

Recommended Practice No.

SNT-TC-1A

1996



**The American Society for
Nondestructive Testing, Inc.**



Documents

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This document is intended as a guideline for employers to establish their own written practice for the qualification and certification of nondestructive testing personnel. It is not intended to be used as a strict specification.

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SNT-TC-1A*

1996

*** Society for Nondestructive Testing (SNT)—Technical Council—First Document**



**The American Society for
Nondestructive Testing, Inc.**

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Foreword

This recommended practice establishes the general framework for a qualification and certification program. In addition, the document provides recommended educational, experience, and training requirements for the different test methods. Supplementary documents include question and answer lists which may be used in composing examinations for nondestructive testing personnel.

This recommended practice is not intended to be used as a strict specification. It is recognized, however, that contracts require programs which meet the intent of this document. For such contracts, acceptability of an employer's program must be agreed upon by purchaser and supplier.

The verb "should" has been used throughout this document to emphasize the recommendation presented herein. It is the employer's responsibility to address specific needs and to modify these guidelines as appropriate in a written practice. In the employer's written practice, the verb "shall" is to be used in place of "should" to emphasize the employer's needs.

The 1996 Edition of *SNT-TC-1A* is annotated so that users of the 1992 Edition can quickly and easily locate new and updated material. The vertical lines in the margins of this document indicate that information in the text has been modified in some way.

Inquiries related to this recommended practice should be directed to the Chairman of the Personnel Qualification Division at the following address:

The American Society for Nondestructive Testing
1711 Arlingate Lane
P.O. Box 28518
Columbus, Ohio 43228-0518

Review Committee

Publication and review of this recommended practice was under the direction of the *SNT-TC-1A* Review Committee which is a committee of the Personnel Qualification Division. The Personnel Qualification Division reports to the Education and Qualification Council of the American Society for Nondestructive Testing.

Personnel Qualification (PQ) Division:

Claude D. Davis, Chairman
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Education and Qualification (E&Q) Council:

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Review Committee Members:

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Cornelius Murren
William J. Norton, Jr.
Adrian A. Pollock
John A. Titano
Israel Vasquez
Randy Wainwright

ASNT Staff Contributor:

Robert Anderson, Technical Services Manager

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Personnel Qualification and Certification in Nondestructive Testing

Recommended Practice No. SNT-TC-1A

Personnel Qualification and Certification in Nondestructive Testing

1. Scope

- 1.1 It is recognized that the effectiveness of nondestructive testing (NDT) applications depends upon the capabilities of the personnel who are responsible for, and perform, NDT. This Recommended Practice has been prepared to establish guidelines for the qualification and certification of NDT personnel whose specific jobs require appropriate knowledge of the technical principles underlying the nondestructive tests they perform, witness, monitor, or evaluate.
- 1.2 **This document provides guidelines for the establishment of a qualification and certification program.**
- 1.3 These guidelines have been developed by The American Society for Nondestructive Testing, Inc., to aid employers in recognizing the essential factors to be considered in qualifying personnel engaged in any of the NDT methods listed in Section 3.
- 1.4 It is recognized that these guidelines may not be appropriate for certain employers' circumstances and/or applications. In developing a written practice as required in Section 5, the employer should review the detailed recommendations presented herein and modify them, as necessary, to meet particular needs.

2. Definitions

- 2.1 Terms included in this document are defined as follows:
 - (1) *Certification*: written testimony of qualification.
 - (2) *Certifying authority*: the person or persons properly designated in the written practice to sign certifications on behalf of the employer.
 - (3) *Certifying agency*: the employer of the personnel being certified.
 - (4) *Closed-book examination*: an examination administered without access to reference material except for materials supplied with or in the examination (See 8.7).
 - (5) *Comparable*: being at an equivalent or similar level of NDT responsibility and difficulty as determined by the employer's Level III.

- (6) *Documented*: the condition of being in written form.
- (7) *Employer*: the corporate, private, or public entity which employs personnel for wages, salary, fees, or other considerations.
- (8) *Experience*: work activities accomplished in a specific NDT method under the direction of qualified supervision including the performance of the NDT method and related activities but not including time spent in organized training programs.
- (9) *Outside agency*: a company or individual who provides NDT Level III services and whose qualifications to provide these services have been reviewed by the employer engaging the company or individual.
- (10) *Qualification*: demonstrated skill, demonstrated knowledge, documented training, and documented experience required for personnel to properly perform the duties of a specific job.
- (11) *Recommended practice*: a set of guidelines to assist the employer in developing uniform procedures for the qualification and certification of NDT personnel to satisfy the employer's specific requirements.
- (12) *Training*: the organized program developed to impart the knowledge and skills necessary for qualification.

3. Nondestructive Testing Methods

- 3.1 Qualification and certification of NDT personnel in accordance with this Recommended Practice is applicable to each of the following methods:

Acoustic Emission Testing	AE
Electromagnetic Testing	ET
Leak Testing	LT
Liquid Penetrant Testing	PT
Magnetic Particle Testing	MT
Neutron Radiographic Testing	NRT
Radiographic Testing	RT
Thermal/Infrared Testing	TIR
Ultrasonic Testing	UT
Vibration Analysis Testing	VA
Visual Testing	VT

4. Levels of Qualification

- 4.1 There are three basic levels of qualification. These levels may be further subdivided by the employer for situations where additional levels are deemed necessary for specific skills and responsibilities.
- 4.2 While in the process of being initially trained, qualified, and certified, an individual should be considered a trainee. A trainee should work with a certified individual. The trainee shall not independently conduct, interpret, evaluate, or report the results of any NDT.
- 4.3 The three basic levels of qualification are as follow:
 - (1) **NDT Level I.** An NDT Level I individual should be qualified to properly perform specific calibrations, specific NDT, and specific evaluations for acceptance or rejection determinations according to written instructions and to record results. The NDT Level I should receive the necessary instruction or supervision from a certified NDT Level II or III individual.
 - (2) **NDT Level II.** An NDT Level II individual should be qualified to set up and calibrate equipment and to interpret and evaluate results with respect to applicable codes, standards, and specifications. The NDT Level II should be thoroughly familiar with the scope and limitations of the methods for which qualified and should exercise assigned responsibility for on-the-job training and guidance of trainees and NDT Level I personnel. The NDT Level II should be able to organize and report the results of NDT.
 - (3) **NDT Level III.** An NDT Level III individual should be capable of establishing techniques and procedures; interpreting codes, standards, specifications, and procedures; and designating the particular NDT methods, techniques, and procedures to be used. The NDT Level III should be responsible for the NDT operations for which qualified and assigned and should be capable of interpreting and evaluating results in terms of existing codes, standards, and specifications. The NDT Level III should have sufficient practical background in applicable materials, fabrication, and product technology to establish techniques and to assist in establishing acceptance criteria when none are otherwise available. The NDT Level III should have general familiarity with other appropriate NDT methods, as demonstrated by the ASNT

Level III Basic examination or other means. The NDT Level III, in the methods in which certified, should be capable of training and examining NDT Level I and II personnel for certification in those methods.

5. Written Practice

- 5.1 The employer shall establish a written practice for the control and administration of NDT personnel training, examination, and certification.
- 5.2 The employer's written practice should describe the responsibility of each level of certification for determining the acceptability of materials or components in accordance with the applicable codes, standards, specifications, and procedures.
- 5.3 The employer's written practice shall describe the training, experience, and examination requirements for each level of certification.
- 5.4 The employer's written practice shall be maintained on file.

6. Education, Training, and Experience Requirements for Initial Qualification

- 6.1 Candidates for certification in NDT should have sufficient education, training, and experience to ensure qualification in those NDT methods in which they are being considered for certification. Documentation of prior certification may be used by an employer as evidence of qualification for comparable levels of certification.
- 6.2 Documented training and/or experience gained in positions and activities comparable to those of Levels I, II, and/or III prior to establishment of the employer's written practice may be considered in satisfying the criteria of Section 6.3.
- 6.3 To be considered for certification, a candidate should satisfy one of the following criteria for the applicable NDT level:
 - (1) **NDT Levels I and II**

Table 6.3.1A (page 9) lists the recommended training and experience factors to be considered by the employer in establishing written practices for initial qualification of Level I and Level II individuals.

Table 6.3.1B (page 10) lists alternate training and experience factors which may be considered by the employer in establishing written practices for initial qualification of Level I and Level II individuals.
 - (2) **NDT Level III**
 - (a) Have graduated from a minimum four-year college or university curriculum

with a degree in engineering or science, plus one year's experience in NDT in an assignment comparable to that of an NDT Level II in the applicable NDT method(s), or:

- (b) Have completed with passing grades at least two years of engineering or science study at a university, college, or technical school, plus two years' experience in NDT in an assignment at least comparable to that of NDT Level II in the applicable NDT method(s), or:
- (c) Have four years' experience in NDT in an assignment at least comparable to that of an NDT Level II in the applicable NDT method(s).

The above Level III requirements may be partially replaced by experience as a certified NDT Level II or by assignments at least comparable to NDT Level II in other methods listed in Section 3 of this Recommended Practice as defined in the employer's written practice.

7. Training Programs

- 7.1 Personnel being considered for initial certification should complete sufficient organized training to become thoroughly familiar with the principles and practices of the specified NDT method related to the level of certification desired and applicable to the processes to be used and the products to be tested.
- 7.2 The training program should include sufficient examinations to assure that the necessary information has been comprehended.
- 7.3 Recommended training course outlines for NDT Levels I, II, and III personnel and recommended references which may be used as technical source material to follow in the Recommended Training Courses section of this Recommended Practice.
- 7.4 The employer who purchases outside training services is responsible for assuring that such services are in accordance with the employer's written practice.

8. Examinations

- 8.1 Administration and Grading
 - (1) An NDT Level III shall be responsible for the administration and grading of examinations specified in Section 8.3 through 8.8 for NDT Level I, II, or other Level III personnel. The administration and grading of examinations may be delegated to a qualified representative of the NDT Level III and so recorded. The actual

administration and grading of Level III examinations specified in 8.8 may be performed by a qualified representative of the employer.

- (2) For Level I and II personnel, a composite grade should be determined by simple averaging of the results of the general, specific, and practical examinations described below. For Level III personnel, the composite grade should be determined by simple averaging of the results of the basic, method, and specific examinations described below.
 - (3) Examinations administered for qualification should result in a passing composite grade of at least 80 percent, with no individual examination having a passing grade less than 70 percent.
 - (4) When an examination is administered and graded for the employer by an outside agency and the outside agency issues grades of pass or fail only, on a certified report, then the employer may accept the pass grade as 80 percent for that particular examination.
 - (5) The employer who purchases outside services is responsible for assuring that the examination services are in accordance with the employer's written practice.
- 8.2 Vision Examinations
 - (1) Near-Vision Acuity. The examination should assure natural or corrected near-distance acuity in at least one eye such that the applicant is capable of reading a minimum of Jaeger Number 2 or equivalent type and size letter at a distance of not less than 12 inches (30.5 cm) on a standard Jaeger test chart. The ability to perceive an Ortho-Rater minimum of 8 or similar test pattern is also acceptable. This should be administered annually.
 - (2) Color Contrast Differentiation. The examination should demonstrate the capability of distinguishing and differentiating contrast among colors or shades of gray used in the method as determined by the employer. This should be conducted upon initial certification and at three-year intervals thereafter.
 - 8.3 General (Written - for NDT Levels I and II)
 - (1) The general examinations should address the basic principles of the applicable method.
 - (2) In preparing the examinations, the NDT Level III should select or devise appropriate questions covering the applicable method to the degree required by the employer's written practice.
 - (3) See the Appendix for example questions.

- (4) The minimum number of questions which should be given is as follows:

Test Method	Number of Level II Questions	Number of Level I Questions
Acoustic Emission Testing	40	40
Electromagnetic Testing	40	40
Leak Testing	20	20
Liquid Penetrant Testing	30	30
Magnetic Particle Testing	30	30
Neutron Radiographic Testing	40	40
Radiographic Testing	40	40
Thermal/Infrared Testing	40	40
Ultrasonic Testing	40	40
Vibration Analysis Testing	40	40
Visual Testing	30	30

8.4 Specific (Written - for NDT Levels I and II)

- (1) The specific examination should address the equipment, operating procedures, and NDT techniques that the individual may encounter during specific assignments to the degree required by the employer's written practice.
- (2) The specific examination should also cover the specifications or codes and acceptance criteria used in the employer's NDT procedures.
- (3) The minimum number of questions which should be given is as follows:

Test Method	Number of Level I Questions	Number of Level II Questions
Acoustic Emission Testing	20	20
Electromagnetic Testing	20	20
Leak Testing		
1. Bubble Test	15	15
2. Absolute Pressure Leak Test (Pressure Change)	15	15
3. Halogen Diode Leak Test	15	15
4. Mass Spectrometer Leak Test	20	40
Liquid Penetrant Testing	20	15
Magnetic Particle Testing	20	15
Neutron Radiographic Testing	15	15
Radiographic Testing	20	20
Thermal/Infrared Testing	20	20
Ultrasonic Testing	20	20
Vibration Analysis Testing	20	60
Visual Testing	20	20

8.5 Practical (for NDT Level I and II)

- (1) The candidate should demonstrate familiarity with and ability to operate the necessary NDT equipment, record, and analyze the resultant information to the degree required.

- (2) At least one selected specimen should be tested and the results of the NDT analyzed by the candidate.
- (3) The description of the specimen, the NDT procedure, including check points, and the results of the examination should be documented.
- (4) NDT Level I Practical Examination. Proficiency should be demonstrated in performing the applicable NDT on one or more samples approved by the NDT Level III and in evaluating the results to the degree of responsibility as described in the employer's written practice. At least ten (10) different checkpoints requiring an understanding of test variables and the employer's procedural requirements should be included in this practical examination.
- (5) NDT Level II Practical Examination. Proficiency should be demonstrated in selecting and performing the applicable NDT technique within the method and interpreting and evaluating the results on one or more samples approved by the NDT Level III. At least ten (10) different checkpoints requiring an understanding of NDT variables and the employer's procedural requirements should be included in this practical examination.

- 8.6 Sample questions for general examinations are presented in the separate question booklets which can be obtained from ASNT Headquarters. These questions are intended as examples only and should not be used verbatim for qualification examinations. The following is a list of the booklets:

Test Method	Question Booklets
Acoustic Emission Testing Method	G*
Electromagnetic (Eddy Current and Flux Leakage) Testing Method	E
Leak Testing	
1. Bubble Test	HB
2. Pressure Change Measurement	HP
3. Halogen Diode Leak Test	HH
4. Mass Spectrometer Test Method	HM
Liquid Penetrant Testing Method	D
Magnetic Particle Testing Method	B
Neutron Radiographic Testing Method	F
Radiographic Testing Method	A
Thermal/Infrared Testing Method	J*
Ultrasonic Testing method	C
Vibration Analysis Testing Method	K*
Visual Testing Method	I*

- 8.7 All Level I, II, and III written examinations should be closed-book except that necessary data, such as graphs, tables, specifications, procedures, codes, etc., may be provided with or in the examination. Questions utilizing such reference materials should require an understanding of the information rather than merely locating the appropriate answer. All questions used for Level I and Level II examinations should be approved by the responsible Level III.

8.8 **NDT Level III Examinations**

- (1) **Basic Examination** (required only once when more than one method examination is taken). The minimum number of questions which should be given is as follows:
 - (a) Fifteen (15) questions relating to understanding the SNT-TC-1A document.
 - (b) Twenty (20) questions relating to applicable materials, fabrication, and product technology.
 - (c) Twenty (20) questions that are similar to published Level II questions for other appropriate NDT methods.
- (2) **Method Examination** (for each method).
 - (a) Thirty (30) questions relating to fundamentals and principles that are similar to published ASNT Level III questions for each method, and
 - (b) Fifteen (15) questions relating to application and establishment of techniques and procedures that are similar to the published ASNT Level III questions for each method, and
 - (c) Twenty (20) questions relating to capability for interpreting codes, standards, and specifications relating to the method.
- (3) **Specific Examination** (for each method).
 - (a) Twenty (20) questions relating to specifications, equipment, techniques, and procedures applicable to the employer's product(s) and methods employed and to the administration of the employer's written practice.
 - (b) The employer may delete the specific examination if the candidate has a valid ASNT NDT Level III certificate in the method and if documented evidence of experience exists, including the preparation of NDT procedures to codes, standards, or specifications and the evaluation of test results.
- (4) A valid endorsement on an ASNT NDT Level III certificate fulfills the examination criteria described in 8.8(1) and 8.8(2) for each applicable NDT method.

8.9 **Reexamination**

Those failing to attain the required grades should wait at least thirty (30) days or receive suitable additional training as determined by the NDT Level III before reexamination.

9. **Certification**

- 9.1 Certification of all levels of NDT personnel is the responsibility of the employer.
- 9.2 Certification of NDT personnel shall be based on demonstration of satisfactory qualification in accordance with Sections 6, 7, and 8, as modified by the employer's written practice.
- 9.3 At the option of the employer, an outside agency may be engaged to provide NDT Level III services. In such instances, the responsibility of certification is retained by the employer.
- 9.4 Personnel certification records shall be maintained on file by the employer and should include the following:
 - (1) Name of certified individual.
 - (2) Level of certification and NDT method.
 - (3) Educational background and experience of certified individuals.
 - (4) Statement indicating satisfactory completion of training in accordance with the employer's written practice.
 - (5) Results of the vision examinations prescribed in 8.2 for the current certification period.
 - (6) Current examination copy(ies) or evidence of successful completion of examinations.
 - (7) Other suitable evidence of satisfactory qualifications when such qualifications are used in lieu of the specific examination prescribed in 8.8(3) (b) or as prescribed in the employer's written practice.
 - (8) Composite grade(s) or suitable evidence of grades.
 - (9) Dates of certification and/or recertification and the dates of assignments to NDT.
 - (10) Signature of employer's certifying authority.
- 9.5 Recertification
 - (1) All levels of NDT personnel shall be recertified periodically in accordance with one of the following criteria:
 - (a) Evidence of continuing satisfactory performance.
 - (b) Reexamination in those portions of the examinations in Section 8 deemed necessary by the employer's NDT Level III.
 - (2) Recommended maximum recertification intervals are:
 - (a) Levels I and II - 3 years

- (b) Level III - 5 years
- (3) NDT personnel may be reexamined any time at the discretion of the employer and have their certificates extended or revoked.
- (4) The employer's written practice should include rules covering the duration of interrupted service that requires reexamination and recertification.

10. Termination

- 10.1 The employer's certification shall be deemed revoked when employment is terminated.
- 10.2 A Level I, Level II, or Level III whose certification has been terminated may be certified to the former NDT level by a new employer

based on examination, as described in Section 8, provided all of the following conditions are met to the new employer's satisfaction:

- (1) The employee has proof of prior certification.
- (2) The employee was working in the capacity to which certified within six (6) months of termination.
- (3) The employee is being recertified within six (6) months of termination.
- (4) Prior to being examined for certification, employees not meeting the above requirements should receive additional training as deemed appropriate by the NDT Level III.

Table 6.3.1A Recommended Initial Training and Experience Levels

Examination Method	Level	Technique	Initial Training (Hours)		Experience Level** (Months)
			High School Graduate or Equivalent	Completion with a Passing Grade of at Least 2 Years of Engineering or Science Study in a University, College or Technical School	
AE	I		40	32	3
	II		40	40	9
ET	I		40	24	3
	II		40	40	9
LT	I	BT	2	2	*
	II	BT	4	2	0.5
	I	PCT	24	16	1.5
	II	PCT	16	12	4
	I	HDLT	12	8	1.5
	II	HDLT	8	6	4
	I	MSLT	40	28	4
	II	MSLT	24	16	6
MT	I		12	8	1
	II		8	4	3
NRT	I		28	20	6
	II		40	40	24
PT	I		4	4	1
	II		8	4	2
RT	I		39	29	3
	II		40	35	9
TIR	I		40	36	3
	II		40	35	18
UT	I		40	30	3
	II		40	40	9
VA	I		24	24	6
	II		80	56	24
VT	I		8	4	1
	II		16	8	2

Techniques: BT = Bubble Test
PCT = Pressure Change Test
HDLT = Halogen Diode Leak Test
MSLT = Mass Spectrometer Leak Test

* = 2 Hours

** = Work Time Experience Per Level

NOTES:

- (1) For Level II certification, the experience shall consist of time at Level I or equivalent. If a person is being qualified directly to Level II with no time at Level I, the required experience shall consist of the sum of the times required for Level I and Level II and the required training shall consist of the sum of the hours required for Level I and Level II.
- (2) Listed training hours may be adjusted as described in the employer's written practice depending on the candidate's actual education level, e.g., grammar school, college graduate in engineering, etc.
- (3) Initial experience may be gained simultaneously in two or more methods if:
 - (a) the candidate spends a minimum of 25% of work time on each method for which certification is sought, and
 - (b) the remainder of the work time claimed as experience is spent in NDT-related activities defined in the employer's written practice.
- (4) Training shall be outlined in the employer's written practice.

Table 6.3.1B Alternate Initial Training and Experience Levels

Exam ination M ethod	L evel	T echnique	Initial Training (H ours)		Experience Level** (M onths/H ours)
			H igh School G raduate or E quivalent	C om pletion W ith a Passing G rade of at L east 2 Years of E ngineering or S cience Study in a U niversity, College or T echnical School	
AE	I		40	32	3/210
	II		40	40	9/630
ET	I		40	24	3/210
	II		40	40	9/630
LT	I	BT	2	2	*/3
	II	BT	4	2	0.5/35
	I	PCT	24	16	1.5/105
	II	PCT	16	12	4/280
	I	HDLT	12	8	1.5/105
	II	HDLT	8	6	4/280
	I	MSLT	40	28	4/280
	II	MSLT	24	16	6/420
MT	I		12	8	1/70
	II		8	4	3/210
NRT	I		28	20	6/420
	II		40	40	24/1680
PT	I		4	4	1/70
	II		8	4	2/140
RT	I		39	29	3/210
	II		40	35	9/630
TIR	I		40	36	3/210
	II		40	35	18/1260
UT	I		40	30	3/210
	II		40	40	9/630
VA	I		24	24	6/420
	II		80	56	24/1680
VT	I		8	4	1/70
	II		16	8	2/140

Techniques: BT = Bubble Test
PCT = Pressure Change Test
HDLT = Halogen Diode Leak Test
MSLT = Mass Spectrometer Leak Test

*= one (1) day

** = Work time experience per level shall be required over the time frame in 1/2 to 3 times the months shown and shall include a minimum of the hours shown in the specific method for which certification is sought.

Recommended Training Courses

Acoustic Emission Testing Method

(AE – Training Course Outline – TC-8)

	Recommended Hours of Instruction	
	A *	B *
Level I		
Basic Acoustic Emission Physics Course	12	10
Basic Acoustic Emission Technique Course	28	22
Total	40	32
Level II		
Acoustic Emission Physics Course	12	12
Acoustic Emission Technique Course	28	28
Total	40	40

***A** High school graduate or equivalent

***B** Completion with passing grades of at least two years of engineering or science study at a university, college, or technical school.

This is a progressive training course; i.e., consideration as Level I is based on satisfactory completion of the Level I training course; consideration as Level II is based on satisfactory completion of both Level I and Level II training courses.

Topics in the training outline may be deleted or expanded to meet the employer's specific applications or for limited certification and may be accompanied by a corresponding change in training hours.

Recommended Training for Level I Acoustic Emission Testing

Basic Acoustic Emission Physics Course

1. Principles of Acoustic Emission Testing

- 1.1 Characteristics of acoustic emission
 - 1.1.1 Continuous emission
 - 1.1.2 Burst emission
 - 1.1.3 Emission/signal levels and frequencies
- 1.2 Sources of acoustic emission
 - 1.2.1 Sources in crystalline materials - introduction
 - 1.2.2 Sources in nonmetals - introduction
 - 1.2.3 Sources in composites - introduction
 - 1.2.4 Other sources
- 1.3 Wave propagation - introduction
 - 1.3.1 Wave velocity in materials
 - 1.3.2 Attenuation
 - 1.3.3 Reflections, multiple paths
 - 1.3.4 Source input vs. signal output
- 1.4 Repeated loadings: Kaiser and Felicity effects and Felicity ratio

1.4.1 In metals

1.4.2 In composites

- 1.5 Terminology (refer to AE Glossary, ASTM E1316)

2. Sensing the AE Wave

- 2.1 Sensors
 - 2.1.1 Principles of operation
 - 2.1.2 Construction
 - 2.1.3 Frequency
- 2.2 Sensor attachment
 - 2.2.1 Coupling materials
 - 2.2.2 Attachment devices

Total recommended hours of instruction for this course:

Classification A - 12 hours

Classification B - 10 hours

Basic Acoustic Emission Technique Course

1. Instrumentation and Signal Processing

- 1.1 Cables
 - 1.1.1 Coaxial cable
 - 1.1.2 Twisted pair cable
 - 1.1.3 Noise problems in cables
 - 1.1.4 Connectors
- 1.2 Signal conditioning
 - 1.2.1 Preamplifiers
 - 1.2.2 Amplifiers
 - 1.2.3 Filters
 - 1.2.4 Units of gain measurement
- 1.3 Signal detection
 - 1.3.1 Threshold comparator
 - 1.3.2 Units of threshold measurement
 - 1.3.3 Sensitivity determined by gain and/or threshold
- 1.4 Signal processing
 - 1.4.1 Waveform characteristics
 - 1.4.2 Discrimination techniques
 - 1.4.3 Distribution techniques
- 1.5 Source location techniques
 - 1.5.1 Single channel location
 - 1.5.2 Linear location
 - 1.5.3 Planar location
 - 1.5.4 Other location techniques

- 1.6 Acoustic emission test systems
 - 1.6.1 Single channel systems
 - 1.6.2 Multi-channel systems
 - 1.6.3 Dedicated industrial systems
- 1.7 Accessory techniques
 - 1.7.1 Audio indicators
 - 1.7.2 X-Y and strip chart recording
 - 1.7.3 Oscilloscopes
 - 1.7.4 Others

2. Acoustic Emission Test Techniques

- 2.1 Equipment calibration and setup for test
 - 2.1.1 Calibration signal generation techniques
 - 2.1.2 Calibration procedures
 - 2.1.3 Sensor placement
 - 2.1.4 Adjustment of equipment controls
 - 2.1.5 Discrimination technique adjustments
- 2.2 Loading procedures
 - 2.2.1 Type of loading
 - 2.2.2 Maximum test load
 - 2.2.3 Load holds
 - 2.2.4 Repeated and programmed loadings
 - 2.2.5 Rate of loading

- 2.3 Data display
 - 2.3.1 Selection of display mode
 - 2.3.2 Use and reading of different kinds of display
- 2.4 Noise sources and pre-test identification techniques
 - 2.4.1 Electromagnetic noise
 - 2.4.2 Mechanical noise
- 2.5 Precautions against noise
 - 2.5.1 Electrical shielding
 - 2.5.2 Electronic techniques
 - 2.5.3 Prevention of movement
 - 2.5.4 Attenuating materials and applications
- 2.6 Data interpretation and evaluation: introduction
 - 2.6.1 Separating relevant AE indications from noise
 - 2.6.2 Accept/reject techniques and evaluation criteria
- 2.7 Reports
 - 2.7.1 Purpose
 - 2.7.2 Content and structure
- 3. Codes, Standards and Procedures**
 - 3.1 Guide-type standards (glossaries, calibration etc.)
 - 3.2 Standardized/codified AE test procedures
 - 3.3 User-developed test procedures
- 4. Applications of Acoustic Emission Testing (course should include at least 3 categories from 4.1 and at least 4 categories from 4.2)**
 - 4.1 Laboratory studies (material characterization)
 - 4.1.1 Crack growth and fracture mechanics
 - 4.1.2 Environmentally assisted cracking
 - 4.1.3 Dislocation movement (metals)
 - 4.1.4 Clarifying deformation mechanisms (composites)
 - 4.1.5 Phase transformation and phase stability
 - 4.1.6 Creep
 - 4.1.7 Residual stress
 - 4.1.8 Corrosion
 - 4.1.9 Fatigue
 - 4.1.10 Rupture
 - 4.1.11 Ductile/brittle transition
 - 4.1.12 Other material characterization applications
 - 4.2 Structural applications
 - 4.2.1 Pressure vessels (metal)
 - 4.2.2 Storage tanks (metal)
 - 4.2.3 Pressure vessels/storage tanks (composite)
 - 4.2.4 Piping and pipelines
 - 4.2.5 Bucket trucks
 - 4.2.6 Aircraft
 - 4.2.7 Bridges
 - 4.2.8 Mines
 - 4.2.9 Dams, earthen slopes
 - 4.2.10 Pumps, valves etc.
 - 4.2.11 Rotating plant
 - 4.2.12 In-process weld monitoring
 - 4.2.13 Leak detection and monitoring
 - 4.2.14 Other structural applications

Total recommended hours of instruction for this course:

Classification A - 28 hours

Classification B - 22 hours

Recommended Training for Level II Acoustic Emission Testing

Acoustic Emission Physics Course

- 1. Principles of Acoustic Emission Testing**
 - 1.1 Characteristics of acoustic emission testing
 - 1.1.1 Introductory concepts of source, propagation, measurement, display, evaluation
 - 1.1.2 Relationships between AE and other NDT methods
 - 1.1.3 Significance of applied load in AE testing
 - 1.1.4 Basic math review (exponents, graphing, metric units)
 - 1.2 Materials and deformation
 - 1.2.1 Constitution of crystalline and noncrystalline materials
 - 1.2.2 Stress and strain
 - 1.2.3 Elastic and plastic deformation; crack growth
 - 1.3 Sources of acoustic emission
 - 1.3.1 Burst emission, continuous emission
 - 1.3.2 Emission/signal levels, units of amplitude measurement
 - 1.3.3 Sources in crystalline materials

- a. Dislocations - plastic deformation
 - b. Phase transformations
 - c. Deformation twinning
 - d. Nonmetallic inclusions
 - e. Subcritical crack growth
 - 1. Subcritical crack growth under increasing load
 - 2. Ductile tearing under increasing load
 - 3. Fatigue crack initiation and growth
 - 4. Hydrogen embrittlement cracking
 - 5. Stress corrosion cracking
 - 1.3.4 Sources in nonmetals
 - a. Microcracking
 - b. Gross cracking
 - c. Crazing
 - d. Other sources in nonmetals
 - 1.3.5 Sources in composites
 - a. Fiber breakage
 - b. Matrix cracking
 - c. Fiber-matrix debonding
 - d. Delamination
 - e. Fiber pull-out, relaxation
 - f. Friction
 - 1.3.6 Other sources
 - a. Pressure leaks
 - b. Oxide and scale cracking
 - c. Slag cracking
 - d. Frictional sources
 - e. Liquefaction and solidification
 - f. Loose parts, intermittent contact
 - g. Fluids and nonsolids
 - h. Crack closure
 - 1.4 Wave propagation
 - 1.4.1 Near-field impulse response
 - 1.4.2 Modes of propagation
 - 1.4.3 Mode conversion, reflection and refraction
 - 1.4.4 Wave velocity in material
 - 1.4.5 Anisotropic propagation in composites
 - 1.4.6 Specimen geometry effects
 - 1.5 Attenuation
 - 1.5.1 Geometric attenuation
 - 1.5.2 Dispersion
 - 1.5.3 Scattering, diffraction
 - 1.5.4 Attenuation due to energy loss mechanisms
 - 1.5.5 Attenuation vs. frequency
 - 1.6 Kaiser and Felicity effects, and Felicity Ratio
 - 1.6.1 In metals
 - 1.6.2 In composites
 - 1.6.3 In other materials
 - 1.7 Terminology (refer to AE Glossary, ASTM E1316)
 - 2. Sensing the AE Wave**
 - 2.1 Transducing processes (piezoelectricity, etc.)
 - 2.2 Sensors
 - 2.2.1 Construction
 - 2.2.2 Conversion efficiencies
 - 2.2.3 Calibration (sensitivity curve)
 - 2.3 Sensor attachment
 - 2.3.1 Coupling materials
 - 2.3.2 Attachment devices
 - 2.3.3 Waveguides
 - 2.4 Sensor utilization
 - 2.4.1 Flat response sensors
 - 2.4.2 Resonant response sensors
 - 2.4.3 Integral-electronics sensors
 - 2.4.4 Special sensors (directional, mode responsive)
 - 2.4.5 Sensor selection
- Total recommended hours of instruction for this course:
- Classification A - 12 hours
Classification B - 12 hours

Acoustic Emission Technique Course

1. Instrumentation and Signal Processing

- 1.1 Cables
 - 1.1.1 Coaxial cable
 - 1.1.2 Twisted pair cable
 - 1.1.3 Optical fiber cable
 - 1.1.4 Noise problems in cables
 - 1.1.5 Impedance matching
 - 1.1.6 Connectors
- 1.2 Signal conditioning
 - 1.2.1 Preamplifiers
 - 1.2.2 Amplifiers
 - 1.2.3 Filters
 - 1.2.4 Units of gain measurement
- 1.3 Signal detection
 - 1.3.1 Threshold comparator
 - 1.3.2 Units of threshold measurement
 - 1.3.3 Sensitivity determined by gain and/or threshold
- 1.4 Signal processing
 - 1.4.1 Waveform characteristics
 - a. Amplitude analysis
 - b. Pulse duration analysis

- c. Rise time analysis
 - d. Event and event rate processing
 - e. MARSE
- 1.4.2 Discrimination techniques
- 1.4.3 Distribution techniques
- 1.5 Source location techniques
 - 1.5.1 Single channel location
 - 1.5.2 Linear location
 - 1.5.3 Planar location
 - 1.5.4 Other location techniques
- 1.6 Acoustic emission test systems
 - 1.6.1 Single channel systems
 - 1.6.2 Multi-channel systems
 - 1.6.3 Dedicated industrial systems
- 1.7 Accessory techniques
 - 1.7.1 Audio indicators
 - 1.7.2 X-Y and strip chart recording
 - 1.7.3 Oscilloscopes
 - 1.7.4 Magnetic recorders
 - 1.7.5 Others
- 1.8 Advanced signal processing techniques
 - 1.8.1 Signal definition
 - 1.8.2 Signal capture
 - 1.8.3 Frequency analysis
 - 1.8.4 Pattern recognition

2. Acoustic Emission Test Techniques

- 2.1 Factors affecting test equipment selection
 - 2.1.1 Material being monitored
 - 2.1.2 Location and nature of emission
 - 2.1.3 Type of information desired
 - 2.1.4 Size and shape of test part
- 2.2 Equipment calibration and setup for test
 - 2.2.1 Calibration signal generation techniques
 - 2.2.2 Calibration procedures
 - 2.2.3 Sensor selection and placement
 - 2.2.4 Adjustment of equipment controls
 - 2.2.5 Discrimination technique adjustments
- 2.3 Loading procedures
 - 2.3.1 Type of loading
 - 2.3.2 Maximum test load
 - 2.3.3 Load holds
 - 2.3.4 Repeated and programmed loadings
 - 2.3.5 Rate of loading
- 2.4 Special test procedures
 - 2.4.1 High temperature/low temperature tests
 - 2.4.2 Interrupted tests (including cyclic fatigue)
 - 2.4.3 Long term tests
 - 2.4.4 Tests in high noise environments
- 2.5 Data display
 - 2.5.1 Selection of display mode
 - 2.5.2 Use and reading of different kinds of display

- 2.6 Noise sources and pre-test identification techniques
 - 2.6.1 Electromagnetic noise
 - 2.6.2 Mechanical noise
- 2.7 Precautions against noise
 - 2.7.1 Electrical shielding
 - 2.7.2 Electronic techniques
 - 2.7.3 Prevention of movement
 - 2.7.4 Attenuating materials and applications
- 2.8 Data interpretation
 - 2.8.1 Recognizing noise in the recorded data
 - 2.8.2 Noise elimination by data filtering techniques
 - 2.8.3 Relevant and nonrelevant AE response
- 2.9 Data evaluation
 - 2.9.1 Methods for ranking, grading, accepting/rejecting
 - 2.9.2 Comparison with calibration signals
 - 2.9.3 Source evaluation by complementary NDT methods
- 2.10 Reports
 - 2.10.1 Purpose
 - 2.10.2 Content and structure

3. Codes, Standards, Procedures and Societies

- 3.1 Guide-type standards (glossaries, calibration etc.)
- 3.2 Standardized/codified AE test procedures
- 3.3 User-developed test procedures
- 3.4 Societies active in AE

4. Applications of Acoustic Emission Testing (course should include at least 3 categories from 4.1 and at least 4 categories from 4.2)

- 4.1 Laboratory studies (material characterization)
 - 4.1.1 Crack growth and fracture mechanics
 - 4.1.2 Environmentally assisted cracking
 - 4.1.3 Dislocation movement (metals)
 - 4.1.4 Clarifying deformation mechanisms (composites)
 - 4.1.5 Phase transformation and phase stability
 - 4.1.6 Creep
 - 4.1.7 Residual stress
 - 4.1.8 Corrosion
 - 4.1.9 Fatigue
 - 4.1.10 Rupture
 - 4.1.11 Ductile/brittle transition
 - 4.1.12 Other material characterization applications
- 4.2 Structural applications

- 4.2.1 Pressure vessels (metal)
- 4.2.2 Storage tanks (metal)
- 4.2.3 Pressure vessels/storage tanks (composite)
- 4.2.4 Piping and pipelines
- 4.2.5 Bucket trucks
- 4.2.6 Aircraft
- 4.2.7 Bridges
- 4.2.8 Mines
- 4.2.9 Dams, earthen slopes

- 4.2.10 Pumps, valves etc.
- 4.2.11 Rotating plant
- 4.2.12 In-process weld monitoring
- 4.2.13 Leak detection and monitoring
- 4.2.14 Other structural applications

Total recommended hours of instruction for this course

Classification A - 28 hours

Classification B - 28 hours

Acoustic Emission Testing Method

Level III Topical Outline

1.0 Principles and Theory

- 1.1 Characteristics of acoustic emission testing
 - 1.1.1 Concepts of source, propagation, loading, measurement, display, evaluation
 - 1.1.2 Proper selection of AE as technique of choice
 - a. Differences between AE and other techniques
 - b. Complementary roles of AE and other methods
 - c. Potential or conflicting results between methods
 - d. Factors that qualify/disqualify the use of AE
 - 1.1.3 Math review (exponents, logarithms, metric units, and conversions)
- 1.2 Materials and deformation
 - 1.2.1 Materials constitution
 - a. Crystalline/noncrystalline
 - b. Isotropic/anisotropic
 - c. Metals/composites/other
 - 1.2.2 Stress and strain (including triaxial, residual, thermal)
 - 1.2.3 Elastic and plastic deformation; crack growth
 - 1.2.4 Materials properties (strength, toughness, etc.)
- 1.3 Sources of acoustic emission
 - 1.3.1 Broadband nature of source spectra
 - 1.3.2 Emission/signal levels, units of amplitude measurement
 - 1.3.3 Sources in crystalline materials
 - a. Dislocations - plastic deformation
 - b. Phase transformations
 - c. Deformation twinning
 - d. Nonmetallic inclusions
 - e. Subcritical crack growth
 - 1. Subcritical crack growth under increasing load
 - 1.3.4 Sources in nonmetals
 - a. Microcracking
 - b. Gross cracking
 - c. Cracking
 - d. Other sources in nonmetals
 - 1.3.5 Sources in composites
 - a. Fiber breakage
 - b. Matrix cracking
 - c. Fiber-matrix debonding
 - d. Delamination
 - e. Fiber pull-out, relaxation
 - f. Friction
 - 1.3.6 Other sources
 - a. Pressure leaks; cavitation
 - b. Oxide and scale cracking
 - c. Slag cracking
 - d. Frictional sources
 - e. Liquefaction and solidification
 - f. Loose parts, intermittent contact
 - g. Fluids and nonsolids
 - h. Crack closure
 - i. Corrosion
- 1.4 Wave propagation
 - 1.4.1 Near-field impulse response
 - 1.4.2 Modes of propagation (including Lamb waves)
 - 1.4.3 Mode conversion, reflection and refraction
 - 1.4.4 Wave velocity in material (including velocity dispersion)
 - 1.4.5 Anisotropic propagation in composites
 - 1.4.6 Specimen geometry effects
- 1.5 Attenuation

- 1.5.1 Geometric attenuation
- 1.5.2 Dispersion
- 1.5.3 Scattering, diffraction
- 1.5.4 Effects of contained fluids
- 1.5.5 Attenuation due to energy loss mechanisms
- 1.5.6 Attenuation vs. frequency
- 1.6 Kaiser and Felicity effects, and Felicity Ratio
 - 1.6.1 In metals
 - 1.6.2 In composites
 - 1.6.3 Emission during load holds
- 1.7 Terminology (refer to AE Glossary, ASTM 1316)

2.0 Equipment and Materials

- 2.1 Transducing processes (piezoelectricity, etc.)
- 2.2 Sensors
 - 2.2.1 Construction
 - a. Single ended
 - b. Differential
 - c. Test environment considerations
 - d. Wave mode sensitivity
 - 2.2.2 Conversion efficiencies; temperature effects
 - 2.2.3 Calibration
 - a. Methods and significance
 - b. Calculations from absolute sensitivity curve
 - 2.2.4 Reciprocity
- 2.3 Sensor attachment
 - 2.3.1 Coupling materials: selection and effective use
 - 2.3.2 Attachment devices
 - 2.3.3 Waveguides: design considerations, effect on signal
- 2.4 Sensor utilization
 - 2.4.1 Flat response sensors
 - 2.4.2 Resonant response sensors
 - 2.4.3 Integral-electronics sensors
 - 2.4.4 Special sensors (directional, mode responsive, accelerometers)
 - 2.4.5 Sensor selection
- 2.5 Simulated AE sources
 - 2.5.1 Hsu-Nielsen Source (lead break)
 - 2.5.2 Piezoelectric transducers and associated electronics
 - 2.5.3 Gas jet
 - 2.5.4 Other devices
- 2.6 Cables
 - 2.6.1 Cable types
 - a. Coaxial
 - b. Twisted pair
 - c. Multiscreened
 - d. Optical
 - e. Others

- 2.6.2 Shielding and other factors governing cable selection
- 2.6.3 Cable length effects
- 2.6.4 Noise problems in cables
- 2.6.5 Cables as transmission lines
- 2.6.6 Impedance matching
- 2.6.7 Connectors
- 2.7 Signal conditioning
 - 2.7.1 Preamplifiers (dynamic range, cable drive capability, etc.)
 - 2.7.2 Amplifiers
 - 2.7.3 Filters: selection, roll-off rates
 - 2.7.4 Units of gain measurement
 - 2.7.5 Electronic noise
- 2.8 Signal detection
 - 2.8.1 Threshold comparator
 - 2.8.2 Units of threshold measurement
 - 2.8.3 Sensitivity determined by gain and/or threshold
 - 2.8.4 Use of floating threshold
 - 2.8.5 Dead time
- 2.9 Signal processing
 - 2.9.1 Waveform characteristics
 - a. Amplitude
 - b. Pulse duration
 - c. Rise time
 - d. Signal strength (MARSE)
 - e. Threshold crossing counts
 - f. Hit vs. event processing
- 2.10 Source location
 - 2.10.1 Single channel location
 - 2.10.2 Linear location
 - 2.10.3 Planar location
 - 2.10.4 Hit-sequence zonal location
 - 2.10.5 Other location methods
 - 2.10.6 Guard channels and spatial filtering
- 2.11 Advanced signal processing
 - 2.11.1 Data filtering
 - 2.11.2 Signal definition
 - 2.11.3 Signal capture
 - 2.11.4 Frequency analysis (Fourier theorem, theory of spectrum)
 - 2.11.5 Pattern recognition
 - 2.11.6 Source function determination by deconvolution/Green's function
- 2.12 Acoustic emission test systems
 - 2.12.1 Single channel systems
 - 2.12.2 Multi-channel systems
 - 2.12.3 Dedicated industrial systems
 - 2.12.4 Interpreting and writing system specifications
- 2.13 Accessory materials
 - 2.13.1 Audio indicators
 - 2.13.2 X-Y and strip chart recording
 - 2.13.3 Oscilloscopes
 - 2.13.4 Magnetic recorders

- 2.13.5 Computers and their use
 - a. Operating systems
 - b. Data storage and transfer
 - c. Data output
- 2.13.6 Others
- 2.14 Factors affecting test equipment selection
 - 2.14.1 Material being monitored
 - 2.14.2 Location and nature of emission
 - 2.14.3 Type of information desired
 - 2.14.4 Size and shape of test part

3.0 Techniques

- 3.1 Equipment calibration and setup for test
 - 3.1.1 Calibration signal generation techniques
 - 3.1.2 Calibration procedures
 - 3.1.3 Sensor selection and placement
 - 3.1.4 Adjustment of equipment controls
 - 3.1.5 Discrimination technique adjustments
- 3.2 Establishing loading procedures
 - 3.2.1 Type of loading
 - 3.2.2 Maximum test load
 - 3.2.3 Load holds
 - 3.2.4 Repeated and programmed loadings
 - 3.2.5 Rate of loading
- 3.3 Precautions against noise
 - 3.3.1 Noise identification
 - a. Electromagnetic noise
 - b. Mechanical noise
 - 3.3.2 Noise elimination/discrimination before test
 - a. Electrical shielding
 - b. Grounding
 - c. Frequency filtering
 - d. Gain and/or threshold adjustment
 - e. Floating threshold
 - f. Attenuating materials and applications
 - g. Prevention of movement, friction
 - h. Guard channels, spatial filtering
 - i. Time- and load-based gating
 - j. Discrimination based on waveform characteristics
- 3.4 Special test procedures
 - 3.4.1 High temperature/low temperature tests
 - 3.4.2 Interrupted tests (including cyclic fatigue)
 - 3.4.3 Long term tests, permanent/continuous monitoring
 - 3.4.4 Tests in high noise environments
- 3.5 Data displays
 - 3.5.1 Purpose and value of different displays

- a. Time- and load-based plots
- b. Location displays
- c. Distribution functions
- d. Crossplots
- e. Other displays

- 3.5.2 Selection of displays

4.0 Interpretation and Evaluation

- 4.1 Data interpretation
 - 4.1.1 Relevant and nonrelevant AE response
 - 4.1.2 Recognizing noise vs. true AE in the recorded data
 - 4.1.3 Distribution function analysis
 - 4.1.4 Crossplot analysis
 - 4.1.5 Noise elimination - data filtering techniques
 - a. Spatial filtering
 - b. Filtering on waveform characteristics
 - c. Time-based and parametric-based filtering
- 4.2 Data evaluation
 - 4.2.1 Methods for ranking, grading, accepting/rejecting
 - 4.2.2 Comparison with calibration signals
 - 4.2.3 Source evaluation by complementary NDT methods
- 4.3 Reports
 - 4.3.1 Purpose
 - 4.3.2 Content and structure
 - 4.3.3 Developing a standard report format

5.0 Procedures

- 5.1 Guide-type standards (glossaries, calibration, etc.)
- 5.2 Standardized/codified AE test procedures
- 5.3 User-developed test procedures
- 5.4 Societies active in AE
- 5.5 Interpretation of codes, standards, and procedures
- 5.6 Developing and writing AE test procedures
- 5.7 Training and examining Level I and II NDT personnel

6.0 Safety and Health

- 6.1 Hazards associated with structural failure during test
- 6.2 Other hazards associated with AE testing
- 6.3 Importance of local regulations

7.0 Applications

- 7.1 Laboratory studies (material characterization)
 - 7.1.1 Crack growth and fracture mechanics
 - 7.1.2 Environmentally assisted cracking

- | | | | |
|--------|---|--------|---|
| 7.1.3 | Dislocation movement (metals)
(strain rate and volume effects) | 7.2.1 | Pressure vessels (metal) |
| 7.1.4 | Clarifying deformation mechanisms
(composites) | 7.2.2 | Storage tanks (metal) |
| 7.1.5 | Phase transformation and phase
stability | 7.2.3 | Pressure vessels/storage tanks
(composite) |
| 7.1.6 | Creep | 7.2.4 | Piping and pipelines |
| 7.1.7 | Residual stress | 7.2.5 | Bucket trucks |
| 7.1.8 | Corrosion | 7.2.6 | Aircraft |
| 7.1.9 | Fatigue | 7.2.7 | Bridges |
| 7.1.10 | Rupture | 7.2.8 | Mines |
| 7.1.11 | Ductile/brittle transition | 7.2.9 | Dams, earthen slopes |
| 7.1.12 | Other material characterization
applications | 7.2.10 | Pumps, valves, etc. |
| 7.2 | Structural applications | 7.2.11 | Rotating plant |
| | | 7.2.12 | In-process weld monitoring |
| | | 7.2.13 | Leak detection and monitoring |
| | | 7.2.14 | Other structural applications |

Recommended Training References

Acoustic Emission Testing Method, Level I, II, and III

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* Available from The American Society for Nondestructive Testing, Inc., Columbus, OH.

Electromagnetic Testing Method

(ET – Training Course Outline – TC-5)

	Recommended Hours of Instruction	
	A *	B *
Level I		
Basic Electromagnetic Physics Course	24	12
Basic Electromagnetic Technique Course	16	12
	Total	40
Level II		
Electromagnetic Evaluation Course	Total	40

***A** High school graduate or equivalent

***B** Completion with passing grades of at least two years of engineering or science study at a university, college, or technical school.

This is a progressive training course; i.e., consideration as Level I is based on satisfactory completion of the Level I training course; consideration as Level II is based on satisfactory completion of both Level I and Level II training courses.

Topics in the training outline may be deleted or expanded to meet the employer's specific applications or for limited certification and may be accompanied by a corresponding change in training hours.

Recommended Training for Level I Electromagnetic Testing

Basic Electromagnetic Physics Course

1. Introduction to Electromagnetic Testing (Eddy Current/Flux Leakage)

- a. Brief history of testing
- b. Basic principles of testing

2. Electromagnetic Theory

- a. Eddy current theory
 - (1) Generation of eddy currents by means of an AC field
 - (2) Effect of fields created by eddy currents (impedance changes)
 - (3) Effect of change of impedance on instrumentation
 - (4) Properties of eddy current
 - (a) Travel in circular direction
 - (b) Strongest on surface of test material
 - (c) Zero value at center of solid conductor placed in an alternating magnetic field
 - (d) Strength, time relationship, and orientation as functions of test-system parameters and test-part characteristics
 - (e) Have properties of compressible fluids
 - (f) Small magnitude of current flow
 - (g) Relationship of frequency and plane with current in coil

- (h) Effective permeability variations when induced in magnetic materials
- (i) Effect of discontinuity orientation
- (j) Power losses

b. Flux leakage theory

- (1) Terminology and units
- (2) Principles of magnetization
 - (a) B-H curve
 - (b) Magnetic properties
 - (c) Magnetic field
 - (d) Hysteresis loop
 - (e) Magnetic permeability
 - (f) Factors affecting permeability
- (3) Magnetization – electromagnetism theory
 - (a) Oersted's law
 - (b) Faraday's law
 - (c) Electromagnetic
- (4) Flux leakage theory and principle
 - (a) Residual
 - (b) Active
 - (c) Tangential leakage
 - (d) Normal leakage fields

Total recommended hours of instruction for this course:

Classification A - 24 hours

Classification B - 12 hours

Electromagnetic Technique Course

1. Readout Mechanism

- a. Calibrated or uncalibrated meter
- b. Null meter with dial indicator
- c. Oscilloscope and other monitor displays
- d. Alarm, lights, etc.
- e. Numerical counters
- f. Marking system
- g. Sorting gates and tables
- h. Cutoff saw or shears
- i. Automation and feedback
- j. Strip-chart recorder

2. Types of Eddy Current Sensing Elements

- a. Probes

(1) Types of arrangements

- (a) Absolute
- (b) Differential

(2) Lift-off

(3) Theory of operation

(4) Applications

(5) Advantages

(6) Limitations

b. Through, encircling, or annular coils

(1) Types of arrangements

- (a) Absolute
- (b) Differential

(2) Fill factor

(3) Theory of operation

- (4) Applications
- (5) Advantages
- (6) Limitations
- c. Factors affecting choice of sensing elements
 - (1) Type of part to be inspected
 - (2) Type of discontinuity to be detected
 - (3) Speed of testing required
 - (4) Amount of testing (percentage) required
 - (5) Probable location of discontinuity

3. Types of Flux Leakage Sensing Elements

- a. Principles of magnetic-measurement techniques
- b. Inductive-coil sensors
 - (1) Theory of electromotive force (emf) induced in coil
 - (2) Various constructions and designs of coils
 - (3) Coil parameters affecting the flux leakage response

- (4) Sensing-coil systems and connections (single- and multielement probes)
- c. Semiconductor sensing elements
 - (1) Hall-effect probes
 - (2) Magnetoresistors
 - (3) Magnetodiodes
 - (4) Magnetotransistors
 - (5) Magnetic and electric characteristics of semiconductor sensing elements
- d. Other methods of magnetic leakage field detection
 - (1) Magnetic-tape system
 - (2) Magnetic powder
 - (3) Magnetic-resonance sensor

Total recommended hours of instruction for this course:

Classification A -16 hours

Classification B -12 hours

Recommended Training for Level II Electromagnetic Testing

Electromagnetic Evaluation Course

1. Review of Electromagnetic Theory

- a. Eddy current theory
- b. Flux leakage theory
- c. Types of eddy current sensing probes
- d. Types of flux leakage sensing probes

2. Factors That Affect Coil Impedance

- a. Test part
 - (1) Conductivity
 - (2) Permeability
 - (3) Mass
 - (4) Homogeneity
- b. Test system
 - (1) Frequency
 - (2) Coupling
 - (3) Field strength
 - (4) Test coil and shape

3. Factors That Affect Flux Leakage Fields

- a. Degree of magnetization
- b. Defect geometry
- c. Defect location
- d. Defect orientation
- e. Velocity factor
- f. Distance between adjacent defects

4. Signal-to-Noise Ratio

- a. Definition
- b. Relationship to eddy current testing
- c. Relationship to flux leakage testing
- d. Methods of improving signal-to-noise ratio

5. Selection of Test Frequency

- a. Relationship of frequency to type of test
- b. Considerations affecting choice of test
 - (1) Signal-to-noise ratio
 - (2) Phase discrimination
 - (3) Response speed
 - (4) Skin effect

6. Selection of Method of Magnetization for Flux Leakage Testing

- a. Magnetization characteristics for various magnetic materials
- b. Magnetization by means of electric fields
 - (1) Circular field
 - (2) Longitudinal field
 - (3) Value of flux density
- c. Magnetization by means of permanent magnets
 - (1) Permanent magnet relationship and theory
 - (2) Permanent magnet materials
- d. Selection of proper magnetization method

7. Coupling

- a. "Fill factor" in through-coil inspection
- b. "Lift-off" and compensation in probe coil inspection
- c. Flux leakage "fill factor" in flux leakage testing
- d. "Lift-off" in flux leakage testing

8. Field Strength and Its Selection

- a. Permeability changes
- b. Saturation
- c. Effect of AC field strength on eddy current testing
- d. Effect of field strength in flux leakage testing

9. Field Orientation for Flux Leakage Testing

- a. Circular field
- b. Longitudinal field

10. Instrument Design Considerations

- a. Amplification
- b. Phase detection
- c. Differentiation of filtering

11. Applications

- a. Flaw detection
 - (1) Eddy current methods
 - (2) Flux leakage methods
- b. Sorting for properties related to conductivity – eddy current
- c. Sorting for properties related to permeability
 - (1) Eddy current methods
 - (2) Flux leakage methods
- d. Thickness evaluation – eddy current
- e. Measurement of magnetic-characteristic values
 - (1) Eddy current methods
 - (2) Flux leakage methods

12. User Standards and Operating Procedures

- a. Explanation of standards and specifications used in electromagnetic testing
- b. Explanation of operating procedures used in electromagnetic testing

Total recommended hours of instruction for this course:

Classification A - 40 hours

Classification B - 40 hours

Electromagnetic Testing Method Level III Topical Outline

1.0 Principles/Theory

- 1.1 Eddy Current Theory
 - 1.1.1 Generation of eddy currents
 - 1.1.2 Effect of fields created by eddy currents (impedance changes)
 - 1.1.3 Properties of eddy current
 - a. Travel mode
 - b. Depth of penetration
 - c. Effects of test part characteristics
 - d. Current flow
 - e. Frequency and phase
 - f. Effects of permeability variations
 - g. Effects of discontinuity orientation

2.0 Equipment/Materials

- 2.1 Probes
 - 2.1.1 Advantages
 - 2.1.2 Limitations
- 2.2 Through, encircling or annular coils
 - 2.2.1 Advantages
 - 2.2.2 Limitations

- 2.3 Factors affecting choice of sensing elements
 - 2.3.1 Type of part to be inspected
 - 2.3.2 Type of discontinuity to be detected
 - 2.3.3 Speed of testing required
 - 2.3.4 Amount of testing required
 - 2.3.5 Probable location of discontinuity
 - 2.3.6 Applications other than discontinuity detection
- 2.4 Read out selection
 - 2.4.1 Meter
 - 2.4.2 Oscilloscope and other monitor displays
 - 2.4.3 Alarm, lights, etc.
 - 2.4.4 Strip chart recorder
- 2.5 Instrument design considerations
 - 2.5.1 Amplification
 - 2.5.2 Phase detection
 - 2.5.3 Differentiation or filtering

3.0 Techniques/Calibrations

- 3.1 Factors which affect coil impedance
 - 3.1.1 Test part
 - 3.1.2 Test system
- 3.2 Selection of test frequency

- 3.2.1 Relation of frequency to type of test
- 3.2.2 Consideration affecting choice of test
 - a. Signal/noise ratio
 - b. Phase discrimination
 - c. Response speed
 - d. Skin effect
- 3.3 Coupling
 - 3.3.1 Fill factor
 - 3.3.2 Lift off
- 3.4 Field strength
 - 3.4.1 Permeability changes
 - 3.4.2 Saturation
 - 3.4.3 Effect of AC field strength on eddy current testing

4.0 Interpretation/Evaluation

- 4.1 Flaw detection
- 4.2 Sorting for properties related to conductivity
- 4.3 Sorting for properties related to permeability
- 4.4 Thickness gaging
- 4.5 Measurement of magnetic characteristics
- 4.6 Process control

5.0 Procedures

6.0 Safety and Health

Recommended Training References

Electromagnetic Testing Method, Level I, II, and III

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* Available from The American Society for Nondestructive Testing, Inc., Columbus, OH.

† Currently published by The American Society for Nondestructive Testing, Inc., Columbus, OH.

Leak Testing Methods

(LT – Training Course Outline – TC-7)

	Recommended Hours of Instruction	
	A *	B *
Level I		
Fundamentals in Leak Testing Course	14	8
Safety in Leak Testing	14	8
Leak Testing Methods	14	8
Total	42	24
Level II		
Principles of Leak testing	24	12
Pressure and Vacuum Technology Course	12	6
Leak Test Selection Course	12	6
Total	48	24

***A** High school graduate or equivalent

***B** Completion with passing grades of at least two years of engineering or science study at a university, college, or technical school.

Hours of instruction may vary according to the technique being instructed, i.e., the hours of instruction for one or two techniques may be less than for four techniques.

The minimum recommended training hours are shown in Table 6.3.1(A), page 9.

Recommended Training for Level I Leak Testing

Fundamentals in Leak Testing Course

1. Introduction

- a. History of leak testing
- b. Reasons for leak testing
 - (1) Material loss prevention
 - (2) Contamination
 - (3) Component/system reliability
 - (4) Pressure-differential maintenance
 - (5) Personnel/public safety
- c. Functions of leak testing
 - (1) Categories
 - (2) Applications
- d. Training and certification

2. Leak Testing Fundamentals

- a. Terminology
 - (1) Leakage terms
 - (2) Leakage tightness
 - (3) Quantitative/semi-quantitative
 - (4) Sensitivity/calibration terms
- b. Leak testing units
 - (1) Mathematics in leak testing
 - (2) Exponential notation
 - (3) Basic and fundamental units
 - (4) Système Internationale (SI) units
- c. Physical units in leak testing
 - (1) Volume and pressure
 - (2) Time and temperature
 - (3) Absolute values
 - (4) Standard or atmospheric conditions
 - (5) Leakage measurement
- d. Leak testing standards
 - (1) Capillary or permeation
 - (2) National Institute of Standards and Technology (NIST) standards
 - (3) System vs. instrument calibration
 - (4) Inaccuracy of calibration
- e. Flow characteristics
 - (1) Gas flow
 - (2) Liquid flow
 - (3) Correlation of leakage rates
 - (4) Anomalous leaks
 - (5) Leak clogging
- f. Vacuum fundamentals
 - (1) Introduction to vacuum
 - (a) Terminology
 - (b) Principles
 - (c) Units of pressure
 - (2) Characteristics of gases
 - (a) Kinetic theory

- (b) Mean free path
 - (3) Gas laws
 - (4) Quantity, throughput, and conductance of gas
 - (a) Quantity
 - (1₁) Comparison with an electric circuit
 - (2₁) Comparison with water flow
 - (b) Conductance analogy with electrical resistance
 - (1₁) Resistance connected in series
 - (2₁) Resistance connected in parallel
- g. Vacuum system operation
 - (1) Effects of evacuating a vessel
 - (2) Pump-down time
- h. Vacuum system characteristics
 - (1) General
 - (a) Operating limits
 - (b) Rate of pressure rise – measurement
 - (2) Vacuum pumps
 - (a) Mechanical pumps (positive displacement)
 - (1₁) Oil-sealed rotary pumps
 - (a₁) Construction
 - (b₁) Operation
 - (c₁) Pump fluids
 - (d₁) Difficulties with rotary pumps
 - (e₁) Care of rotary pumps
 - (2₁) Mechanical booster pumps
 - (b) Vapor (diffusion) pumps
 - (1₁) Construction
 - (2₁) Operation
 - (3₁) Pump fluids
 - (4₁) Difficulties with diffusion pumps
 - (5₁) Diagnosis of diffusion pump trouble
 - (c) Sublimation pumps (getter pumps)
 - (d) Ion pumps
 - (e) Turbomolecular pumps
 - (f) Absorption pumps
 - (g) Cryopumps

Total recommended hours of instruction for this course:

Classification A - 14 hours

Classification B - 8 hours

Safety in Leak Testing Course

Note: It is recommended that the trainee, as well as all other leak testing personnel, receive instruction in this course prior to performing work in leak testing.

1. Safety Considerations

- a. Personnel and the public
- b. Product serviceability
- c. Test validity
- d. Safe work practices

2. Safety Precautions

- a. Explosive/implosive hazards
- b. Flammability, ignitability, combustibility hazards
- c. Toxicity and asphyxiation hazards
- d. Cleaning and electrical hazards

3. Pressure Precautions

- a. Pressure test vs. proof test
- b. Preliminary leak testing
- c. Pressurization check
- d. Design limitations
- e. Equipment and setup

4. Safety Devices

- a. Pressure control valves and regulators

- b. Pressure relief valves and vents
- c. Flow rate of regulator and relief valves

5. Hazardous and Tracer Gas Safety

- a. Combustible gas detection and safety
- b. Toxic gas detection and safety
- c. Oxygen-deficiency detectors
- d. Radioisotope detection

6. Types of Monitoring Equipment

- a. Area monitors
- b. Personnel monitors
- c. Leak-locating devices

7. Safety Regulations

- a. State and federal regulations
- b. Safety codes/standards
- c. Hazardous gas standards
- d. Nuclear Regulatory Commission (NRC) radiation requirements

Total recommended hours of instruction for this course:

Classification A - 14 hours

Classification B - 8 hours

Leak Testing Methods Course

1. The following leak testing methods may be incorporated as applicable.

- a. Each of these methods can be further divided into major techniques as shown in the following examples.

(1) Bubble testing

- (a) Immersion
- (b) Film solution

(2) Ultrasonic testing

- (a) Sonic/mechanical flow
- (b) Sound generator

(3) Voltage discharge testing

- (a) Voltage spark
- (b) Color change

(4) Pressure leak testing

- (a) Hydrostatic
- (b) Pneumatic

(5) Ionization

- (a) Photoionization
- (b) Flame ionization

(6) Conductivity

- (a) Thermal conductivity
- (b) Solid state

(7) Radiation absorption

- (a) Infrared
- (b) Ultraviolet
- (c) Laser

(8) Chemical-based

- (a) Chemical penetrants
- (b) Chemical gas tracer (colorimetric)

(9) Halogen detector

- (a) Halide torch
- (b) Electron capture
- (c) Halogen diode

(10) Pressure change measurement

- (a) Absolute
- (b) Reference
- (c) Pressure rise
- (d) Flow
- (e) Pressure decay
- (f) Volumetric

(11) Mass spectrometer

- (a) Helium or argon leak detector
- (b) Residual gas analyzer

(12) Radioisotope

2. Leak Testing Method Course Outline

- a. The following may be applied to any of the listed methods.
- b. Terminology
- c. Basic techniques and/or units
 - (1) Leak location – measurement/ monitoring
 - (2) Visual and other sensing devices
 - (3) Various techniques
- d. Testing materials and equipment
 - (1) Materials, gases/fluids used
 - (2) Control devices and operation
 - (3) Instrument/gages used
 - (4) Range and calibration of instrument/gages
- e. Testing principles and practices
 - (1) Pressure/vacuum and control used
 - (2) Principles of techniques used

- (3) Effects of temperature and other atmospheric conditions
- (4) Calibration for testing
- (5) Probing/scanning or measurement/monitoring
- (6) Leak interpretation evaluation
- f. Acceptance and rejection criteria
- g. Safety concerns
- h. Advantages and limitations
- i. Codes/standards

Total recommended hours of instruction for this course:

Classification A - 14 hours

Classification B - 8 hours

Recommended Training for Level II Leak Testing

Principles of Leak Testing Course

1. Introduction

- a. Leak testing fundamentals
 - (1) Reasons for leak testing
 - (2) Functions of leak testing
 - (3) Terminology
 - (4) Leak testing units
 - (5) Leak conductance
- b. Leak testing standards
 - (1) Leak standards
 - (2) National Institute of Standards and Technology (NIST) traceability and calibration
 - (3) Instrument calibration vs. test qualification
 - (4) System calibration techniques
 - (5) Inaccuracy of calibration
 - (6) Tracer-gas leak rate/air-equivalent leak rate
- c. Leak testing safety
 - (1) Safety considerations
 - (2) Safety precautions
 - (3) Pressure precautions
 - (4) Tracer gas safety and monitoring
 - (5) Safety devices
 - (6) Cleaning and electrical hazards
 - (7) Safe work practices
 - (8) Safety regulations
- d. Leak testing procedure
 - (1) Basic categories and techniques
 - (2) Leak location vs. leakage measurement
 - (3) Pressurization or evacuation

- (4) Sealed units with or without tracer gas
- (5) Units inaccessible from one or both sides
- (6) System at, above, or below atmospheric pressure
- e. Leak testing specifications
 - (1) Design vs. working conditions
 - (2) Pressure and temperature control
 - (3) Types of leak testing methods
 - (4) Sensitivity of leak testing methods
 - (5) Test method and sensitivity needed
 - (6) Preparation of a leak testing specification
- f. Detector/instrument performance factors
 - (1) Design and use
 - (2) Accuracy and precision
 - (3) Linearity (straight/logarithmic scale)
 - (4) Calibration and frequency
 - (5) Response and recovery time

2. Physical Principles in Leak Testing

- a. Physical quantities
 - (1) Fundamental units
 - (2) Volume and pressure
 - (3) Time and temperature
 - (4) Absolute values
 - (5) Standard vs. atmospheric conditions
 - (6) Leakage rates
- b. Structure of matter
 - (1) Atomic theory
 - (2) Ionization and ion pairs
 - (3) States of matter
 - (4) Molecular structure