Ultrasonic Testing courses at DGZfP Education and Training Ltd

A few topics on ultrasonic testing training courses level 1 to 3 at a glance

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Introduction

This presentation aims to give an insight into a few topics related to the training activities of the German Society for Non-Destructive Testing in the field of Ultrasonic Testing. Among others there are to be mentioned a new Syllabus for the UT levels 1-3 which was recently introduced and on the other side advanced complementary courses on level 2 which are currently been discussed.

With more than 60,000 participants over the past 60 years, DGZfP is one of the largest institutions for training NDT personnel in Europe.
From the very beginning our society has attached particular importance to the dissemination of knowledge and to the training of NDT personnel.

The professional formation and the training and qualification scheme were always discussed in terms of efficiency and luckily the more sustainable concept prevailed which can be summarized somehow by the equation:

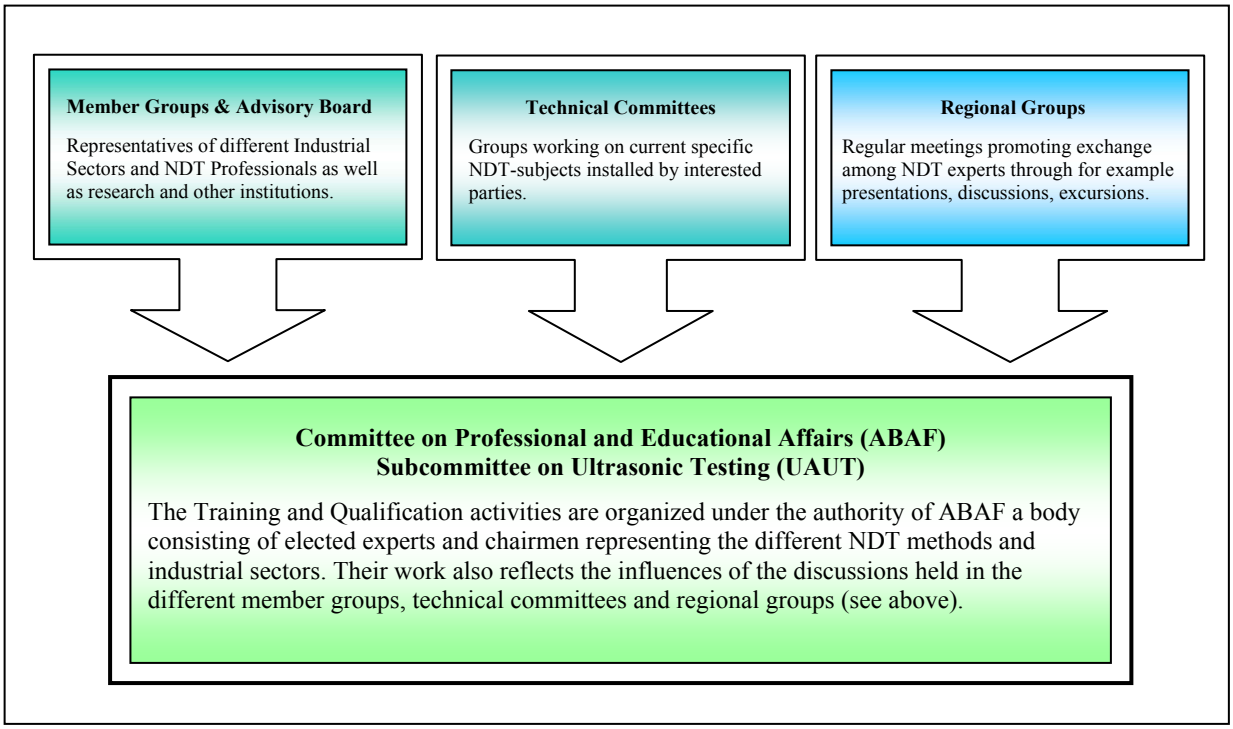
More knowledge = better understanding = more job satisfaction = higher reliability = more confidence = **Higher benefit**

In other words: Investment in knowledge pays the highest interest.

1. NDT-Training at DGZfP

The many bodies, boards, committees and groups representing the German Society for Non-Destructive testing have a direct influence on the design and implementation of the training activities (see Table 1)
The different bodies influence directly or indirectly the training program through its members who represent all relevant sectors of the NDT community.

Table 1. Collaboration to optimise UT Training



2. Training Syllabus DGZfP Ultrasonic Testing Level 1-3

Ultrasonic testing courses at DGZfP have latterly been run on the basis of a syllabus which is mainly based on the structure given in the recommendations of the CEN/TC 138 document TC 138 WI 100 (February 2004) taking into consideration the training experiences of the past decades and the valuable influences of the different professional bodies of our company.

The following Table 2 shows the syllabus elaborated in the Committee on Professional and Educational affairs of DGZfP (Subcommittee on Ultrasonic testing).

The training hours were assigned on the basis of 2-Week courses.

Table 2. UT Training Syllabus

L: lectures, P: practical exercises

Nr	L	P	LEVEL 1	L	P	LEVEL 2	L	P	LEVEL 3
1. Introduction, terminology, purpose and history of NDT									
1	.5	0	Introduction, terminology, purpose and history of NDT. Basic principles of Ultrasonics. Applications.	.5	0	Terminology, Definitions. Symbols and Units. History of UT.	1	0	General survey. Overview of Ultrasonic testing. Scope. Capabilities and limitations of UT
2. Physical principles of the method and associated knowledge 2.1 General terms and definitions. Waves and wave modes 2.2 Sound field. Interaction of ultrasound with material. Attenuation 2.3 Influence of size, shape and distance of reflectors on the amplitude									
2.1	2	0	General Terms. Oscillations. Waves and wave modes. Nature of sound waves. Modes of sound waves: LW, TW, Surface- and Lamb waves. Relationship between sound velocity, frequency and wavelength. Amplitude. Sound waves at interfaces, reflection, transmission. Acoustic impedance. Continuous waves, pulses.	1	0	Interface, Acoustic impedance, Sound pressure. Transmission- and reflection- coefficient. Mode conversion Beam displacement	1	0	Terms and definitions, other modes of waves, surface and interface waves, plate waves, creeping waves, comparison, sound velocity, dispersion. Sound at interfaces, transmission and reflexion, calculations. Polarization of TW
2.2	1.5	0	Sound field features Attenuation of ultrasound Characteristics of the sound field of a circular X-cut crystal. Size of the transducer. Sound field, Near and Far field, Beam axis, beam spread, divergence angle. Sound attenuation.	2	0	Sound field of ABP, effective transducer size, beam-intensity characteristics. Directivity pattern. Focal point. Interference. Sound attenuation coefficient, absorption, scattered energy. Measurement	1	0	Sound beam, directional characteristics. Measurement and calculations. Beam profile Attenuation, scattering of sound, scattering modes. Different ways of measurement
2.3	2	0	Influences on the amplitude of signals. Snells law (oblique incidence) Factors influencing the echo height: Distance, shape and size of the reflector, sound beam, material, attenuation. Snells law, reflection, refraction, mode conversion, critical angles, calculations. Oblique, axial and radial incidence on surfaces. Corner reflectors	2	0	Acoustic pressure distance and size laws for different reflectors: Back wall, cylindrical reflector, disc shaped reflector. Presentation in DGS Diagrams	1	0	Appraisal of the different methods for sizing of discontinuities. Comparison of techniques and methods
3. Product knowledge and capabilities of the method and its derivate techniques 3.1 Product knowledge (Knowledge on discontinuities). Test tasks for UT 3.2 Products and their characteristics related to the manufacturing process 3.3 In-service Machinery and equipment (Revision, maintenance)									
3.1			Basics on product knowledge (knowledge on discontinuities)			Test- characteristics, Types, orientation, capabilities of the UT methods			Product knowledge, test-characteristics, capabilities of the UT method. Gathering Information, sources

Nr	L	P	LEVEL 1	L	P	LEVEL 2	L	P	LEVEL 3
3.2 -1	1	0	Welds Types Welding discontinuities - location: internal, near surface - shape: planar, non-planar	1	0	Welding techniques process review, Definitions Weld preparation geometry, Welding discontinuities, types, origin, typical shape, orientation and location. Standards. Response of ultrasound	1	0	Type of welds and associated discontinuities. Austenitic welds, Claddings. Importance of different weld defects according the intended use. Codes and standards
3.2 -2	.5	0	Castings Casting properties Types casting discontinuities - location: internal, near surface - shape: planar, non-planar	1	0	Casting techniques process review. Materials and their behaviour during solidification. Surface conditions. Discontinuities, types, origin, typical shape, orientation and location. Standards. Response of ultrasound	1	0	Type of discontinuities and their importance according the intended use. Codes and standards
3.2 -3	.5	0	Forgings Types forging discontinuities - location: internal, near surface - shape: planar, non-planar	1	0	Forging process review. Open and closed die forging. Materials and their behaviour during hot and cold deformation. Surface conditions. Discontinuities, types, origin, typical shape, orientation and location. Standards. Response of ultrasound	1	0	Type of discontinuities and their location in dependence on the manufacturing process. Importance according their use. Failures, analysis. Codes and standards
3.2 -4	1	0	Plate and sheet Typical defects originated by the rolling process						
3.2 -6.			Plastics, composite materials				1	0	Materials, processes and Discontinuities - Ceramics - High performance composite materials
3.3			In service defects In-service Machinery and equipment (Revision, maintenance)	1	0	In service conditions. Type of stresses, mechanical, thermal, chemical, electrochemical. Overload, brittle fracture, fatigue, wear, corrosion.	1	0	Objects at higher temperature. Test characteristics. Modes of failure
4. Equipment and Instrumentation **4.1 Equipment, properties, verifications** **4.2 Probes for standard contact applications** **4.3 Special techniques, mechanized and automated Test systems**									
4.1	1.5	1	Equipment, Basic configuration of ultrasonic equipments, block diagrams, functions, controls and circuits. Digital and analogue systems. Signal generator, emission and initial pulse; pulse shift, delay, power, gain control, gates, threshold, suppression. Range and sensitivity setting, Screen presentation. Verification of the test unit, Checks	1	1	Verification of the ultrasonic examination equipment according EN 12668-3	1	0	Properties of the Equipment according EN 12668-1 to 3 Measurements Appraisal of the Influences of deviations on the test results
4.2	3	0	Probes Generation of sound Piezoelectric effect, Material for transducers, backing of the transducer. Types and construction of probes, size, frequency, principles and characteristics: - Straight beam probes (SBP) - Double transducer probes (TRP) - Angle beam probes (ABP)	1	0	Other probes and techniques Current developments of probes and techniques and their properties and other techniques, principles e.g.: - Composite transducers - Tandem and LLT technique - Creeping waves. - Focussing probes - Dual Longitudinal ABP (for austenite testing) - TOFD-technique	3	3	Probe and technique developments with demonstrations - Composite transducers - Tandem and LLT technique - Creeping waves. - Focussing probes - Dual Longitudinal ABP Sensitivity. Frequency, bandwidth backing, damping, resolution. Assessing influence on performance of tests

Nr	L	P	LEVEL 1	L	P	LEVEL 2	L	P	LEVEL 3
4.3	**0**	**0**	**Special techniques, mechanized and automated Test systems**	**1**	**0**	**Overview on different techniques: - Immersion technique - Phased array technique - P-Scan, TOFD**	**6**	**3**	**Principles, and comparison of different techniques: - Immersion technique - Acoustical holography - Echo tomography - Phased array technique - P-Scan, SAFT, TOFD**
5. Information prior to the test. General Information prior to the test Drafting NDT procedures using standards. Drafting NDT instructions and related standards									
5	**.5**	**1**	**Information prior to the test General Information before starting the test. Preparation for testing according given procedures**	**2**	**4**	**Drafting written NDT instructions describing step by step the measures to be followed to meet the requirements of a given test problem**	**4**	**3**	**Drafting written NDT procedures with a description of all essential parameters to be observed in a particular test problem. Use of related standards and other information sources**
6. Testing 6.1 Test methods, Calibration. Material, geometry. Tasks: detection of defects, measuring wall thicknesses, material characterization, other test objectives: e.g. sizing, characterization 6.2 Tests during manufacturing. 6.3 In-service-Inspection. Applications, maintenance.									
6.1	**6.5**	**12**	**Testing. general principles Applying test techniques and methods following standards or written test procedures. Knowledge, proficiency and skills: - Straight and Angle beam probes - Pulse-echo-technique - Time base adjustment, verification - Sensitivity calibration, basic - Use of calibration and reference blocks - Techniques for location of reflectors and measuring of wall thickness**	**2**	**2**	**Choosing, establishing and applying appropriate test techniques and methods adapted to the purpose of the test and in line with applicable standards: - Considering the requirements of the actual test piece and environment - Implementing the principles of UT to the actual test problem (good workmanship) - Interpreting of test standards - Choosing proper test conditions Application of EN 583-1 to -5**	**3**	**3**	**Following the general principles of the method. Choosing, establishing and applying adequate test techniques and methods adapted to the purpose of the test and in line with applicable standards. - Implementing the principles of UT to the actual test problem - Considering the circumstances of the actual test piece and environment - Choosing appropriate test conditions - Estimate the consequences of non expected influences on the test result - Taking measures for corrective action or compensation if necessary - Interpreting test standards**
6.2 -1	**2**	**7**	**Ultrasonic Testing of welded joints. Test techniques for longitudinal- and transverse defects in welds. Calibration of distance range and sensitivity following test instructions or standards. Scanning procedures, reporting results**	**4**	**9**	**Testing of welded joints for general and pressure devices applications. Testing different types of welded joints: Butt (plates and pipes), T- and nozzle joints. Choosing applicable UT techniques and methods. Auxiliary means to ease interpretation of signals. Drafting of written test procedures. Case studies.**	**5**	**5**	**Testing of welded joints. Choosing applicable UT techniques, methods, proceedings for different applications. Writing test procedures following requirements of standards, codes and also other aspects resulting from a given test problem.**
6.2 -2	**.5**	**2**	**Ultrasonic Testing of castings Applicable test techniques Calibration of distance range and sensitivity following test instructions or standards. Reporting results**	**2**	**3**	**Testing of different casting materials. Choosing applicable UT techniques and methods. Drafting of written test procedures. Case studies.**	**2**	**2**	**Testing of castings, casting materials. Choosing applicable UT techniques, specific probes and methods. Writing test procedures following requirements of standards, codes and also other aspects resulting from a given test problem.**

Nr	L	P	LEVEL 1	L	P	LEVEL 2	L	P	LEVEL 3
6.2 -3	1	5	Ultrasonic Testing of forgings Test techniques for steel forgings. Calibration of distance range and sensitivity following test instructions or standards. Reporting results	2	5	Testing of forgings with simple shape for general applications Choosing applicable UT techniques and methods. Drafting of written test procedures. Case studies.	3	2	Testing of forgings. Choosing applicable UT techniques, methods, proceedings for different applications. Writing test procedures following requirements of standards, codes and also other aspects resulting from the test problem.
6.2 -4 -5	1	3	Ultrasonic Testing of plates and sheets Testing of plates and sheets and tubes following test instructions or standards						
6.2 -6 -7 -9	.5	1	Various applications Testing other materials than steel. Measuring wall thickness and sound velocity.	1	1	Austenitic materials, Other and various applications. Overview	2 5	- 2	Testing of different materials e.g. composite materials with the immersion technique. Testing of austenitic materials and -claddings. Ceramics.
6.3	.5	1	In-service Inspection Introduction	1	0	Methods and techniques for the detection of service induced discontinuities. Fatigue failure, material damage	1	1	In-service Tests. Applications in revision inspections and maintenance Detection of in service induced discontinuities. Testing of components at higher temperature.
7. Evaluation and Report **7.1 Evaluation of indications. Reporting test results. General principles** **Evaluation of time-of-flight, echo amplitude. Reflectivity, DAC and DGS Method, echo dynamic pattern and other parameters** **7.2 Evaluation of indications for different products** *(see 6.2)* **7.3 Evaluation of indications during in-service inspection** *(see 6.3)*									
7.1	1	3	Evaluation and reporting of test results. General principles of evaluation and reporting. Using forms and reporting results.	1	2	Keeping of records Presentation of the test data A-. B-, C-Scan displays. Report and documentation	1	0	Presentation as A-, B-, TD-, C- D-, F-scans Other types of presentation. P-scan
7.1 -1	2	9	Evaluation of the time-of-flight Localization of reflectors with SBP and ABP: -Time of flight and distance -Geometrical correlations. -Referencing system of coordinates	1	1	Localization of reflectors when curved geometries or other materials are to be considered EN 583-2	1	1	Evaluation of time-of-flight. Influences and corrections
7.1 -2	1	1	Evaluation of Reflectivity. DAC and DGS Methods Sensitivity calibration and evaluation of indications according test instructions. Measuring transfer correction following given steps	9	8	Principles of echo height evaluation. - DAC-Method - AVG-Method - Transfer correction - Limitations. - Correction of attenuation losses - Use of scales, digital devices distance-amplitude compensation	1	0	General considerations on the evaluation of the amplitude Significance, limitations
7.1 -3	1	2	Evaluation of the echo dynamic pattern Evaluation methods: - fixed amplitude level or - 6 dB drop from maximum (Half-value method)	1	2	Pulse echo and transmission techniques, probe movement techniques, Applications and limitations - Fixed amplitude level - 6 dB drop from maximum (Half-value method) - other techniques *Applications for different objects: see 6.2*	1	1	Characterization and sizing of discontinuities. Pulse echo and transmission techniques. Probe movement sizing techniques, applications and limitations - Fixed amplitude level - 6 dB drop method - 12 or 20 dB drop technique - drop to noise level technique

Nr	L	P	LEVEL 1	L	P	LEVEL 2	L	P	LEVEL 3
8. Assessment **8.1 Assessment. General principles. Classification and characterization of discontinuities. Applicable standards** **8.2 Assessment of manufacturing defects** *(classification of products: see 3.2)* **8.3 Assessment in test objects during in-service inspection** *(classification: see 3.3)*									
8	**0**	**0**	**Assessment of discontinuities**	**2**	**0**	**Assessment. General principles for classification and characterization of discontinuities. Applicable standards**	**2**	**0**	**Assessment. Classification and Characterization of discontinuities Assessment and severity estimation concepts: Quality assurance and fitness for purpose approaches. Fracture mechanics.**
9. Quality aspects									
9	**.5**	**0**	**Quality aspects Levels of competence and responsibilities of level 1 personnel**	**.5**	**0**	**Levels of competence and responsibilities of level 2 personnel - supervision of tests and level 1 duties - guidance of personal below level 2**	**1**	**0**	**Level of competence and responsibilities of Level 3 personnel - validation of procedures - supervision of Level 1 and 2 personal - accreditation of the NDT-laboratories - code of ethics**
10. Environmental and Safety conditions									
10	**.5**	**0**	**Occupational safety Following of given safety instructions and regulations**	**.5**	**0**	**Implementing and monitoring of safety and environmental regulations**	**1**	**0**	**Establishing and supervising a safety and environmental protection system**
11. Developments									
11	**0**	**0**	**Developments**	**.5**	**0**	**NDT methods abstract. Principles and Applications. Comparison and Developments**	**2**	**0**	**Developments and technical advances in the field of UT. e.g. instrumentation, testing, evaluation and assessment.**
Σ	**32**	**48**	**Total UT1= 80 h**	**42**	**38**	**Total UT2= 80 h**	**54**	**26**	**Total UT3= 80 h**

3. Duration of training courses

Table 3 shows the duration for training as stipulated by EN 473 and in the document TC138 WI 100:2004 (draft) compared with DGZfP.
It is easily seen that the EN 473 and the EN-Syllabus from TC 138 require to be harmonized.

Table 3 Duration of training for UT

Duration of training		Level 1		Level 2		Level 3	
		h	d	*h*	d	*h*	d
EN 473	Σ	*40*	**5**	*80*	**10**	/	/
TC138 WI 100:2004	Σ	*62*	**≅8**	*95*	**≅12**	*82,5*	**≅10**
	L	*38*		*57*		*54,5*	
	P	*24*		*38*		*28*	
DGZfP (basic)	Σ	*80*	**10**	*80*	**10**	*80*	**10**
	L	*32*		*42*		*54*	
	P	*48*		*38*		*26*	
Ratio L/P		**0.7**		**1.1**		**2.1**	

The duration of training at DGZfP is 10 days irrespective of the level of the course. However the ratio between lectures (L) and practical exercises (P) increases to the higher level of qualification from Level 1 (.7) to level 2 (1.1) to level 3 (2.1).
In addition to the regular courses there are practical training courses offered (4 days for level 1 and 5 days for level 2) with the objective to improve skills (see Table 3.1).
Most candidates take the opportunity to attend these courses (UT1: 87% and UT2: 99%)

Table 3.1 Duration of training for UT at DGZfP
Standard Course and practical training

Duration of training		Level 1		Level 2		Level 3	
		h	d	*h*	d	*h*	d
DGZfP Standard Course	*L*	*32*		*42*		*54*	
	P	*48*		*38*		*26*	
Practical training	*P*	*32*		*40*		-	
Total		**112**	**14**	**120**	**15**	**80**	**10**
Ratio L/P		**0.4**		**0.5**			**2.1**

4. Course contents

4.1 Level 1

Despite the minimum training requirements of EN 473 for level 1 courses on ultrasonic testing of 40 h it has been decided to maintain a duration of 80 h, following a tradition which relies on a thorough understanding of the principles of the method combined with enough practice to enable the person dealing with UT to face not only the different situations arising during routine tests but also giving the necessary background knowledge to face other tasks and challenges.

4.2 Level 2

The level 2 training at DGZfP is designed to give not only broad knowledge and skills to perform regularly occurring test problems but also the ability to cope with tasks deviating from standard procedures. In view of changing tasks and occasionally arising new test situations it is necessary to have a good command of the test method and at the same time the necessary skills to develop proper strategies to deal with them.
The 2 week course has a modular structure, concentrating the first Week on a deeper understanding of the principles and techniques related to the method.
It is followed by an object related module which concentrates on the application of codes and standards as well as specifications and procedures to prepare written instructions. Main topics are the testing of welded products, forgings and castings, as well as in-service inspections.

The basic course level 2 enables the technician to cope with the most common products and most frequently occurring test problems.

4.2.1 Expert-Courses Level 2.
A new concept to improve the specific skills of the level 2 personnel

A special requirement due to a specific object to be tested or the application of a new technique or method requires, in certain fields, deeper knowledge, specialized skills and experience.
To meet this demand complementary specialized training becomes necessary.
Adequate specific knowledge and skills can be acquired through on- or off-the-job-training or both; however not only a systematic training procedure should be planned and performed but also an unbiased significant performance check and scope of competence for the operator must be documented.

For this purpose DGZfP has designed a new system of courses covering specific demands originated for example by a specific industrial sector (e.g. railways, aviation, chemical plants, power generation) or product or material sectors (e.g. castings, forgings, welds, austenitic materials) or newer or specialized test techniques and methods (e.g. mechanised UT, phased arrays, TOFD)

Since these courses have the character of advanced vocational training, to attend and benefit from these courses a level 2 basic qualification is a precondition. Under these circumstances a 4 day intensive and targeted course is followed by a 1 day examination, which can render an effective and important gain in experience.

4.3 Level 3

Participants of the level 3 courses on ultrasonic testing are almost equal parts level 2 certificate holders or have a level 3 basic qualification.

The course has the same duration as level 1 and 2 emphasizing deeper knowledge on the method and advanced techniques, comparing and choosing appropriate techniques and parameters according to the particularities of the test problem.

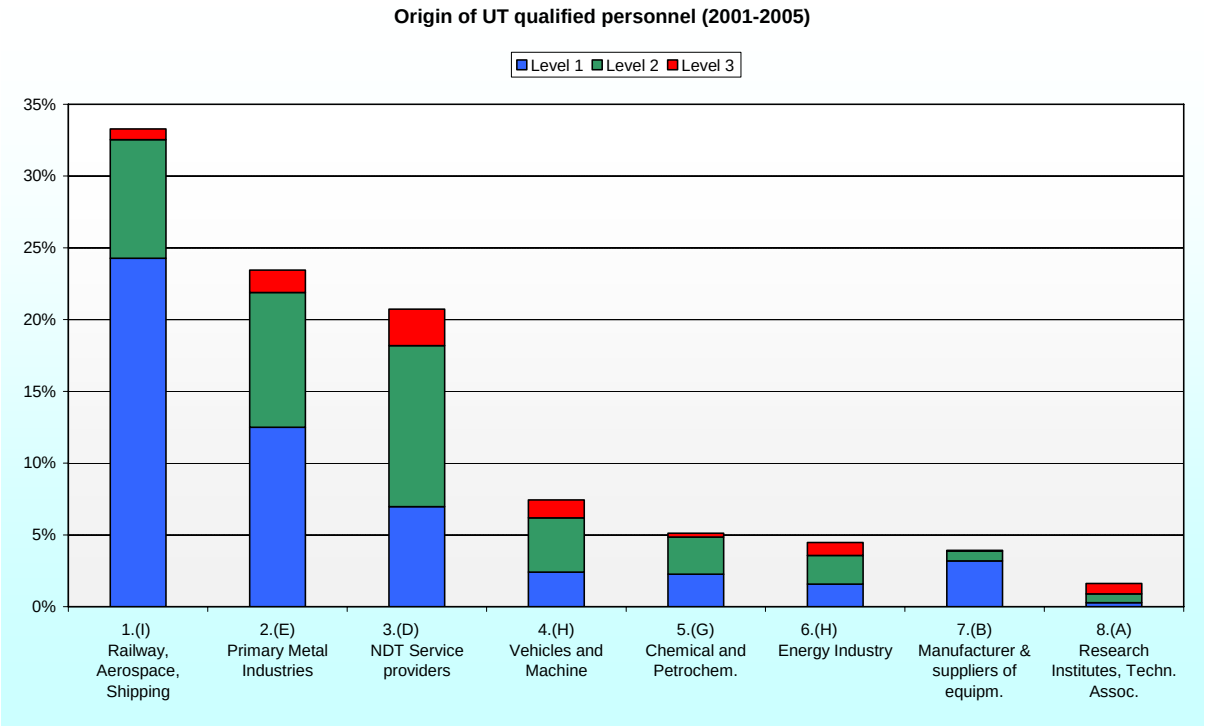
A 1 day visit to the Ultrasonic labs of the Federal Institute of Materials Research and Testing in Berlin gives the opportunity to learn about newest developments and advanced techniques and at the same time to establish valuable links with renowned scientists and experts on NDT.

The training of the level 3 candidates is performed mainly by our companies' professional lecturers while on specific subjects and newer developments leading experts are invited.

Besides others, the working on well planned case studies in groups developing testing procedures which are taken into practice and tested by another group has proven to be an excellent training tool which renders interesting discussions, experiences paired with fun, altogether contributing to develop and strengthen the learning process.

5. Some figures and statistics (2001-2005)

Picture 1



Picture 2