Record films Scanner
	Properties of record films	Linearity and measuring/dynamic range Wearout and damage Use of cassettes and casings
	Digital matrix detectors (DR; Digital Radiography with DDA)	
		Structure and functionality
		Portable detectors for mobile use
	Properties of DDAs	Linearity and measuring/dynamic range Solution Bit depth Calibration (Offset / Gain, Bad Pixel)
		Long-term stability ASTM E 2737
	Computed tomography (CT)	
		Structure and functionality
Digital image processing	Concept	Bit/Byte Pixel/Voxel Bit depth
	Hardware	
	Computer	
	Monitor	Brightness and contrast
Determining image quality	Image quality indicator	Penetrameter (ASTM 1742, ASTM E 2104, TAM,…) Step wedge Wire penetrameter Twin wire penetrameter
Requirements for test personnel		Visual test
		Qualification
		Duration of training
Enviroment protection and job safety		Radiation protection
		Workplace (ambient light, clearness) Ambient conditions for detectors (Temp., airmoisture)
Standards and regulations		
Practical exercises		Exercises practicing the handling of aeroau-tical parts

Radiographic inspection NonFilm, level 2 (≥40h)		
X-ray tube	Structure	Focal spot (dimensions and measuremethod)
	Type of tubes	Normal, mini, micro
Digital X-ray detectors	Image intensifiers	
	Properties image intensifiers	Pros and cons Application
	Phosphor record films (CR; Computed Radiography)	
	Properties of record films	Classification Artefact Film deletion Sampling rate Pros and cons Application
	Long-term stability	Record films
		Scanner (distortion, jitter, blooming, shading)
	Digital matrix detectors (DR; Digital Radiography with DDA)	
	Properties DDAs	Resolution SRb Performance Frame rate Binning Image integration Artefacts (image lag, ghosting, bad pixel, blooming…) Ray tolerance of electronics Pros and cons Application
		Long-term stability ASTM E 2737
Image processing	Hardware	
	Monitor	Types (LCD, LED, OLED) Resolution Presentation bit depth Calibration Test picture Check
	Software	
	Image description	Histogram Average and standard deviation Image invert
	Representation gray scale	Window Width / Level
		Look up Table (LUT)
		Threshold

Image processing **(Continued)**	Analysis	Line profile Region of Interest (ROI)
	Filter	Convolution Median filter Low-pass filter High-pass filter Band-pass filter Sharpness filter Pseudo plastic filter Edge extraction filter
	Arithmetical image operations	Addition Subtraction Division Multiplication Image Average Binarization
	Archiving	Digital media (CD, DVD, magnetic tape) Order of hard disks (RAID) Center archive Image format (Jpeg, Tiff, Diconde, bmp,…) Recopy of image data
Determining image quality	Measure image quality	Signal-to-noise ratio (SNR) Standard Signal-to-noise ratio (SNRn#9 Resolution SRb Image unsharpness Contrast-to-noise ratio (CNR) Contrast sensitivity Geometric increase
Specification X-ray technique		Projection angle
		Choice test specimens
		Disposal test specimens
	Exposure technique	Welded joints on tubes Welded joints on sheets Cast part examination
Analysis		Types of defects
		Digitale Fehlerbildkataloge (ASTM comparison image)
		Digital measurement of indications (and calibrations)
		Thickness measurement by gray scale
		Acceptance standards
Standards and regulations		
Practical e*xercises*		Exercises practicing the handling of aeroautical parts

Radiographic inspection NonFilm, level 3		
X-ray tube	Structure	Focal spot (dimensions and measuremethod)
	Type of tubes	Normal, mini, micro
Digital X-ray detectors	Image intensifiers	
	Properties image intensifiers	Pros and cons Application
	Phosphor record films (CR; Computed Radiography)	
	Properties of record films	Classification Artefact Film deletion Sampling rate Pros and cons Application
	Long-term stability	Record films
		Scanner (distortion, jitter, blooming, shading)
	Digital matrix detectors (DR; Digital Radiography with DDA)	
	Properties DDAs	Resolution SRb Performance Frame rate Binning Image integration Artefacts (image lag, ghosting, bad pixel, blooming…) Ray tolerance of electronics Pros and cons Application
		Long-term stability ASTM E 2737
Image processing	Concept	Nyquist-Shannon-sampling theorem
	Hardware	
	Monitor	Types (LCD, LED, OLED) Resolution Presentation bit depth Calibration Test picture Check
	Software	
	Image description	Histogram Average and standard deviation Image invert
	Representation gray scale	Window Width / Level Look up Table (LUT) Threshold Adaption histogram Pseudo color image

Image processing **(Continued)**	Analysis	Line profile Region of Interest (ROI) Statistic tools
	Filter	Convolution Median filter Low-pass filter High-pass filter Band-pass filter Sharpness filter Pseudo plastic filter Edge extraction filter
	Arithmetical image operations	Addition Subtraction Division Multiplication Image Average Binarization
	Archiving	Digital media (CD, DVD, magnetic tape) Order of hard disks (RAID) Center archive Image format (Jpeg, Tiff, Diconde, bmp,…) Image compression Recopy of image data
Determining image quality	Measure image quality	Signal-to-noise ratio (SNR) Standard Signal-to-noise ratio (SNRn#9 Resolution SRb Image unsharpness (Uim) Modulation transfer function (MTF) Contrast-to-noise ratio (CNR) Contrast sensitivity Geometric increase Principle compensation
Specification X-ray technique		Projection angle
		Choice test specimens
		Disposal test specimens
	Exposure technique	Welded joints on tubes Welded joints on sheets Cast part examination

Analysis		Types of defects
		Automatic error detection
		Digitale Fehlerbildkataloge (ASTM comparison image)
		Digital measurement of indications (and calibrations)
		Thickness measurement by gray scale
		Acceptance standards
Standards and regulations		

Thermography levels 2 (≥40h)		
Preface, table of contents, introduction	Introduction	General information Inspection tasks in the aerospace industry Sample inspection tasks
Basic physical information	General information	
	Basic principles of thermography	
	Vibrations	Amplitude Period duration Frequency Phase
	Waves	Transverse waves Longitudinal waves Standing waves
	Thermography terminology	Systems Temperature (true, calculated, apparent, reflected, atmospheric, background, ambient, and object environment temperature) Heat Heat transition Thermal conduction Convection Heat radiation (infrared radiation) Heat capacity
	Radiation laws	Planck's law of radiation Stefan-Boltzmann's law of radiation (T4 law) Wien's displacement law
		Net total radiation Emission/emissivity Absorption/absorptivity Transmission/transmission factor
		Specular reflection, diffuse reflection / reflectance
		Radiant flux Kirchhoff's law of radiation
	Specular reflections	
	Induction	
	Full radiator Selective radiators	
	Thermography, influences and defect sources	Atmospheric window Object-to-detector distance
	Thermography in NDT	Passive thermography Active thermography
		Comparative thermography Quantitative thermography

Thermography techniques	General information	
	Transient thermography	Test setup Measuring principle
	Pulsed thermography	Test setup Measuring principle
	Optically excited lock-in thermography	Test setup Measuring principle
	Ultrasound excited thermography	Test setup Measuring principle
	Ultrasound burst phase thermography	Test setup Measuring principle
	Pulse phase thermography	Test setup Measuring principle
	Thermoelastic stress analysis	Test setup Measuring principle
Thermography equipment	General information	
	Detectors	
	Characteristics / equipment selection	
	Cooling concepts	
	Calibration	
	NUC, drift	
	Detectivity	
Excitation and loading techniques in practical applications	Pulsed thermography	
	Optical lock-in thermography	
	Ultrasound excited lock-in thermography	
	Pulse phase thermography	
	Mechanical excitation, power ultrasonics	
	Laser excitation (continuous, pulsed)	
	Continuous line radiator	
	Quartz glass source, surface source, carbon source	
Detectable types of flaws	General information	
Calibration	Requirements for calibration and reference blocks	Adjustment blocks Reference blocks Requirements for simulated flaws Summary
Analysis, evaluation, and documentation	Analysis and evaluation	Documentation for the customer Documentation for the manufacturer Structure of a test report Test reports and component identification Test instruction Information on preparing test instructions

Industrial safety	General information Actions	
Standards and safety regulations		
Measuring systems for practical training	Transient thermography FLIR system	Description of the measuring system Description of the software
	"Sherlock" pulsed thermography system	Description of the measuring system Description of the software Performance of inspections Analysis
	"edvis" lock-in thermography system	Description of the measuring system Infrared camera Measuring and analysis station Description of the software Performance of inspections Representation of phases/amplitudes for lock-in thermography Function of burst results
	Thermography system for measuring fluids inside honeycomb structures	Description of the measuring system Infrared camera Monitor Hot air blower Infrared camera menu description
Practical training exercises	Exercise 1 Exercise 2 Exercise 3 Exercise 4 Exercise 5 Exercise 6 Exercise 7 Exercise 8 Exercise 9	Basic test Consideration of external disturbances Capabilities of active thermography Influence through surfaces Test as per NTM for fluids in honeycomb structures Delamination on monolithic CFRP CFRP component with stringers Inspection of a repair Sandwich structure with foam core

Ultrasonic testing, level 1 (≥40h)		
Basic physical concepts	Generation of sound	Basic principles
		Theory of oscillations
		Theory of waves
	Wave forms	Longitudinal wave
		Transverse wave
		Surface waves
		Pulses / pulse shapes
		Allocation of sound waves
	Behavior of sound waves in matter	Sound waves in gases and solid media Refraction Reflection
		Sound waves in fluids
	Ultrasound techniques	Through transmission technique
		Pulse-echo technique
Application of ultrasound	Calibration and verification	Calibration of ultrasonic devices
		Calibration of a straight beam probe
		Calibration of angle probes
		Calibration with known sound velocity
		Calibration with unknown sound velocity
		Verification of the calibration
	Ultrasonic testing devices	Design of an ultrasonic device
		Properties of test wires
		Design of straight beam probes
		Design of angle probes
		Design of dual-element probes
		Sound fields of straight beam probes
Test performance	Ultrasonic testing	Measuring accuracy for calibration
		Linearity error
		Selection of a suitable calibration range
		Selection of suitable calibration systems
		Wall thickness measurement
		Measuring with delayed time-base sweep
		Multiple echo method
		Scanning process
		Half-amplitude technique
		Testing of other materials
		Testing of CFRP composites
Verification of the equipment properties	Checks	Time base linearity
		Amplification linearity
		Near-surface resolution
		Back surface resolution
		Measurement of echo width
		Measurement of emitted pulse width
		Influences of probes/transducers

Shear wave scanning	Calculations for shear wave scanning	Working with the reflection law
		Working with the refraction law
		First and second critical angle
		Wave conversion
		Corner reflector
Axial scanning	Scanning of narrow parts	Axial scanning
		Grazing incidence
		Secondary echoes
		Working with secondary echoes
		Computation of secondary echoes
Radial scanning	Scanning of round stock	Radial scanning
		Radial scanning with conversion
		Radial scanning without conversion
Shear wave scanning	Angle probe test	Design of angle probes
		Sound fields of angle probes
		Shear wave scanning - terminology
Calibration of angle probes	Calibrations	Calibration of angle probes
		Selection of a suitable calibration range
		Adjustment on semicircular disks
		Adjustments on K1
		Adjustments on K2
		Calibration on edges
Working with angle probes	Determining defect locations	Defect position triangle
		Sound path length
		Projection distance
		Shortest distance between surface and reflector (B dimension)
		Depth measurement
		Determining defect locations using digital devices
Testing of aeronautical components	Testing of metallic materials	Testing of aeronautical components
		Testing of structural parts
		Testing of rivet joints
	Testing of CFRP composites	Testing of fiber composites
		Manufacturing of fiber composites
		Ultrasonic testing of CFRP
		Equipment for CFRP testing
		Test probes for CFRP testing
		Types of defects of CFRP composites
		Testing as per AITM
Documentation and reports		Documentation
		Analysis of indications
		Evaluation of indications
		Detection threshold
		Allowable limit

Materials science	Defects in metallic materials	Defects generated during master forming
		Pores
		Slag
		Segregations
		Casting defects in moldings
		Rolling defects
		Forging defects
		Defects cased during part processing
		Weld seam imperfections
		Fatigue defects
		Corrosion and types of corrosion
Practical exercises		Distance calibrations
		Calibration range / reading accuracy
		Signal width measurement
		Calibration with delayed time-base sweep
		Wall thickness measurement
		Lamination defect testing
		Calibration of dual-element probes
		Sound velocity measurement
		Testing of amplifier linearity
		Axial scanning
		Radial scanning
		Axial testing of a turned part with a step
		Immersion test technique
		Determining the probe index point for angle probes
		Determining the actual angle of refraction
		Distance calibrations for angle probes
		Adjustment on semicircular disks
		Adjustment on reference blocks
		Determining X and α along edges
		Comparison of indication dynamics of angle probes
		Determining defect locations using angle probes
		Testing of fiber composites
		Delamination testing on structural parts
		Testing of a longitudinal joint

Ultrasonic testing, level 2 (≥40h)		
Inspection tasks in the aerospace industry	Objectives of NDT in aerospace	Sample tests
		Fuselage shell joints
		CFRP spoilers
		Flap tracks
		Objectives of NDT
		Design concepts
		Fail-safe concept
		Damage Tolerance concept
		Safe-life concept
		Creation of parts significant for structural integrity
Basic physical information	Vibrations and waves	Basic concepts of the theory of vibrations and waves
		Wave forms
		Transverse waves
		Longitudinal waves
		Surface waves
		Pulse shape
		Broad band pulses
		Narrow band pulses
		Sound wave spectrum
		Sound waves in solids
		Sound waves in fluids
		Sound waves in gases
		Sound cycle pressure
		Acoustical impedance
		Penetration factor
		Reflection factor
Sound generation	Sound generation procedures	Electrodynamic procedures
		Piezoelectric procedures
		Ultrasound generated by laser
Sound field magnitudes	Sound field geometry	Sound fields of straight beam probes
		Sound fields of angle probes
		Rotation-symmetrical transducers
		Rectangular pulse transducers
		Influences on the sound field geometry
Design and types of ultrasound probes	Types of probes	Straight beam probes
		Angle probes
		Dual-element probes
		Immersion technique probes
		Probes for spot welding
		High-temperature probes
		Focus probes
		Phased array probes

Ultrasonic testing techniques		Transmission test
		Pulse-echo technique
		Automated ultrasonic testing
		Immersion technique
		Phased array test engineering
Ultrasonic test equipment	Design and use of ultrasonic devices	General design of ultrasonic devices
		Analog ultrasonic test equipment
		Digitized equipment
		Interfaces with peripheral equipment
		Digital devices in the field
		Working with the USM 25
		Handling concept
Ultrasonic phased array test engineering	Operating method of phased arrays	Phased array technology
		Basics of the phased array method
		Equipment for the phased array method
		Focusing with phased arrays
		Panning of the sound beam
		Linear scanning with phased arrays
Localization aids		Visualization of normal beam incidence
		Tools for shear wave scanning
		Determining defect locations with conventional Equipment
		Determining defect locations with digital Equipment
Ultrasound screen representation	Forms of representation	A-scan representation
		B-scan representation
		C-scan representation
		D-scan representation
Direct methods for defect evaluation	Magnitudes and inverse-square law of calibration reflectors	Reference block requirements
		Backwall
		Circular disk
		Side-drilled hole
		Inverse-square laws of calibration reflectors
		Magnitude laws of calibration reflectors
		Equivalent disk calculation
	Reference block base line method	Direct method for indication Evaluation
		Reference block method
		Base line method
		Amplification settings for base line method
		Testing using the base line method
		Time corrected gain: TCG method
		Defect evaluation using the base line method
Indirect method for indication evaluation	Distance gain size (DGS) method	Indirect method for indication Evaluation
		Structure of the DGS diagram
		Special DGS diagram
		Testing using DGS

Adjusting the test sensitivity	Amplification and corrections	Amplification settings
		Calibration base amplification
		Amplification adjustment
		Transfer correction
		Coupling correction
		Reference block correction
Sound attenuation	Attenuation mechanisms Determining the sound attenuation	Sound attenuation
		Sound scattering
		Sound absorption
		Attenuation mechanisms
		Determining the sound attenuation
Testing of fiber composites	AFRP, GFRP, CFRP	Manufacturing of fiber composites
		Types of fiber composites
		Fiber composite characteristics
		Special features of fiber composites
		Ultrasonic testing of fiber composites
		Working with probes with probe shoes
		Identification of delaminations
		Finding inclusions
		Impact testing on fiber composites
Documenting the ultrasonic test	Analysis and evaluation	Significance of documentation
		Customized documentation
		Quality-based documentation
		Analysis
		Evaluation
		Structure of a test report
Test instruction		Test instruction requirements
		Structure of a test instruction
		Wording in test instructions
		Preparation of a test instruction
Materials science	Defects generated during master forming	Pores
		Slag
		Segregations
		Casting defects in moldings
	Defects generated during further processing	Rolling defects
		Forging defects
		Defects caused during part processing
		Weld seam imperfections
	Defects caused by operational conditions	Fatigue defects
		Corrosion and types of corrosion
	Defects in CFRP materials	Pores Delaminations Inclusions of foreign matter Water absorbed in honeycomb components

Practical exercises		Distance calibrations
		Calibration range / reading accuracy
		Signal width measurement
		Calibration with delayed time-base sweep
		Wall thickness measurement
		Testing for horizontal linearity
		Testing for vertical linearity
		Signal width measurement
		Determining the measuring accuracy
		Residual thickness measurement
		Working with dual-element probes
		Axial scanning
		Immersion test technique
		Sound velocity measurement
		Sound field measurement of straight beam probes
		Determining the attenuation coefficient
		Measurement of transfer losses
		Determining the coupling correction
		Recording of base lines
		Recording of base lines using TCG
		Attenuation correction
		Sound attenuation in CFRP
		Testing of CFRP in production
		Preparation of test instructions

Ultrasonic testing, level 3		
Basic physical information	Vibrations and waves, refraction Acoustical impedance	Ultrasound testing principle
		Vibrations
		Pulse
		Wave
		Sound propagation
		Sound field
		Reflectors within the sound field
		Sound along boundary layers
		Refraction
		Reflection
		Total reflection of same wave type Law of refraction: conversion of angles of refraction
		Sound pressure amplitudes along boundary layers
		Sound transmission along boundary layers
		Lateral wall effect
		Wave conversion
		Wave separation
Ultrasound generation	Sound generation procedures	Piezoelectric effect
		Magnetostriction effect
		Electrodynamic sound generation
		Laser ultrasound
		Electroacoustic sound generation
		Physical correlations
Materials and designs	Metals and plastics	Aluminum and aluminum alloys
		Laser-welded skin panel/stringer
		Glare
		Plastics
		CFRP
		Manufacturing methods for CFRP
		Thermoplastics
		Superplastic forming
		Diffusion welding
		Friction stir welding (FSW)
		GFRP materials and their applications
		Sandwich design
Capabilities of ultrasound and other NDT methods	Comparison of test methods	Categorization of test methods
		Ultrasound testing being compared
		Requirements for ultrasound testing
		Ultrasonic testing techniques
		Advantages and disadvantages of the techniques
		Capability
		Capabilities of other NDT methods

Ultrasonic testing procedure	Ultrasonic testing techniques	Pulse-echo technique
		Through transmission technique
		Selection of the scanning technique
		Normal beam incidence
		Shear wave scanning
		Tandem scanning
		Dual-element probe technique
		Selection of the coupling method
		Contact testing technique
		Immersion technique
		Squirter technique
		Gap testing technique
		Dry disconnect coupling
		Manual test
		Automatic test
		Ultrasonic testing of fiber composite material
		Inspection of monolithic components
		Inspection of sandwich components
		Fiber structures of FRP
		Air-coupled ultrasonic testing
		Laser ultrasound
Selection of the ultrasonic testing system		Probe
		Ultrasonic test instrument
		Test wires and connectors
		Couplants
		Probe encoder system
		Electronic and computer based systems
		Automatic test
		Component fixation devices
		Adjustment blocks
Monitoring of the ultrasonic testing system	Distance adjustment and sensitivity adjustment	Calibration
		Selection of the adjustment/reference block
		Distance adjustment
		Amplification settings
		Echo height evaluation method
		Amplification corrections
		Preparation of the test specimen
		Implementation of the inspection
		Indications and their evaluation
		Documentation
		Post-processing of the test specimen

Identification and allocation of ultrasound signals	Screen interpretation	Transmission pulse indication
		Through transmission indication
		Echo indications
		Interface echo
		Backwall echo
		Contour echo
		Phantom echo
		Spurious echo
		Microstructure signals
		Noise signals
		Discontinuity echo
Representation of ultrasonic signals	Representation options	A-scan
		B-scan
		C-scan
		D-scan
		S-scan
		Polar scan
		Other types of scans
Ultrasonic testing of CFRP components	Particularities of CFRP testing	Ultrasonic testing of radius areas
		Ultrasonic testing of inside radii
		Ultrasonic testing of outside radii
		Outside and inside radii through transmission
		Outside radius pulse-echo array
		Inside radius pulse-echo array
		Outside radius pulse-echo surface array
Ultrasonic testing of Glare laminates		Glare material properties
		Inspection of Glare
Evaluation of indications	Indication evaluation procedures	General information on indication evaluation
		Prerequisites for indication evaluation
		Path length evaluation
		Echo height evaluation
		Direct method
		Indirect method
		Echo dynamic evaluation
Scanning methods		Zeroing method
		Full X at tenth maximum method
		Quartile method
		Half-amplitude technique
		Indication evaluation as per rules and regulations
Case studies		Test instruction for rod
		Test instruction for Airbus rudder fairing

Test instruction	Preparation of test instructions	Specifications for the test specimen
		Inspection specifications
		for the areas to be inspected
		Content and layout of the test instruction
Standards and formulary		Standards
		Procedures
		Specifications and instructions

Phased Array Ultrasonic Testing, level 2		
Theoretical training		
Functional principle		
Focal Laws		
Options of sound field steering		
Configuration and structure of phased array test units		
Sound field modelling		
Scan techniques		
Data presentation		
Laboratory instruments and mobile devices		
Phased Array probes		
Calibration		
Data acquisition		
Materials and designs		
Standards and regula-tions		

Practical training		
Linear scan of an aluminium block with flat bottoms holes		
Linear scan of an aluminium block with cross-holes		
Sector scan of an aluminium block with cross-holes		
Linear scan and data analysis of a CFRP part with impact damage		
Linear scan and data analysis of a CFRP stringer-skin connection		
Linear scan using DAC / TCG-curves of a CFRP-step wedge		
Sector scan using wedge delay line (example: Scribe mark inspection of longitudinal weld structures)		