Aerospace NDT Boards' Forum

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Document: ANDTBF/06

Issue 02

Date: 31 July 2015

Revision Status

Issue/Rev.No.	Release Date	Page/ Pages	Description
Issue 01	29 June 2013	All	First Issue of the ANDTBF Task Group
Issue 02	31 July 2015	11-14	Syllabus for Digital Radiography added

General Note

The intention of the this document is to support training centers to set-up or adapt their training syllabuses for NDT technicians in accordance with EN 4179.

The table "General Part" contains a summary of possible general and physical topic items for each NDT method.

All table "Specific part" contain a list of possible specific inspection items, which are currently applicable in Aviation industry.

Missing items or new inspection methods can be added to this document as necessary.

Table of Contents

1. RT – General

RT-General		
Theory, Physics	Introduction	History
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		Capabilities
		Process of Radiography
		Types of electromagnetic radiation sources
		Electromagnetic spectrum
		Penetration ability or quality of X-rays and gamma rays
		X-ray tube
	Principles of Radiography	Electromagnetic spectrum
		Significance of wavelength
		Theory, Physics
		Characteristics and key properties
		Interaction: absorption and scatter
		Nature and properties of X-rays
		Interaction X-rays/materials
		X-rays absorption, attenuation coefficient
		Radiography principle
	X-rays generation	Generation principles, spectrum of radiation
		X-ray tubes up-to 420kV
		X-ray accelerator
	Image formation	Rectilinear propagation
		Affecting factors
		Inverse square law consideration
		Types and choice of film
		Types and uses of screens
	Radiographic film	Radiation quality
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		Significance and effect of type of ray source
		Effect of time
		Milliamperage and FFD on exposure
		Exposure charts
		Identification, marking out and sitting up
		Intensifying screens role and use
		Filters
		Geometric unsharpness

Exposure Techniques	General principles	Contrast: object, image, average gradient
		Radiation energy
		Scattered radiation, limitations
		Source-to-film distance
	Exposure	Focal-spot size
		Determination of focal spot size
		Exposure parameters determination
		RT-techniques, with constant exposure
		Defects position, triangulation
		Enlargement and projection

RT-General		
Exposure Techniques	Single-wall radiography	Specimen configuration
	Double-wall radiography	Double-wall exposure, single-wall viewing
		Offset double-wall exposure, single-wall viewing
		Elliptical projections
		Panoramic radiography
		Specimen configuration
	Multiple-film techniques	Use of Multiple-film loading
		Thickness-variation parameters
		Film speed
		Film latitude
	Penetrameters or Image Quality Indicators (IQI's)	Types of penetrameters or IQI's
		Use rules
		Standards
		Calculation of IQI sensitivity
Basic principles	Geometric exposure principles	Shadow formation and distortion
		Shadow enlargement calculation
		Shadow sharpness
		Geometric unsharpness
	Radiographic screens	Lead intensifying screens
		Fluorescent intensifying screens
		Intensifying factors
		Importance of screen-to film contact
Radiographs	General	Film packing
		Film material and classification systems

		Formation of the latent image on film
		Inherent unsharpness
	Arithmetic of radiographic exposure	Milliamperage-Distance-time relationship
		Reciprocity law
		Photographic density
		Inverse-square-law considerations
Radiographic Image Quality	Radiographic sensitivity	
	Radiographic contrast	
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	Subject contrast	
	Film graininess and screen mottle effects	
	Penetrameters or image-quality indicators	

RT-General		
Darkroom Facilities, Film Processing	Photographic emulsion chemistry	
	Facilities and equipment	Automatic film processor versus manual processing
	Processing of film - manual	Developer and replenishment
		Stop bath
		Fixer and replenishment
		Washing
		Prevention of water spots
		Drying
		Temperature control
	Film filing and storage	Retention-life measurements
		Long-term storage
		Filing and separation techniques
	Unsatisfactory radiographs - causes and cures	High film density
		Insufficient film density
		High contrast
		Low contrast
		Poor definition

		Fog
		Light leaks
		Handling faults, Artifacts
	Film density	Step-wedge comparison film
		Densitometers
Forgings, Castings	Metallurgy knowledge and manufacturing techniques	
	Defects met:	cavities, gas holes, shrinkage, foreign material
	Application of standards	Castings NDT inspection
		NDT technique instructions
		Shooting, use of the IQI and interpretation / evaluation
		Disposition and NDT report
Assemblies, Weldings, Brazing, Riveting	Welding Processes	
	Defects met:	cracks, lack of penetration or brazing, inclusions
	Application of standards	
	Welding NDT inspection	Examination of circumferential in pipes welding / butt welds
		NDT technique instructions
		Disposition and NDT report

RT-General		
Composite materials	Concepts of development	
	Defects met:	cavities
	Application of standards	
	Composite NDT inspection	Tangential shooting
		NDT technique instructions
		Shooting, use of the IQI and interpretation / evaluation
		Disposition and NDT report
Indications, Discontinuities and Defects	Indications	Adventitious images
		Causes and effects
	Discontinuities	Inherent

		Processing
		Service
	Defects	
Manufacturing Processes and Associated Discontinuities	Casting processes and associated discontinuities	Ingots, blooms and billets
		Sand casting
		Centrifugal casting
		Investment Casting
	Wrought processes and associated discontinuities	Forgings
		Rolled products
		Extruded products
	Welding processes and associated discontinuities	Submerged arc welding
		Shielded metal arc welding
		Gas metal arc welding
		Flux corded arc welding
		Gas tungsten arc welding

RT-General		
Evaluation	Radiographic standards	
	Radiographic Viewing	Film-illuminator requirements
		Background lighting
		Multiple-composite viewing
		Penetrameter placement
		Personnel dark adaptation and visual acuity
		Film identification
		Location markers
		Film-density measurement
		Film artifacts
		Viewing conditions
		Illuminator requirements
	Evaluation of casting images	Casting-method review
		Casting discontinuities
		Origin and typical orientation of discontinuities
		Radiographic appearance
		Castings codes/standards - applicable acceptance criteria
		Reference radiographs
		Welding-method review

	Evaluation of welding images	Welding discontinuities
		Origin and typical orientation of discontinuities
		Radiographic appearance
		Welding codes/standards - applicable acceptance criteria
		Reference radiographs or pictograms
Safety	Radiation Safety Principles	Controlling personnel exposure
		Time, distance, shielding concepts
		ALARA concepts
		Radiation-device operation characteristics
Quality assessment	Standards, codes and Procedures for Radiography	Acceptable radiographic techniques and setups
		Applicable employer procedures
		Procedure for radiograph parameter verification
		Radiographic reports
	Construction concept	Safe live
		Fail Safe
		Damage Tolerance
	Comparison to other NDT methods	Limits of RT inspections
		Detectable flaw size
		Other NDT Procedures
	Documentation	Issue of inspection procedures
		Inspection reports
	Personnel requirements	

2. RT Specific

RT-Specific		
Airframe	Water ingress in honeycomb structures	
	Imperfections in composites	Blow holes
		Porosity
		Inclusions
	Crack and corrosion, porosity detection in	Fittings and lugs
		Fastenerholes
		Riveted structures
		Bolts
		Tubes
		Multilayered structure
		Welded structure
		Wrought materials
		Forged materials
Engine	Crack detection in	Blades
		Stators
		Welded parts
		Wrought materials
		Forged materials
		Cast materials
	General overview	Foreign objects
		Blocked gas passes
		Misalignments of parts
Composites	Water ingress in honeycomb structures	
	Imperfections in composites	Blow holes
		Porosity
		Inclusions
		Layer orientation
		Distribution of glass fibers
Components	Crack detection in	Tubes
		Welded parts
		Bolts
	Water ingress in honeycomb structures	
	Imperfections in components	Blow holes

		Porosity
		Inclusions
		Foreign objects
		Blocked gas passes
		Misalignments of parts

3. Digital Radiography

Digital Radiography		
Radiation contrast, noise	Signal-to-noise ratio (SNR)	
	Contrast-to-noise ratio	
	Basic spatial resolution	
	Pixel Size	
	Normalised SNR (SNRN)	
Optimization of image quality	Compensation principles	Contrast vs. SNR
		Basic spatial resolution s. SNR
		Local unsharpness vs. SNR
Geometrical projection conditions	Effect of magnification	
	Optimum magnification	
	Difference between radiography and radioscopy	
Image quality indicators	Measurement of basic spatial resolution	
	Converging line pairs	
	Line pair gauges (MTF)	
Computer-Radiography (CR), Imagine plates	Phosphor imaging plates	Introduction
		Design
	Imaging plate and CR-scanner	
	CR system and classification	
	Quality assurance (phantom)	
	Exposure conditions	
	Working with exposure charts	
	Handling	
	System selection	
DDA's	Digital Detector Arrays (DDA)	Introduction
		Design
	Indirect converting	
	Direct converting	
	Indirect converting	
	Direct converting	
	CCED, amporph. SI, CMOS	

	Detector calibration	
	Quality assurance	
	Exposure conditions	
	Handling	
	System selection	
LDA's	Line Detector Arrays (LDA)	Introduction
		Design
	Application areas	
	Comparison to DDA's	
	Quality Assurance (phantom)	
	Exposure conditions and Diagrams	
	Handling	
	System Selection	

Digital Radiography		
Intensifiers, fluoroscope	Introduction	
	Design	
	Application areas	
	Quality assurance (phantom)	
	Exposure conditions and diagrams	
	Handling	
	System selection	
	Comparison to DDA's	
Date acquisition, detector calibration	A/D interface	
	Computer Structure	Processor
		Memory
		Bus
		Disk
	Load and safe of digital images	Image Formats
	Image integration	On chip integration/ frame time
		In memory integration/frame number
	Optimum gain and latitude settings	Accumulation vs. integration
Digital Image Processing	Image structure, quantization (bit and Bytes)	
	Basic operations	Picture element (pixel)
		Gray value
	Point operations	Contrast
		Brightness
		Gamma correction
		Histogram
	Matrix operations, filters	Look up table (LUT)
		Smoothing, improvement of SNR
		High pass, gradient

		Edge enhancement, line extraction
		Median
	Measurement tools	Calibration
		Line profile
		Measurement of flaw length
		Measurement of areas
		Measurement of depth
	Correction of raw data	Linearization, LUT
		Bad pixel interpolation
Automated image interpretation	Principles	
	Binarization	
	Measurement of dimensions	

4. UT General

UT-General		
Basic Principles of Acoustics	Mathematic basics	
	Frequency, velocity, and wavelength	
	Different acoustic waves	Long-waves
		Shear-waves
		Surface- waves
		Plate-waves
Generation of UTwaves	Generation	Piezoelectricity and types of crystals
		Frequency-crystal thickness relationships
		Conversion efficiencies of various crystals
	Characteristics of search units	Construction of ultrasonic search units
		Damping and resolution
	Sound beam	Sound beam characteristics
		Beam intensity characteristics
	Ultrasonic Equipment	Broad band / Small band signal
		Impulse form and repetitions frequency
Propagation of UTwaves	Acoustic impedance	
	Reflection/ Transmission	
	Phase inversion	
	Angle beam	
	Refraction	
	Wave transformation	
	Critical angle	
	Wave propagation in material and gas	
	Wave propagation in liquids	
UT methods	Contact testing	

UT-General		
Basic Principles of Acoustics	Mathematic basics	
	Frequency, velocity, and wavelength	
	Different acoustic waves	Long-waves
		Shear-waves
		Surface- waves
		Plate-waves
Generation of UTwaves	Generation	Piezoelectricity and types of crystals
		Frequency-crystal thickness relationships
		Conversion efficiencies of various crystals
	Characteristics of search units	Construction of ultrasonic search units
		Damping and resolution
	Sound beam	Sound beam characteristics
		Beam intensity characteristics
	Ultrasonic Equipment	Broad band / Small band signal
		Impulse form and repetitions frequency
Propagation of UTwaves	Acoustic impedance	
	Reflection/ Transmission	
	Phase inversion	
	Angle beam	
	Refraction	
	Wave transformation	
	Critical angle	
	Wave propagation in material and gas	
	Wave propagation in liquids	
UT methods	Contact testing	
	Immersion testing	
	Through transmission	
	Pulse-Echo	
	Dual transducer	
	Angle beam	

	Phased arrays	

UT-General		
UT Systems	Equipment	Analog
		Digital
		Phased array (PAUT)
		Thickness gages
	Transducer	Straight beam transducers
		Dual transducers
		Angle beam transducer
		Phased array transducers
		Focused transducers
	Wedges	
	Couplants	
	Reference standards	Standardized reference standards
		Specific reference standards
	Cables	
Displays	A-scan	
	B-scan	
	C-scan	
	D-scan	
	Sector-scan	
Influence of part	Influence of surface/geometry	Surface roughness
		Concave/Convex surfaces
		Object geometry
		Wave transformation
		Triangle reflection
		Angle reflection
	Influence of material properties	Sound absorption
		Acoustic noise
		Diffusion
		Signal to noise ratio (SNR)
		Improvement of SNR

Calibration	Artificial defects	Flat bottom holes
		Cross holes
		Groove
		Ball reflector
		Variation of sound distance
		Variation of artificial defect
		Different defects
	Calibration and functional tests	Calibration standards
		Sensitivity
		Depth compensation
		Functional tests
		Analysis of probe data
		Redundancy checks

UT-General		
Evaluation	Evaluation of indication	Display indications (True/false)
		Defects dependency
		Location of defects
		Depth of defects
		Half-value methods
		Loss of back wall signal
		Composition with artificial defects
		Evaluation with tables
Quality assessment	Construction concept	Safe live
		Fail Safe
		Damage Tolerance
	Comparison to other NDT methods	Limits of UT inspections
		Detectable flaw size
		Other NDT Procedures
	Procedures and Standards	National and international standards
	Documentation	Issue of inspection procedures
		Inspection reports
	Personnel requirements	

5. UT Specific

UT-Specific		
Airframe	Thickness measurement	Corrosion measurement
		Wall thickness measurement
		On metallic structure
		On composite structure
	Delamination	CFRP
		GFRP
		Glare
	Water ingress in honeycomb structures	
	Debonding	Honeycomb structure
		Glare
		Metallic structure
	Imperfections in composites	Blow holes
		Porosity
		Inclusions
	Crack and discontinuous detection in	Fittings and lugs
		Fastenerholes
		Riveted structures
		Bolts
		Tubes
		Multilayered structure
		Welded structure
		Wrought materials
		Forged materials
		Other applications (glass, plastics)
Engine	Crack detection in	Blades
		High energy rotating hardware (disc, shafts, blade slots)
		Stators
		Welded parts
		Wrought materials
		Forged materials
		Cast materials
	Thickness measurements	

	Delamination	Composite blades

UT-Specific		
Composite	Delamination	CFRP
		GFRP
		Glare
	Water ingress in honeycomb structures	
	Debonding	Honeycomb structure
		Clare
	Imperfections in composites	Blow holes
		Porosity
		Inclusions
Components	Crack detection in	Wheels
		Tubes
		Welded parts
		Bolts
		Gears
	Delamination	CFRP
		GFRP
		Glare
	Water ingress in honeycomb structures	
	Debonding	Honeycomb structure
		Glare
	Imperfections in composites	Blow holes
		Porosity
		Inclusions

6. ET General

ET-General		
Physic and fundamentals of Eddy current	Electricity	Direct current: current, voltage
		Resistance
		Conductance
		Ohm's law
		Resistivity
		Conductivity
		Conductivity values for some metals
		Alternating current: sinusoidal current and voltage
		Amplitude
		Frequency
		Period
		Phase
		Vector representation
		Other periodic currents
	Magnetism	Magnetic field
		Lines of force
		Magnetic field strength
		Permeability
		Flux density (Induction)
		Flux, Hysteresis loop
		Reluctance
		Magneto-motive force
		Diamagnetism
		Paramagnetism
		Ferromagnetism
	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
		Skin effect
		Penetration depth
Physic and fundamentals of Eddy current (continue)	Impedance plane diagrams	Impedance
		Complex plane representation
		Influence of conductivity
		Influence of frequency
		Influence of permeability
		Influence of probe clearance
		Influence of thickness
		Influence of a non-conductive coating on conductive material
		Influence of a through defect
		Influence of internal defects
Eddy current equipment	EC Probes	Design of probes (Mechanical and electrical)
		Operation of probes (Absolute, differential)
		Use of probes (Pencil, borehole, sliding, ..)
		Connections of probes with EC unit
	EC Instruments	Display modes: Needle, digital Display
		Instrument modules
		Operating principle
		Signal excitation, reception, processing
		Compensation

		Wheatstone bridge
		Filtering: LP, HP, BP
		Single frequency
		Multifrequency
	Reference Standards	Design
		Production
		Storage
		Difference to real defects

ET-General		
Eddy current applications	EC Testing	Conductivity
		Material sorting
		Overheat damage
		Material identification
		Thickness of a non-conductive coating on conductive material
		Influence of temperature
		Influence of inspection speed
		Manual Inspections
		Automated Inspections
		External influence during EC testing
		Crack inspection
		Corrosion inspection
		Sliding probes
		Array applications
Quality assessment	Construction concept	Safe live
		Fail Safe
		Damage Tolerance
	Comparison to other NDT methods	Limits of ET inspections
		Detectable flaw size
		Other NDT Procedures
	Procedures and Standards	National and international standards
	Documentation	Issue of inspection procedures

		Inspection reports
	Personnel requirements	

7. ET Specific

ET-Specific		
Airframe	Paint thickness measurement	On metallic structure
	Cracks	Surface (HFEC)
		Subsurface (LFEC)
		Array applications
		Cracks in multilayered structure
		Cracks in riveted structure
		Bolt hole
	Material Characteristics	Conductivity
		Material sorting
		Overheat damage
		Material identification
	Corrosion detection	Single layer
		Multilayered structure
		Bolt holes
		Array applications
	Crack and discontinuous detection in	Fittings and lugs
		Fastenerholes
		Riveted structures
		Bolts
		Tubes
		Multilayered structure
		Welded structure
		Wrought materials
		Forged materials
Engine	Crack detection in	Blades
		High energy rotating hardware (disc, shafts, blade slots)
		Stators
		Welded parts
		Wrought materials
		Forged materials
		Cast materials
		Automated Systems
Components	Crack detection in	Wheels

		Tubes
		Welded parts
		Bolts
		Gears
		Automated Systems
	Conductivity	Heat treatment
		Overheat damage

8. MT General

MT-General		
Physical principles of Magnetic Particle Inspection	Electrical parameters	Voltage
		Current
		Frequency
		Electrical resistance
		Phase
		Electrical power
		Effect of electrical current
	Magnetical parameters	Ferromagnetism
		Magnetic fields
		Magnetic field strength
		Permeability
		Magnetic flux
		Magnetic flux density
		Hysteresis curve
		Required field strength
	Electromagnetic induction	Transformer
		Skin effect
	Magnetic fields on electrical conductors	Field strength
		Flux density in and around electrical conductors
	Ferromagnetic materials in magnetic fields	
	Evidence of adequate field strength	Hall-effect gaussmeter
	Combined Procedures	Combination of two constant magnetic fields
		Combination of constant and alternating magnetic fields
		Combination of two alternating magnetic fields
		Phase shifted alternating magnetic fields
	Demagnetisation	
Magnetisation	Principles of magnetisation technique	Yoke magnetisation
		Coil magnetisation
		Circular magnetisation with prods

		Circular magnetisation with direct contact
		Circular magnetisation with induced current
		Longitudinal magnetisation
		Combined techniques

MT-General		
Testing equipment and utilities	Equipment	Portable Equipment
		Stationary equipment
		Demagnetisation coils
	Test products	Fluorescent and coloured test products
		Preparation of testing suspension
	Test blocks and tools	Test block for systems performance
		Test block for equipment performance
	Tangential field strength measurement	Field strength measuring instrument
		Berthold test block
		Test block for magnetisation control
	Radiation facilities	UV-A- lamp
		Examination conditions
		Measuring tools for lumination and radiation
Procedure monitoring	Lumination and radiation measurement	UV-A-Radiation measurement
		White light measurement
Viewing	Characteristics of the human eye	Acuity performance
		Ability to discriminate colour
		Contrast sensitivity
		Brightness adaptation
		Astigmatism
Evaluation and reporting of testing instructions	Evaluation	
	Assessment	
	Inspection protocol	
	Structure of inspection procedure	
	Case studies	
	Standards	
	Inspection instructions	

	Company internal regulations	
Material science	Defects during manufacturing process	Inclusion
		Porosity
		Cracks
	Defects during machining process	Roll and forging flaws
		Turning and grinding flaws
		Flaws through hardening process
	Flaws through operation	Cracks
		Corrosion
Safety	Electrical hazards	
	Product related risks	
	UV-related risks	

MT-General		
Quality assessment	Construction concept	Safe live
		Fail Safe
		Damage Tolerance
	Comparison to other NDT methods	Limits of MT inspections
		Detectable flaw size
		Other NDT Procedures
	Documentation	National and international standards
		Issue of inspection procedures
	Personnel requirements	

9. MT Specific

MT-Specific		
Airframe	Crack detection in	Fittings and lugs
		Bolts
		Landing gear
		Rods
		Links
Engine	Crack detection in	Pins
		Gears
		Mounts
		Bolts
		Shafts
		Cases
Components & Reworked parts	Crack detection in	Tubes
		Welded parts
		Bolts
		Cases

10. PT General

PT-General		
Principles	Physical principles	Surface tension
		Wetting
		Capillarity
	Penetrant systems	Penetrants
		Remover
		Developer
		Classification of penetrants
Cleaning	Precleaning Procedure	Types of precleaning
	Mechanical precleaning	Impact of the mechanical precleaning
		Impact on the figures after grinding
		Impact on the figures after shotpeening
		Acid cleaning
	Chemical precleaning	Watery degreasing
		Electrolytical cleaning
		Paint stripping agent
Process of testing	Penetration procedure	Temperature requirements as per standards
		Penetrant application
		Wetting
		Dwell time
		Dipping time, drain time
	Penetrant removal	Water
		Lipophil emulsifier
		Solvent
		Hydrophil emulsifier
	Drying	Drying process after precleaning
		Drying process after penetrant removal
	Developing	Dry developer
		Water soluble developer
		Water suspended developer

		Solvent based developer
		Special developer
	Radiation facilities	UV-A lamp
		Examination conditions
		Measuring tools for lumination and radiation

PT-General		
Viewing	Characteristic of human eye	Acuity performance
		Ability to discriminate colour
		Contrast sensitivity
		Brightness adaptation
		Astigmatism
Selection of penetrant	Classification of penetrant	Low
		Medium
		High
Control of penetrant characteristics	Penetrant Testing as per EN ISO 3452-2	Sample test
		Batch testing
		Monitoring by the user
	Characteristics to be tested	Density
		Wetting / marginal angles
		Viscosity
		Flashpoint
		Vapour pressure
		UV-Resistance
		Corrosive components
		Characteristics of developer
Control of penetrant process	System performance check	Reference test block EN ISO 3452-3
		Storage of reference test block
Evaluation and reporting of testing instructions	Detectable defects on different materials	Related and non-related indication
		Inspection of non metallic material
		Inspection of ceramic materials
		Inspection of composite
Safety	Product related risks	

	UV-related risks	
	Environmental Waste Water Management	
Quality assessment	Procedures and Standards	National and international standards
	Construction concept	Safe live
		Fail Safe
		Damage Tolerance
	Comparison to other NDT methods	Limits of PT inspections
		Detectable flaw size
		Other NDT Procedures
	Documentation	Issue of inspection procedures
		Inspection reports
	Personnel requirements	

11. PT Specific

PT-Specific		
Airframe	Crack and corrosion detection in	Fittings and lugs
		Bolts
		Landing gear
		Rods
		Links
		Structure
		Skin
Engine	Crack detection in	Pins
		Gears
		Mounts
		Bolts
		Shafts
		Cases
		Blades
		Discs
		Slots
		Bores
Components & Reworked parts	Crack detection in	Wheels
		Pins
		Gears
		Mounts
		Bolts
		Shafts
		Cases
		Blades
		Discs
		Slots
		Bores