



AMERICAN SOCIETY
for
NONDESTRUCTIVE TESTING
Recommended Practice
No. SNT-TC-1A
(August 1984 Edition)

THIS DOCUMENT IS INTENDED AS A GUIDELINE FOR EMPLOYERS
TO ESTABLISH THEIR OWN WRITTEN PRACTICE FOR THE QUALI-
FICATION AND CERTIFICATION OF THEIR NDT PERSONNEL. IT IS
NOT INTENDED TO BE USED AS A STRICT SPECIFICATION.

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FOREWORD

The recommended practice contained herein 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 questions and answer lists which may be used in composing examinations for nondestructive testing personnel.

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

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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 persons who are responsible for, and perform, non-destructive testing. This Recommended Practice has been prepared to establish guidelines for the qualification and certification of nondestructive testing 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 to aid employers in recognizing the essential factors to be considered in qualifying employees engaged in any of the test methods listed in Par. 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 Par. 5, the employer shall review the detailed recommendations presented herein, and shall modify them as necessary to meet particular needs.

2. DEFINITIONS

- 2.1** Terms included in this document are defined as follows:
- (1) Qualification — Demonstrated skill, training, knowledge and experience required for personnel to properly perform the duties of a specific job.
 - (2) Certification — Written testimony of qualification.
 - (3) Certifying Agency — The employer of the personnel being certified.
 - (4) Recommended Practice — A set of guidelines to assist the employer in developing uniform procedures for the qualification and certification of nondestructive testing personnel to satisfy the employer's specific requirements.
 - (5) Employer — The corporate, private, or public entity which employs personnel for wages, salary, fees, or other considerations.

- (6) Training — The program developed to impart the knowledge and skills necessary for qualification.
- (7) Outside Agency — A company or individual that provides NDT Level III services and whose qualifications to provide these services have been reviewed by the employer that engages the company or individual.

3. NONDESTRUCTIVE TEST METHODS

- 3.1** Qualification and certification of nondestructive testing personnel in accordance with this Recommended Practice is applicable to each of the following methods
- | | |
|----------------------------------|-------|
| (1) Radiographic Testing | (RT) |
| (2) Magnetic Particle Testing | (MT) |
| (3) Ultrasonic Testing | (UT) |
| (4) Liquid Penetrant Testing | (PT) |
| (5) Electromagnetic Testing | (ET) |
| (6) Neutron Radiographic Testing | (NRT) |
| (7) Leak Testing | (LT) |
| (8) Acoustic Emission | (AE) |

4. LEVELS OF QUALIFICATION

- 4.1** There are three basic levels of qualification. These levels may be further subdivided by the employer for specific situations where additional levels of skills and responsibilities are deemed necessary.
- 4.2** While in the process of being qualified and certified to NDT Level I, an individual should be considered a Trainee. A Trainee should work with a certified individual and shall not independently conduct any tests, interpret or evaluate the results of a test, or report test results.
- 4.3** The three basic levels of qualification are as follows:
- (1) NDT Level I — An NDT Level I individual should be qualified to properly perform specific calibrations, specific tests, and specific evaluations for acceptance or rejection determinations according to written instructions and to record results. The NDT Level I shall 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 the individual is 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 prepare written instructions, and to organize and report the results of nondestructive tests.
- (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 test methods, techniques, and procedures to be used. The NDT Level III should be responsible for the NDT operations for which qualified and to which 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 where none are otherwise available. The NDT Level III should have general familiarity with other appropriate NDT methods, and should be qualified to train and examine NDT Level I and Level II personnel for certification.

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 shall 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.

6. EDUCATION, TRAINING, AND EXPERIENCE REQUIREMENTS FOR INITIAL QUALIFICATION

- 6.1 Personnel considered for certification in nondestructive testing shall have sufficient education, training, and experience to ensure understanding of the principles and procedures of those areas of testing in which they are being considered for certification.
- 6.2 Documented training and/or experience gained in positions and activities equivalent 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 Par. 6.3.
- 6.3 To be considered for certification, a candidate should satisfy one of the following criteria for the applicable NDT level:
 - 6.3.1 **NDT Levels I and II**
Table 6.3.1 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.

6.3.2 NDT Level III

- (1) Have graduated from a minimum four-year college or university curriculum with a degree in engineering or science plus one years experience in nondestructive testing in an assignment comparable to that of an NDT Level II in the applicable test method(s),
or:
- (2) 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 assignments at least comparable to that of NDT Level II in the applicable test method(s),
or:
- (3) Have four years experience in an assignment at least comparable to that of an NDT Level II in the applicable testing method(s).

When the individual is qualified by examination, the above requirements may be partially replaced by experience as a certified NDT Level II or in assignments at least comparable to NDT Level II, in other methods listed in Par. 3 of this Recommended Practice as defined in the employer's written practice.

7. TRAINING PROGRAMS

- 7.1 Personnel being considered for certification should complete sufficient organized training to become thoroughly familiar with the principles and practices of the specified test method related to the level of certification desired and applicable to the practices 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.
- 7.2.1 Recommended training course outlines for Levels I and II personnel and recommended references which may be used as technical source material are appended as follows:

Test Method	Training Course Table Number	Reference Table Number
Radiographic Testing	I-A	II-A
Magnetic Particle Testing	I-B	II-B
Ultrasonic Testing	I-C	II-C
Liquid Penetrant Testing	I-D	II-D
Electromagnetic Testing	I-E	II-E
Neutron Radiographic Testing	I-F	II-F
Leak Testing	I-G	II-G
Acoustic Emission	I-H	II-H

8. EXAMINATIONS

- 8.1 An NDT Level III individual or his designated representative should administer and grade examinations. The examinations to verify physical and technical qualifications should consist of the following:
 - 8.1.1 **Physical**
 - (1) 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 letters 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 tests pattern is also acceptable.

- (2) The examination should demonstrate the capability of distinguishing and differentiating contrast between colors used in the method.
- (3) The examination should demonstrate additional physical capabilities as required by the employer.
- (4) The examination should be administered on an annual basis.
- (5) Examination results are to be kept on file for the period of certification (see Par. 9.7).

8.1.2 General (Written) (For NDT Levels I and II)

- (1) The general examinations should be addressed to the basic principles of the applicable method.
- (2) In preparing the examination, the employer should select or devise appropriate questions covering the applicable method to the degree required by the employer's written practice.
- (3) The questions and answers provided in the applicable separate Question Booklets (See 8.2) are suggested as guidelines for the development of the general examination.

8.1.3 Specific (Written) (For NDT Levels I and II)

- (1) The specific examination should address the equipment, operating procedures, and test techniques that the applicant 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 by the employer in his nondestructive testing procedures.

8.1.4 Practical (For NDT Level I and II)

- (1) The candidate should demonstrate familiarity with and the ability to operate the necessary test 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 test analyzed by the candidate.
- (3) The description of the specimen, the test procedure, including check points, and the results of the examination should be documented.

8.1.5 NDT Level III Examinations should be in accordance with Par. 8.3.3.

8.2 Suggested examination questions and answers for use in compiling appropriate general examinations are presented in the separate Question Booklets which can be obtained from ASNT Headquarters. The following is a list of the booklets.

Test Method	Question Booklets
Radiographic Testing	A
Magnetic Particle Testing	B
Ultrasonic Testing	C
Liquid Penetrant Testing	D
Electromagnetic Testing	E
Neutron Radiographic Testing	F
Leak Testing	G
Acoustic Emission	H

8.3 The following paragraphs describe the recommended examinations for each NDT level for the various nondestructive testing methods. The written examinations should be administered without access to reference material (closed book) except that necessary data, such as graphs, tables, specifications, procedures, and codes, may be provided. All questions used for Level I and Level II examinations shall be approved by the responsible Level III.

8.3.1 NDT Level I

- (1) General Examination — The recommended minimum number of Level I questions which should be given are:

Test Method	Number of Questions
Radiographic Testing	40
Magnetic Particle Testing	30
Ultrasonic Testing	40
Liquid Penetrant Testing	30
Electromagnetic Testing	40
Neutron Radiographic Testing	40
Leak Testing	20
Acoustic Emission	40

- (2) Specific Examination — The recommended minimum number of questions which should be given are:

Test Method	Number of Questions
Radiographic Testing	20
Magnetic Particle Testing	20
Ultrasonic Testing	20
Liquid Penetrant Testing	20
Electromagnetic Testing	20
Neutron Radiographic Testing	15
Leak Testing	
1. Bubble Test	15
2. Absolute Pressure Leak Test (Pressure Change)	15
3. Halogen Diode Leak Test	15
4. Mass Spectrometer Leak Test	20

- (3) Practical Examination — Proficiency shall be demonstrated in performing the applicable nondestructive tests on one or more samples approved by the NDT Level III. At least ten different checkpoints requiring an understanding of test variables and the employer's procedural requirements shall be included in the practical examination.

8.3.2 NDT Level II

- (1) General Examination — The recommended minimum number of Level II questions to be given are:

Test Method	Number of Questions
Radiographic Testing	40
Magnetic Particle Testing	30
Ultrasonic Testing	40
Liquid Penetrant Testing	30
Electromagnetic Testing	40
Neutron Radiographic Testing	40
Leak Testing	20
Acoustic Emission	40

- (2) Specific Examination — The recommended minimum number of questions to be given are:

Test Method	Number of Questions
Radiographic Testing	20
Magnetic Particle Testing	15
Ultrasonic Testing	20
Liquid Penetrant Testing	15
Electromagnetic Testing	20
Neutron Radiographic Testing	15
Leak Testing	
1. Bubble Test	15
2. Absolute Pressure Leak Test (Pressure Change)	15
3. Halogen Diode Leak Test	15
4. Mass Spectrometer Leak Test	40
Acoustic Emission	20

- (3) Practical Examination — Proficiency should be demonstrated in selecting and performing the applicable nondestructive tests and interpreting and evaluating the results on one or more samples approved by the NDT Level III. At least ten different check-points requiring an understanding of test variables and the employer's procedural requirements should be included in this practical examination.

8.3.3 NDT Level III

- (1) Basic Examination (Required only once when more than one method of examination is taken).
- Twenty (20) questions relating to understanding the SNT-TC-1A document.
 - Fifteen (15) questions relative to applicable materials, fabrication, and product technology
 - Fifteen (15) questions which are selected from or are similar to published Level II questions for other appropriate NDT methods
- (2) Method Examination (for each method).
- Thirty (30) questions relating to fundamentals and principles, which are selected from or are similar to published ASNT Level III questions for each method, and
 - Fifteen (15) questions relating to application and establishment of techniques and procedures which are selected from or are similar to the published ASNT Level III questions for each method, and
 - Twenty (20) questions relating to capability for interpreting codes, standards, and specifications relating to the method.
- (3) Specific Examination (for each method).
- 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.

8.3.4 On the basis of demonstrated ability, achievement, experience, and education, as defined in Par. 4.3(3) and 6.3, the employer may waive examination for the Level III individual. Written certification should be provided, and evidence supporting the certification should be held on file and be made available when verification is required.

8.3.5(a) A valid endorsement on an ASNT NDT Level III certificate fulfills the examination criteria described in Paragraph 8.3.3(1) and 8.3.3(2) for each applicable NDT method.

8.3.5(b) The employer may delete the Specific examination described in Paragraph 8.3.3(3)(a) 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.

8.4 Grading

8.4.1 An NDT Level III shall be responsible for the administration and grading of examinations for NDT Level I and II personnel. The administration and grading of examinations may be delegated to a designated representative of the NDT Level III and so recorded. The employer shall be responsible for administration and grading of examinations for Level III personnel. The actual administration and grading of Level III examinations may be performed by a designated representative of the employer.

8.4.2 A composite grade based upon the general, specific, and practical or upon the basic, method, and specific examinations should be developed by the employer. The composite grade may be a simple average of the examinations or may be developed by applying a weighting factor to each examination. The method of arriving at the composite grade prescribed in the employer's written practice should not be changed indiscriminately to fit the capabilities of the candidate.

8.4.3 When weighting factors are used, the total of the weighting factors shall equal 1.0. The weighting factors should be within the following ranges:

- NDT Level I Weighting Factors
 - General — 0.2 to 0.6
 - Specific — 0.2 to 0.5
 - Practical — 0.3 to 0.7
- NDT Level II Weighting Factors
 - General — 0.3 to 0.7
 - Specific — 0.2 to 0.6
 - Practical — 0.2 to 0.5
- NDT Level III Weighting Factors
 - Basic — 0.2 to 0.5
 - Method — 0.3 to 0.6
 - Specific — 0.2 to 0.4
- The composite grade (Gc) is determined as follows:

$$\text{Levels I and II; } Gc = (Gg \times Wg) + (Gs \times Ws) + (Gp \times Wp)$$

$$\text{Level III; } Gc = (Gb \times Wb) + (Gm \times Wm) + (Gs \times Ws)$$

Where Gc = Composite grade

Gg = Actual grade from general examination in percent

Wg = Weighting factor of general examination

Gs = Actual grade from specific examination in percent

Ws = Weighting factor of specific examination

Gp = Actual grade from practical examination in percent

Wp = Weighting factor of practical examination

Gb = Actual grade from basic examination in percent

Wb = Weighting factor of basic examination

Gm = Actual grade from method examination in percent

Wm = Weighting factor of method examination

8.4.4 When an examination is administered for qualification, a composite passing grade of 80% or greater is recommended. In addition, each passing grade for the general, specific, and practical or the basic, method, and specific examination is recommended to be 70% or greater. Test objects should be used in the practical examination when appropriate.

8.4.5 When 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% for that particular examination.

8.5 Reexamination

(1) Those failing to attain the required grades must wait at least 30 days or show evidence of having received suitable additional training as determined by the employer before reexamination.

9. CERTIFICATION

9.1 Certification of all levels of NDT personnel is the responsibility of the employer.

9.2 The employer shall establish written practices covering all phases of certification including training as specified in Par. 5.

9.3 Certification of NDT personnel shall be based on demonstration of satisfactory qualification as determined by procedures outlined in Par. 6, 7, and 8 as modified by the employer's written practices.

9.4 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 must be retained by the employer.

9.5 The employer who purchases outside services is responsible for assuring that training and examination services are in accordance with the employer's written practices.

9.6 Personnel certifications and copies of the employer's written practices shall be maintained on file by the employer.

9.6.1 The qualification records of the certified individuals shall be maintained by the employer and should include the following:

- (1) Name of certified individual.
- (2) Level of certification and test method.
- (3) Educational background and experience of certified individuals.

(4) Statement indicating satisfactory completion of training in accordance with the employer's written procedure.

(5) Results of the physical examination prescribed in Par. 8.1.1.

(6) Current examination copy(s) or evidence of successful completion of the examinations

(7) Other suitable evidence of satisfactory qualifications when such qualifications are used in lieu of examinations.

(8) Composite grade(s) or suitable evidence of grades.

(9) Dates of certification and/or recertification and the dates of assignment to NDT.

(10) Signature of employer's designated representative.

9.7 Recertification

9.7.1 All levels of NDT personnel should be recertified periodically in accordance with one of the following criteria:

- (1) Evidence of continuing satisfactory performance.
- (2) Reexamination in those portions of the examinations in Par. 8.3 deemed necessary by the employer's NDT Level III.

9.7.2 Recommended maximum recertification intervals are:

- (1) Levels I and II - 3 years
- (2) Level III - 5 years

9.7.3 NDT personnel may be reexamined any time at the discretion of the employer and have their certifications extended or revoked.

9.7.4 The employer's written practice should include rules covering the duration of interrupted service which will require 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 recertified to his former NDT level by a new employer based on examination as described in Par. 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 he certified within six months of termination.
- (3) The employee is being recertified within six months of his termination.

Table 6.3.1
RECOMMENDED INITIAL TRAINING AND EXPERIENCE LEVELS
TRAINING (HOURS)

Examination Method	RT		MT		UT		PT		ET		NRT		AE		LT							
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I				II			
Technique															BT	PCMT	HDLT	MSLT	BT	PCMT	HDLT	MSLT
Completion with a passing grade of at least 2 years of engineering or science study in a university, college, or technical school	29	35	8	4	24	40	4	4	8	8	20	40	40	35	2	16	8	28	2	12	6	16
High School graduation or equivalent	39	40	12	8	40	40	4	8	12	8	28	40	60	65	2	24	12	40	4	16	8	24
Grammar school graduation, or demonstration proficiency, or additional training	88	80	24	16	40	80	12	16	48	24	56	80	80	85	2	60	24	60	4	80	20	80
All educational levels as listed above	3	9	1	3	3	9	1	2	1	9	6	24	6	18	*	1½	1½	4	½	4	4	6

BT = Bubble Test

PCMT = Pressure Change/Measurement Test

HDLT = Halogen Diode Leak Test

MSLT = Mass Spectrometer Leak Test

* = 2 Hours

NOTES:

- (1) For Level II certification, the experience should 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 should consist of the sum of the times required for Level I and Level II and the required training should consist of the sum of the hours required for Level I and Level II.
- (2) Listed training guidelines may be prorated as described in the employer's written practice depending on the candidate's actual educational level.
- (3) Initial experience may be gained simultaneously in two or more methods if:
 - (a) The candidate spends a minimum of 25% of his work time on each method for which certification is sought, and
 - (b) The remainder of his work time claimed as experience is spent in NDT-related activities as defined in the employer's written practice.
- (4) Training should be outlined in the employer's written practice.

Recommended Training Course

Radiography Testing Method

	Recommended Hours of Instruction		
	1*	2*	3*
Level I			
Radiographic Equipment Operating & Emergency Instructions Course	8	4	4
Basic Radiographic Physics Course	40	20	15
Radiographic Technique Course	40	15	10
Total	88	39	29
Level II			
Film Quality and Manufacturing Processes Course	40	20	15
Radiographic Evaluation and Interpretation Course	40	20	20
Total	80	40	35

*Note: 1. Grammar School Graduate
 2. High School Graduate or Equivalent
 3. Completion with passing grades of at least two years of Engineering or Science Study at a University, College, or Technical School.

Recommended Training for Level I Radiographer

Radiographic Equipment Operating and Emergency Instructions Course

Note: It is recommended that the trainee receive instruction in this course prior to performing work in radiography.

1. Personnel Monitoring

- 1.1 Wearing of Personnel Monitoring Badges
- 1.2 Reading of Pocket Dosimeters
- 1.3 Recording of Daily Dosimeter Readings
- 1.4 "Offscale" Dosimeter - Action Required
- 1.5 Permissible Personnel Exposure Limits

2. Survey Instruments

- 2.1 Types of Radiation Survey Instruments
- 2.2 Reading and Interpreting Survey Instrument Meter Indications

RADIOGRAPHY TESTING

- 2.3 Calibration Frequency
- 2.4 Calibration Expiration - Action
- 2.5 Battery Check - Importance

3. Leak Test of Sealed Radioactive Sources

- 3.1 Requirements for Leak Test
- 3.2 Purpose of Leak Test
- 3.3 Performance of the Leak Test

4. Radiological Survey Reports

- 4.1 Requirements for Completing
- 4.2 Description of Report Format

5. Radiography Work Practices

- 5.1 Establishment of Restricted Areas
- 5.2 Posting and Surveillance of Area
- 5.3 Use of Time, Distance and Shielding to Reduce Personnel Radiation Exposure
- 5.4 Applicable Regulatory Requirements for Surveys, Posting and Control of Radiation and High Radiation Areas

6. Exposure Devices

- 6.1 Daily Inspection and Maintenance for Exposure Devices
- *6.2 Radiation Exposure Limits for Gamma Ray Exposure Devices
- 6.3 Labeling of Exposure Devices
- 6.4 Use of Exposure Devices
- 6.5 Use of Collimators to Reduce Personnel Exposure
- *6.6 Use of "Source Changers" from Gamma Ray Sources

7. Storage and Shipment of Exposure Devices and Sources

- *7.1 Vehicle Accidents with Radioactive Sealed Sources
- *7.2 Fire Involving Sealed Sources
- *7.3 "Source Out" — Failure to Return to Safe Shielded Conditions
- *7.4 Emergency Call List

8. State and Federal Regulations

- 8.1 The NRC and Agreement States — Authority
- 8.2 License Reciprocity
- *8.3 Radioactive Materials License Requirements for Industrial Radiography
- 8.4 Qualification Requirements for Radiography Personnel
- 8.5 Regulations for the Control of Radiation (State or NRC as Applicable)
- *8.6 Department of Transportation Regulations for Radiography Source Shipment
- 8.7 Regulatory Requirements for X-ray Machines (State & Federal as Applicable)

Total Recommended Hours of Instruction this Course: $\frac{1}{8 \text{ hr.}}$ $\frac{2}{4 \text{ hr.}}$ $\frac{3}{4 \text{ hr.}}$

*NOTE: Topics so indicated * may be deleted if the Radiography is limited to X-ray exposure devices.

RECOMMENDED TRAINING FOR LEVEL I RADIOGRAPHER

Basic Radiography Physics Course

1. Introduction

- 1.1 History and Discovery of Radioactive Materials
- 1.2 Definition of Industrial Radiography
- 1.3 Radiation Protection, Why?
- 1.4 Basic Math Review, Exponents, Square Root, Etc.

2. Fundamental Properties of Matter

- 2.1 Elements and Atoms

RADIOGRAPHY TESTING

- 2.2 Molecules and Compounds
- 2.3 Atomic Particles, Properties of Protons, Electrons, and Neutrons
- 2.4 Atomic Structure
- 2.5 Atomic Number and Weight
- 2.6 Isotope Versus Radioisotope

3. Radioactive Materials

- 3.1 Production of Radioactive Materials
 - (a) Neutron Activation
 - (b) Nuclear Fission
- 3.2 Stable Versus Unstable (radioactive) Atoms
- 3.3 Curie — the Unit of Activity
- 3.4 Half-life of Radioactive Materials
- 3.5 Plotting of Radioactive Decay
- 3.6 Specific Activity — Curies/Gram

4. Types of Radiation

- 4.1 Particulate Radiation-Properties: Alpha, Beta, Neutron
- 4.2 Electromagnetic Radiation — X-ray, Gamma Ray
- 4.3 X-ray Production
- 4.4 Gamma Ray Production
- 4.5 Gamma Ray Energy
- 4.6 Energy Characteristics of Common Radioisotope Sources
- 4.7 Energy Characteristics of X-ray Machines

5. Interaction of Radiation with Matter

- 5.1 Ionization
- 5.2 Radiation Interaction with Matter
 - (a) Photoelectric Effect
 - (b) Compton Scattering
 - (c) Pair Production
- 5.3 The Unit of Radiation Exposure — the Roentgen
- 5.4 Emissivity of Commonly used Radiography Sources
- 5.5 Emissivity of X-ray Exposure Devices
- 5.6 Attenuation of Electromagnetic Radiation — Shielding
- 5.7 Half Value Layers/Tenth Value Layers
- 5.8 Inverse Square Law

6. Biological Effects of Radiation

- 6.1 “Natural” Background Radiation
- 6.2 The Unit of Radiation Dose — Rem
- 6.3 The Difference Between Radiation and Contamination
- 6.4 Allowable Personnel Exposure Limits and the Banking Concept
- 6.5 Theory of Allowable Dose
- 6.6 Radiation Damage — Repair Concept
- 6.7 Symptoms of Radiation Injury
- 6.8 Acute Radiation Exposure and Somatic Injury
- 6.9 Personnel Monitoring for Tracking Exposure
- 6.10 Organ Radiosensitivity

7. Radiation Detection

- 7.1 The Pocket Dosimeter
- 7.2 The Difference Between Dose and Dose Rate
- 7.3 Survey Instruments:
 - Geiger Muller Tube
 - Ionization Chambers
 - Scintillation Chambers Counters
- 7.4 Film Badge — Radiation Detector
- 7.5 TLD (Thermoluminescent Dosimeters)
- 7.6 Calibration of Survey Instruments

RADIOGRAPHY TESTING

8. Exposure Devices and Radiation Sources

- 8.1 Radioisotope Sources
 - (a) Sealed Source Design and Fabrication
 - (b) Gamma Ray Sources
 - (c) Beta and Bremsstrahlung Sources
 - (d) Neutron Sources
- 8.2 Radioisotope Exposure Device Characteristics
- 8.3 Electronic Radiation Sources — 500 kev & Less — Low Energy
 - (a) Generator — High Voltage Rectifiers
 - (b) X-ray Tube Design and Fabrication
 - (c) X-ray Control Circuits
 - (d) Accelerating Potential
 - (e) Target Material and Configuration
 - (f) Heat Dissipation
 - (g) Duty Cycle
 - (h) Beam Filtration
- *8.4 Electronic Radiation Sources — Medium & High Energy
 - *(a) Resonance Transformer
 - *(b) Van de Graaff Accelerator
 - *(c) Linac
 - *(d) Betatron
 - *(e) Roentgen Output
 - *(f) Equipment Design & Fabrication
 - *(g) Beam Filtration
- *8.5 Fluoroscopic Radiation sources
 - *(a) Fluoroscopic Equipment Design
 - *(b) Direct Viewing Screens
 - *(c) Image Amplification
 - *(d) Special X-ray Tube Considerations & Duty Cycle
 - *(e) Screen Unsharpness
 - *(f) Screen Conversion Efficiency

9. Special Radiographic Sources and Techniques

- *9.1 Flash Radiography
- *9.2 Stereo Radiography
- *9.3 In Motion Radiography
- *9.4 Auto Radiography

Total Recommended Hours of Instruction this Course: $\frac{1}{40 \text{ hr.}}$ $\frac{2}{20 \text{ hr.}}$ $\frac{3}{15 \text{ hr.}}$

*NOTE: Topics so indicated * may be deleted if these methods and techniques are not used by the employer.

RECOMMENDED TRAINING FOR LEVEL I RADIOGRAPHER

Radiography Technique Course

1. Introduction

- 1.1 The Process of Radiography
- 1.2 Types of Electromagnetic Radiation Sources
- 1.3 The Electromagnetic Spectrum
- 1.4 Penetrating Ability or “Quality” of X-rays and Gamma Rays
- 1.5 Spectrum of X-ray Tube source
- 1.6 Spectrum of Gamma Radioisotope Source
- 1.7 X-ray Tube — Change of ma or kvp Effect on “Quality” and Intensity

RADIOGRAPHY TESTING

2. Basic Principles of Radiography

- 2.1 Geometric Exposure Principles
 - (a) “Shadow” Formation and Distortion
 - (b) Shadow Enlargement Calculation
 - (c) Shadow Sharpness
 - (d) Geometric Unsharpness
 - (e) Finding Depth of Discontinuity
- 2.2 Radiographic Screens
 - (a) Lead Intensifying Screens
 - (b) Fluorescent Intensifying Screens
 - (c) Intensifying Factors
 - (d) Importance of Screen/Film Contact
 - (e) Importance of Screen Cleanliness and Care
 - (f) Techniques for Cleaning Screens
- 2.3 Radiographic Cassettes
- 2.4 Composition of Industrial Radiographic Film
- 2.5 The “Heel Effect” with X-ray Tubes

3. The Radiograph

- 3.1 Formation of the Latent Image on Film
- 3.2 Inherent Unsharpness
- 3.3 Arithmetic of Radiograph Exposure
 - (a) Milliamperage — Distance — Time Relationship
 - (b) The Reciprocity Law
 - (c) Photographic Density
 - (d) X-ray Exposure Charts (Material Thickness, kv, and Exposure)
 - (e) Gamma Ray Exposure Chart
 - (f) Inverse Square Law Considerations
 - (g) Calculation of Exposure Time for Gamma and X-ray Sources
- 3.4 The Characteristic (H and D) Curve
- 3.5 Film Speed and Class Descriptions
- 3.6 Selection of Film for Particular Purpose

4. Radiographic Image Quality

- 4.1 Radiographic Sensitivity
- 4.2 Radiographic Contrast
- 4.3 Film Contrast
- 4.4 Subject Contrast
- 4.5 Definition
- 4.6 Film Graininess and Screen Mottle Effects
- 4.7 Penetrameters or Image Quality Indicators

5. Film Handling, Loading, and Processing

- 5.1 Safelight and Darkroom Practices
- 5.2 Loading Bench and Cleanliness
- 5.3 Opening of Film Boxes and Packets
- 5.4 Loading of Film and Sealing Cassettes
- 5.5 Handling Techniques for “Green Film”
- 5.6 Elements of Manual Film Processing

6. Exposure Techniques — Radiography

- 6.1 Single Wall Radiography
- 6.2 Double Wall Radiography
 - (a) Viewing Two Walls Simultaneously
 - (b) Offset Double Wall Exposure Single Wall Viewing
 - (c) Elliptical Techniques
- 6.3 Panoramic Radiography
- 6.4 Use of Multiple Film Loading
- 6.5 Specimen Configuration

RADIOGRAPHY TESTING

7. Fluoroscopic Techniques

- 7.1 Dark Adaptation and Eye Sensitivity
- 7.2 Special Scattered Radiation Techniques
- 7.3 Personnel Protection
- 7.4 Sensitivity
- 7.5 Limitations
- 7.6 Direct Screen Viewing
- 7.7 Indirect and Remote Screen Viewing

Total Recommended Hours of Instruction this Course: $\frac{1}{40 \text{ hr.}}$ $\frac{2}{15 \text{ hr.}}$ $\frac{3}{10 \text{ hr.}}$

RECOMMENDED TRAINING FOR LEVEL II RADIOGRAPHER

Film Quality and Manufacturing Processes Course

1. Review of Basic Radiographic Principals

- 1.1 Interaction of Radiation with Matter
- 1.2 Math Review
- 1.3 Exposure Calculations
- 1.4 Geometric Exposure Principals
- 1.5 Radiographic Image Quality Parameters

2. Dark Room Facilities, Techniques, and Processing

- 2.1 Facilities and Equipment
 - (a) Automatic Film Processor versus Manual Processing
 - (b) Safe Lights
 - (c) View Lights
 - (d) Loading Bench
 - (e) Miscellaneous Equipment
- 2.2 Film Loading
 - (a) General Rules for Handling Unprocessed Film
 - (b) Types of Film Packaging
 - (c) Cassette Loading Techniques for Sheet and Roll
- 2.3 Protection of Radiographic Film in Storage
- 2.4 Processing of Film — Manual
 - (a) Developer and Replenishment
 - (b) Stop Bath
 - (c) Fixer and Replenishment
 - (d) Washing
 - (e) Prevention of Water Spots
 - (f) Drying
- 2.5 Automatic Film Processing
- 2.6 Film Filing and Storage
 - (a) Retention Life Measurements
 - (b) Long Term Storage
 - (c) Filing and Separation Techniques
- 2.7 Unsatisfactory Radiographs, Causes and Cures
 - (a) High Film Density
 - (b) Insufficient Film Density
 - (c) High Contrast
 - (d) Low Contrast
 - (e) Poor Definition
 - (f) Fog
 - (g) Light Leaks
 - (h) Artifacts
- 2.8 Film Density
 - (a) Step Wedge Comparison Film
 - (b) Densitometers

RADIOGRAPHY TESTING

3. Indications, Discontinuities and Defects

- 3.1 Indications
- 3.2 Discontinuities
 - (a) Inherent
 - (b) Processing
 - (c) Service
- 3.3 Defects

4. Manufacturing Processes and Associated Discontinuities

- 4.1 Casting Processes and Associated Discontinuities
 - (a) Ingots, Blooms and Billets
 - (b) Sand Casting
 - (c) Centrifugal Casting
 - (d) Investment Casting
- 4.2 Wrought Processes and Associated Discontinuities
 - (a) Forgings
 - (b) Rolled Products
 - (c) Extruded Products
- 4.3 Welding Processes and Associated Discontinuities
 - (a) Submerged Arc Welding — SAW
 - (b) Shielded Metal Arc Welding — SMAW
 - (c) Gas Metal Arc Welding — GMAW
 - (d) Flux Cored Arc Welding — FCAW
 - (e) Gas Tungsten Arc Welding — GTAW
 - (f) Resistance Welding
 - (g) Special Welding Processes, Electron Beam, Electroslag, Electrogas, etc.

5. Radiological Safety Principals Review

- 5.1 Controlling Personnel Exposure
- 5.2 Time, Distance, Shielding Concepts
- 5.3 ALARA Concepts
- 5.4 Radiation Detection Equipment
- 5.5 Exposure Device Operating Characteristics

Total Recommended Hours of Instruction this Course: $\frac{1}{40 \text{ hr.}}$ $\frac{2}{20 \text{ hr.}}$ $\frac{3}{15 \text{ hr.}}$

RADIOGRAPHY TESTING

RECOMMENDED TRAINING FOR LEVEL II RADIOGRAPHER

Radiographic Evaluation and Interpretation Course

1. Radiographic Viewing

- 1.1 Film Illuminator Requirements
- 1.2 Background Lighting
- 1.3 Multiple-Composite Viewing
- 1.4 Penetrameter Placement
- 1.5 Personnel Dark Adaptation and Visual Acuity
- 1.6 Film Identification
- 1.7 Location Markers
- 1.8 Film Density Measurement
- 1.9 Film Artifacts

2. Application Techniques

- 2.1 Multiple Film Techniques
 - (a) Thickness Variation Parameters
 - (b) Film Speed
 - (c) Film Latitude
- 2.2 Enlargement & Projection
- 2.3 Geometrical Relationships
 - (a) Geometrical Unsharpness
 - (b) Penetrameter Sensitivity
 - (c) Source Film — Distance
 - (d) Focal Spot Size
- 2.4 Triangulation Method for Discontinuity Location
- 2.5 Magnification Localized
- 2.6 Film Handling Techniques

3. Evaluation of Castings

- 3.1 Casting Method Review
- 3.2 Casting Discontinuities
- 3.3 Origin and Typical Orientation of Discontinuities
- 3.4 Radiographic Appearance
- 3.5 Casting Codes/Standards — Applicable Acceptance Criteria
- 3.6 Reference Radiographs

4. Evaluation of Weldments

- 4.1 Welding Method Review
- 4.2 Welding Discontinuities
- 4.3 Origin and Typical Orientation of Discontinuities
- 4.4 Radiographic Appearance
- 4.5 Welding Codes and Standards — Applicable Acceptance Criteria
- 4.6 Reference Radiographs or Pictograms

5. Standards, Codes and Procedures for Radiography

- 5.1 ASTM E94/E142
- 5.2 Acceptable Radiographic Techniques and Setups
- 5.3 Applicable Employer Procedures
- 5.4 Procedure/Radiograph Parameter Verification
- 5.5 Radiographic Reports

Total Recommended Hours of Instruction this Course: $\frac{1}{40 \text{ hr.}}$ $\frac{2}{20 \text{ hr.}}$ $\frac{3}{20 \text{ hr.}}$

Radiographic Testing

- American Society for Testing and Materials Standards and Tentative Standards Relating to Radiographic Testing.* Refer to ASTM Index of latest issue. ASTM: Philadelphia, Pennsylvania.
- Clark, G. L. *Applied X-Rays*, McGraw-Hill Book Company, Inc. New York, 1955.
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- Crowther, J. A. *Handbook of Industrial Radiography*. Edward Arnold and Company: London, England, 1949.
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- Halmshaw, R. ed. *Physics of Industrial Radiology*. Haywood Books (London, American Elsevier Publishing Company, Incorporated): New York, 1966.
- Houldecroft, P. T., J. G. Young, and A. A. Smith. *Classified Radiographs for Defects in Aluminum Fusing Welds*. British Welding Research Assoc.: Abington Hall, Abington, Cambridge, England, 1963.
- Living with Radiation*. No. 1, U.S. Atomic Energy Commission.
- McGonnagle, W. J. *Nondestructive Testing*. 2nd ed. Gordon & Breach, Science Publishers, Inc.: New York, 1969.
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- Radiographic Testing, Classroom Training Handbook (CT-6-6)*: General Dynamics/Convair Division, San Diego, California.*
- Radiographic Testing, Programmed Instruction Handbooks (PI-4-6)*: General Dynamics/Convair Division, San Diego, California.*
- Radiographs of Welds*. International Institute of Welding, 1968.*
- Radiography in Modern Industry*. Eastman Kodak Company: Rochester, New York.*
- St. John, A. and H. R. Isenburger, *Industrial Radiology*. John Wiley and Sons, Inc.: New York, 1943.
- Schneeman, J. G. *Industrial X-Ray Interpretation*. Intex Publishing Company: Evanston, IL 1968.*
- Sproull, W. T. *X-Rays in Practice*. McGraw-Hill Company, Inc.: New York, 1946.
- Wiltshire, W. J., ed. *A Further Handbook of Industrial Radiography*. Edward Arnold and Company: London, England, 1957.

* Available from The American Society for Nondestructive Testing

Recommended Training Course

Magnetic Particle Testing Method

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
B.1 Principles of Magnets and Magnetic Fields	.75	1	2	0	0	
1.1 Theory of magnetic fields						
1. Earth's magnetic field						
2. Magnetic fields around magnetized materials						
1.2 Theory of magnetism						
1. Magnetic poles						
2. Law of magnetism						
3. Materials influenced by magnetic fields:						
a. Ferromagnetic						
b. Paramagnetic						
4. Magnetic characteristics of nonferrous materials						
1.3 Terminology associated with magnetic particle testing						
B.2 Characteristics of Magnetic Fields	.5	1	2	0	0	
2.1 Bar magnet						
2.2 Ring magnet						
B.3 Effect of Discontinuities on Materials	.75	1	2	.5	1	2
3.1 Surface cracks						
3.2 Scratches						
3.3 Subsurface defects						
B.4 Magnetization by Means of Electric Current	1.5	2	4	.5	1	2
4.1 Circular field						
1. Field around a straight conductor						
2. Right-hand rule						
3. Field in parts through which current flows:						
a. Long solid cylindrical regular parts						
b. Irregularly shaped parts						
c. Tubular parts						
d. Parts containing critical holes						
4. Methods of inducing current flow in parts:						
a. Contact plates						
b. Prods						
5. Discontinuities commonly discovered by circular fields						
4.2 Longitudinal field						
1. Field produced by current flow in a coil						
2. Field direction in a current-carrying coil						
3. Field strength in a current-carrying coil						
4. Discontinuities commonly discovered by longitudinal fields						

MAGNETIC PARTICLE TESTING

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
5. Advantages of longitudinal magnetization when inspecting						
6. Disadvantages of longitudinal magnetization when inspecting						
B.5 Selecting the Proper Method of Magnetization	.75	1	2	.75	1 2/3	3
5.1 Alloy, shape and condition of part						
5.2 Type of magnetizing current						
5.3 Direction of magnetic field						
5.4 Sequence of operations						
5.5 Value of flux density						
B.6 Inspection Materials		1		.25	2/3	1
6.1 Wet particles						
6.2 Dry particles						
B.7 Principles of Demagnetization		1		.5	1	2
7.1 Residual magnetism						
7.2 Reasons for requiring demagnetization						
7.3 Longitudinal and circular residual field						
7.4 Basic principles of demagnetization						
7.5 Retentivity and coercive force						
7.6 Methods of demagnetization						
B.8 Magnetic Particle Test Equipment	1.5	1	4	.25	2/3	1
8.1 Equipment selection considerations						
1. Type of magnetizing current						
2. Location and nature of test						
3. Test materials used						
4. Purpose of test						
5. Area inspected						
8.2 Manual inspection equipment						
8.3 Medium and heavy duty equipment						
8.4 Stationary Equipment						
8.5 Mechanized inspection equipment						
1. Semi-automatic inspection equipment						
2. Single-purpose semi-automatic equipment						
3. Multi-purpose semi-automatic equipment						
4. Fully automatic equipment						
B.9 Types of Discontinuities Located by Magnetic Particle Testing	.75	1	2	.25	1/2	1
9.1 Inclusions						
9.2 Blowholes						
9.3 Porosity						
9.4 Flakes						
9.5 Cracks						
9.6 Pipes						
9.7 Laminations						
9.8 Laps						
9.9 Forging Bursts						
9.10 Voids						
B.10 Magnetic Particle Test Indications and Interpretation	1.5	2	6	1	2	4
10.1 Indications of nonmetallic inclusions						
10.2 Indications of surface seams						

MAGNETIC PARTICLE TESTING

	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
10.3 Indications of cracks						
10.4 Indications of laminations						
10.5 Indications of laps						
10.6 Indications of bursts and flakes						
10.7 Indications of porosity						
10.8 Nonrelevant indications						
Total Minimum Hours	8	12	24	4	8	16

- * Completion with a passing grade of at least 2 years of engineering or science study at a university, college, or technical school.
- ** High school graduation, diploma or its equivalent.
- *** Grammar school graduation, or demonstrated proficiency, or additional training

Recommended Training References

Table II-B

Magnetic Particle Testing

<p><i>American Society for Testing and Materials Standards and Tentative Standards Relating to Magnetic Particle Testing.</i> Refer to ASTM Index of latest issue: ASTM, Philadelphia, Pennsylvania.</p> <p>Betz, Carl E. <i>Principles of Magnetic Particle Testing.</i> Magnaflux Corporation: Chicago, Illinois. 1966.</p> <p>Doane, F. G. and C. E. Betz, <i>Principles of Magnaflux</i>, 3rd ed. Magnaflux Corporation: Chicago, Illinois. 1948.</p> <p>“Inspection of Welding.” <i>Welding Handbook</i>, Section 1 (latest ed.). American Welding Society: Miami, Florida.</p>	<p><i>Magnetic Particle Testing, Classroom Training Handbook (CT-6-3):</i> General Dynamics/Convair Division, San Diego California.*</p> <p><i>Magnetic Particle Testing, Programmed Instruction Handbook (PI-4-3):</i> General Dynamics/Convair Division: San Diego, California.*</p> <p>McGonnagle, W J. <i>Nondestructive Testing</i>. 2nd ed. Gordon & Breach, Science Publishers, Inc.: New York, 1969.</p> <p>McMaster, R C., ed. <i>Nondestructive Testing Handbook</i>. Vols. I-II. The Ronald Press Company: New York, 1959.*</p>
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* Available from The American Society for Nondestructive Testing

Recommended Training Course

Ultrasonic Testing Method

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
C.1 Fundamental Properties of Sound	.6	1	1	4	4	8
1.1 Frequency, velocity, and wavelength						
1.2 Definition of ultrasonic vibrations						
1.3 General application of ultrasonic vibrations						
C.2 Principles of Wave Propagation	3.0	5	5	4	4	8
2.1 Modes of vibration						
2.2 Acoustic impedance						
2.3 Reflection						
2.4 Refraction and mode conversion						
2.5 Diffraction, dispersion, and attenuation						
2.6 Fresnel and Fraunhofer effects						
C.3 Generation of Ultrasonic Waves	3.0	5	5	4	4	8
3.1 Piezoelectricity and types of crystals						
3.2 Construction of ultrasonic search units						
3.3 Characteristics of search units						
1. Frequency — crystal thickness relationships						
2. Conversion efficiencies of various crystals						
3. Damping and resolution						
4. Beam intensity characteristics						
5. Divergence						
3.4 Care of search units						
C.4 Ultrasonic Testing Methods	3.6	6	6	4	4	8
4.1 Contact testing						
1. Straight beam						
2. Angle beam						
3. Surface wave						
4. Lamb wave						
5. Through transmission						
4.2 Immersion testing						
1. Straight beam						
2. Angle beam						
3. Through transmission						
4.3 Modified immersion testing						
1. Tests employing special devices						
4.4 Resonance testing						
1. Contact technique						
2. Immersion technique						
C.5 Ultrasonic Testing Equipment	1.8	3	3			
5.1 Description of basic pulse-echo instrument						
1. Time-base (synchronizer) circuit						

ULTRASONIC TESTING

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
2. Pulsar circuit						
3. Receiver or echo-amplifier circuit						
4. A-Scan display circuit						
5.2 Special instruments						
1. B-Scan display						
2. C-Scan display						
3. Monitors and recording devices						
5.3 Scanning equipment						
1. Manipulators						
2. Bridges						
3. Special scanning devices						
C.6 Operation of Specific Equipment	4.8	8	8	4	4	8
6.1 General operating characteristics						
6.2 Functional block diagram of circuits						
6.3 Purpose and adjustment of external controls						
6.4 Care of equipment						
C.7 Specific Testing Procedures	4.8	8	8	12	12	24
7.1 Selection of test parameters						
1. Frequency						
2. Search unit size and type						
3. Water distance (for immersed tests)						
4. Scanning speed and index						
7.2 Test standardization						
1. Ultrasonic standard reference blocks						
2. Adjustment of test sensitivity						
7.3 Interpretation of results						
1. Acceptance standards						
2. Comparison between responses from discontinuities to those from ultrasonic reference standards						
3. Estimated length of discontinuities						
4. Location of discontinuities						
5. Zoning						
7.4 Test records						
1. Data sheets						
2. Maps						
3. Identification stamps and certification						
7.5 Equipment performance variations						
C.8 Variables Affecting Test Results	2.4	4	4	8	8	16
8.1 Instrument performance variations						
8.2 Search unit performance variations						
8.3 Inspected part variations						
1. Entry surface condition						
2. Part size and geometry						
3. Metallurgical structure						
8.4 Discontinuity variations						
1. Size and geometry						
2. Distance location from entry surface						
3. Orientation to entry surface						
4. Type of discontinuity — reflecting characteristics						
Total Minimum Hours	24	40	40	40	40	80

* Completion with a passing grade of at least 2 years of engineering or science study at a university, college, or technical school

** High school graduation, diploma or its equivalent

*** Grammar school graduation, or demonstrated proficiency, or additional training

Ultrasonic Testing

- American Society for Testing and Materials Standards and Tentative Standards Relating to Ultrasonic Testing.* Refer to ASTM Index of latest issue: ASTM, Philadelphia Pennsylvania.
- Carlin, B. *Ultrasonics.* McGraw-Hill Book Company, Inc.: New York, 1949.
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- Ultrasonic Testing Classroom Training Handbook (CT-6-4):* General Dynamics/Convair Division, San Diego, California.*
- Ultrasonic Testing Programmed Instruction Handbooks (PI-4-4):* General Dynamics/Convair Division, San Diego California.*
- Ultrasonic Testing Inspection for Butt Welds in Highway and Railroad Bridges.* U.S. Department of Transportation: 1968.

* Available from The American Society for Nondestructive Testing

Recommended Training Course

Liquid Penetrant Testing Method

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
D.1 Introduction	1/3	1/3	1	1/3	2/3	1 1/3
1.1 Brief history of nondestructive testing and liquid penetrant testing						
1.2 Purpose of liquid penetrant testing						
1.3 Basic principles of liquid penetrant testing						
1.4 Types of liquid penetrants commercially available						
D.2 Liquid Penetrant Processing	1	1	3	1	2	4
2.1 Preparation of parts						
2.2 Application of penetrant to parts						
2.3 Removal of surface penetrant						
2.4 Developer application and drying						
2.5 Inspection and evaluation						
2.6 Post-cleaning						
D.3 Selection of Penetrant Test Method	1/3	1/3	1	1/3	2/3	1 1/3
3.1 Advantages of various methods						
3.2 Disadvantages of various methods						
D.4 Liquid Penetrant Test Equipment	2/3	2/3	2	2/3	1 1/3	2 2/3
4.1 Liquid penetrant test units						
4.2 Lighting for liquid penetrant inspection						
4.3 Materials for liquid penetrant tests						
4.4 Precautions in penetrant inspection						
D.5 Liquid Penetrant Indications	1	1	3	1	2	4
5.1 General						
1. Reason for indications						
2. Appearance of indications						
3. Time for indications to appear						
4. Persistence of indications						
5.2 Factors affecting indications						
1. Penetrant used						
2. Prior processing						
3. Technique used						
5.3 Establishing acceptance standards						
1. Lack of "standards"						
2. Standards for repetitive inspection						
5.4 Indication from cracks						
1. Cracks occurring during solidification						
2. Cracks occurring during processing						
3. Cracks occurring during service						

LIQUID PENETRANT TESTING

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
5.5 Indications from laminar discontinuities						
1. Cold shut or fold						
2. Forging laps						
3. Extrusion defect						
4. Seams						
5.6 Indications from porosity						
5.7 Nonrelevant indications						
D.6 Inspection Procedures and Standards						
6.1 Inspection procedures						
6.2 Standards						
	2/3	2/3	2	2/3	1 1/3	2 2/3
Total Minimum Hours	4	4	12	4	8	16

- * Completion with a passing grade of at least 2 years of engineering or science study at a university, college, or technical school.
- ** High school graduate, diploma or its equivalent.
- *** Grammar school graduate, or demonstrated proficiency, or additional training.

Recommended Training References

Table II-D

Liquid Penetrant Testing

American Society for Testing and Materials Standards and Tentative Standards Relating to Liquid Penetrant Testing. Refer to ASTM Index of latest issue: ASTM, Philadelphia, Pennsylvania.

Betz, C. E. *Principals of Penetrants.* 2nd ed. Magnaflux Corporation: Chicago, Illinois, 1969.*

Buckman, W. B. "Fluorescent Penetrant Inspection of Jet Propulsion Engine Component Parts." *Nondestructive Testing, U.S.A.* Vol. X, No. 3 (1951-1952), p. 11.

Catlin, F. S. "Black Light Inspection of Castings." *Foundry.* Vol. 77, No. 8 (1949).

DeForest, T. "Penetrant Testing." *Nondestructive Testing, U.S.A.* Vol. XIV, No. 4 (1958).

Gilbert, L. and W. B. Bunn. "Inspection Techniques for Quality Welding." *Welding Journal.* Vol. 32 (1952).

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Hitt, W. C. "The Value of Scientific Inspection to Industry." *Western Machinery and Steel World.* Vol. 39, No. 7 (1948).

"Inspection of Welding." *Welding Handbook.* Section 1, latest ed. American Welding Society: Miami, Florida.

Liquid Penetrant Testing, Classroom Handbook (CT-6-2): General Dynamics/Convair Division, San Diego, California.*

Liquid Penetrant Testing, Programmed Instruction Handbook (PI-4-2): General Dynamics/Convair Division, San Diego, California.*

McGonnagle, W. J. *Nondestructive Testing.* 2nd ed. Gordon & Breach, Science Publishers, Inc.: New York. 1969.

McMaster, R. C. ed. *Nondestructive Testing Handbook.* Vols. I-II. The Ronald Press Company: New York, 1959.*

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* Available from The American Society for Nondestructive Testing

Recommended Training Course

Electromagnetic Testing Method

	Recommended Hours of Instruction		
	1*	2*	3*
Level I			
Basic Electromagnetic Physics Course	24	6	4
Electromagnetic Technique Course	24	6	4
Total	48	12	8
Level II			
Electromagnetic Evaluation Course	24	8	8

*Note: 1. Grammar School Graduate
 2. High School Graduate or Equivalent
 3. Completion with passing grades of at least two years of Engineering or Science Study at a University, College, or Technical School.

Recommended Training For Electromagnetic Level I

Basic Electromagnetic Physics Course

1. **Introduction to Electromagnetic Testing (Eddy Current/Flux Leakage)**
 - 1.1 Brief history of testing
 - 1.2 Basic principles of testing
2. **Electromagnetic Theory**
 - 2.1 **Eddy Current Theory**
 - 2.1.1 Generation of eddy currents by means of an A-C field
 - 2.1.2 Effect of fields created by eddy currents (impedance changes)
 - 2.1.3 Effect of change of impedance on instrumentation
 - 2.1.4 Properties of eddy current
 1. Travel in circular direction
 2. Strongest on surface of test material
 3. Zero value at center of solid conductor placed in an alternating magnetic field
 4. Strength, time relationship, and orientation as a function of test system parameters and test part characteristics
 5. Have properties of compressible fluids
 6. Small magnitude of current flow
 7. Relationship of frequency and plane with current in coil
 8. Effect of irrelevant permeability variation when induced in magnetic materials

ELECTROMAGNETIC TESTING

- 9. Effect of discontinuity orientation
- 10. Power losses

2.2 Flux Leakage Theory

- 2.2.1 Terminology and Units
- 2.2.2 Principles of Magnetization
 - 1. B-H Curve
 - 2. Magnetic properties
 - 3. Magnetic field
 - 4. Hysteresis loop
 - 5. Magnetic permeability
 - 6. Factors affecting permeability
- 2.2.3 Magnetization
 - 1. Electromagnetism Theory
 - A. Oersted's Law
 - B. Faraday's Law
 - C. Electromagnetics
- 2.2.4 Flux Leakage
 - 1. Flux Leakage theory and principle
 - A. Residual
 - B. Active
 - C. Tangential leakage
 - D. Normal leakage fields

Total Recommended Hours of Instruction this Course: $\frac{1}{24 \text{ hr.}}$ $\frac{2}{6 \text{ hr.}}$ $\frac{3}{4 \text{ hr.}}$

Recommended Training for Electromagnetic Level I

Electromagnetic Technique Course

- 1. **Read-Out Mechanism**
 - 1.1 Calibrated or Uncalibrated meter
 - 1.2 Null meter with dial indicator
 - 1.3 Oscilloscope
 - 1.4 Alarm lights, etc.
 - 1.5 Numerical counters
 - 1.6 Marking system
 - 1.7 Sorting gates and tables
 - 1.8 Cutoff saw or shears
 - 1.9 Automation and feedback
 - 1.10 Strip chart recorder
- 2. **Types of Eddy Current Sensing Elements**
 - 2.1 Probes
 - 1. Types or arrangements
 - a. Absolute
 - b. Differential
 - 2. Lift-off
 - 3. Theory of operation
 - 4. Applications
 - 5. Advantages
 - 6. Limitations
 - 2.2 Through, encircling, or annular coils
 - 1. Types or arrangements
 - a. Absolute
 - b. Differential
 - 2. Fill Factor
 - 3. Theory of Operation
 - 4. Applications

ELECTROMAGNETIC TESTING

5. Advantages
6. Limitations
- 2.3 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**
 - 3.1 Principles of magnetic measurement techniques
 - 3.2 Inductive Coil sensors
 1. Theory of EMF induced in coil
 2. Various constructions and designs of coils
 3. Coil's parameters affecting the flux leakage response
 4. Sensing coil systems and connections (single and multi-element probes)
 - 3.3 Semiconductor sensing elements
 1. Hall effect probes
 2. Magnetoresistors
 3. Magnetodiodes
 4. Magneto Transistor
 5. Magnetic and electric characteristics of semi-conductor sensing elements
 - 3.4 Other methods of magnetic leakage field detection
 1. Magnetic tape system
 2. Magnetic powder
 3. Magnetic resonance sensor

Total Recommended Hours of Instruction this Course: $\frac{1}{24 \text{ hr.}}$ $\frac{2}{6 \text{ hr.}}$ $\frac{3}{4 \text{ hr.}}$

Recommended Training For Electromagnetic Level II

Electromagnetic Evaluation Course

1. **Review of Electromagnetic Theory**
 - 1.1 Eddy Current Theory
 - 1.2 Flux Leakage Theory
 - 1.3 Types of Eddy Current Sensing Probes
 - 1.4 Types of Flux Leakage Sensing Probes
2. **Factors Which Affect Coil Impedance**
 - 2.1 Test part
 1. Conductivity
 2. Permeability
 3. Mass
 4. Homogeneity
 - 2.2 Test system
 1. Frequency
 2. Coupling
 3. Field strength
 4. Test coil and shape
3. **Factors Which Affect Flux Leakage Fields**
 - 3.1 Degree of magnetization
 - 3.2 Defect geometry
 - 3.3 Defect location
 - 3.4 Defect orientation
 - 3.5 Velocity factor
 - 3.6 Distance between adjacent defects

ELECTROMAGNETIC TESTING

4. Signal/Noise Ratio

- 4.1 Definition
- 4.2 Relationship to eddy current testing
- 4.3 Relationship to flux leakage testing
- 4.4 Methods of improving signal/noise ratio

5. Selection of Test Frequency

- 5.1 Relationship of frequency to type of test
- 5.2 Considerations affecting choice of test
 1. Signal/noise ratio
 2. Phase discrimination
 3. Response speed
 4. Skin effect

6. Selection of Method of Magnetization for Flux Leakage Testing

- 6.1 Magnetization characteristics for various magnetic materials
- 6.2 Magnetization by means of electric fields
 1. Circular field
 2. Longitudinal field
 3. Value of flux density
- 6.3 Magnetization by means of permanent magnets
 1. Permanent magnetic relationship and theory
 2. Permanent magnetic materials
 3. Permanent magnetic design relationship
- 6.4 Selection of proper magnetization method

7. Coupling

- 7.1 "Fill-factor" in through-coil inspection
- 7.2 "Lift-off" and compensation in probe coil inspection
- 7.3 Flux leakage "fill-factor" in flux leakage testing
- 7.4 "Lift-off" in flux leakage testing

8. Field Strength and Its Selection

- 8.1 Permeability Changes
- 8.2 Saturation
- 8.3 Effect of A-C field strength on eddy current testing
- 8.4 Effect of field strength in flux leakage testing

9. Field Orientation for Flux Leakage Testing

- 9.1 Circular field
- 9.2 Longitudinal field

10. Instrument Design Consideration

- 10.1 Amplification
- 10.2 Phase detection
- 10.3 Differentiation of filtering

11. Applications

- 11.1 Flaw detection
 1. Eddy current
 2. Flux leakage
- 11.2 Sorting for properties related to conductivity
 1. Eddy current
- 11.3 Sorting for properties related to permeability
 1. Eddy current
 2. Flux leakage
- 11.4 Thickness evaluation
 1. Eddy current
- 11.5 Measurement of magnetic characteristic values
 1. Eddy current
 2. Flux leakage

ELECTROMAGNETIC TESTING

12. User Standards and Operating Procedures

- 12.1 Explanation of standards and specifications used in electromagnetic testing
- 12.2 Explanation of operating procedures used in electromagnetic testing

Total Recommended Hours of Instruction this Course: $\frac{1}{24 \text{ hr.}}$ $\frac{2}{8 \text{ hr.}}$ $\frac{3}{8 \text{ hr.}}$

Recommended Training References

Table II-E

Electromagnetic Testing

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- Automation-Forster QC-1000 Manual*.
- Black, W. A. "Nondestructive Testing of Steel and Steel Products." *Nondestructive Testing*, U.S.A. Vol. XVIII, No. 3 (1960), p. 185-190.
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- Hochschild, Richard. "Eddy Current Testing by Impedance Analysis." *Nondestructive Testing*. U.S.A., Vol. XII, No. 3 (1954).
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- McClurg, G. O. "Flaw Detection by Eddy Current Methods." *Nondestructive Testing*, U.S.A. March-April, 1957, p. 116-119.
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* Available from The American Society for Nondestructive Testing

Recommended Training Course

Neutron Radiographic Testing Method

	Recommended Hours of Instruction		
	1*	2*	3*
Level I			
Neutron Radiographic Equipment and Emergency Instructions Course	16	8	8
Basic Neutron Radiographic Physics Course	15	7	4
Basic Neutron Radiographic Technique Course	25	13	8
Total	56	28	20
Level II			
Neutron Radiography Physics Course	30	14	14
Neutron Radiographic Technique Course	50	26	26
Total	80	40	40

*Note: 1. Grammar School Graduate
 2. High School Graduate or Equivalent
 3. Completion with passing grades of at least two years of Engineering or Science Study at a University, College, or Technical School.

RECOMMENDED TRAINING FOR LEVEL I NEUTRON RADIOGRAPHER

Neutron Radiographic Equipment Operating and Emergency Instructions Course

NOTE: It is recommended that the trainee receive instruction in this course prior to performing work in Neutron Radiography.

1. **Personnel Monitoring**
 - 1.1 Personnel monitoring dosimeters
 - 1.1.1 Types
 - 1.1.2 Reading
 - 1.1.3 Record keeping
 - 1.2 Permissible personnel exposure limits

NEUTRON RADIOGRAPHIC TESTING

2. Radiation Survey Instruments

- 2.1 Types of radiation survey instruments
- 2.2 Reading and interpreting survey instrument meter indications
- 2.3 Calibration frequency
- 2.4 Calibration expiration — actions to be taken
- 2.5 Battery check — importance

3. Radiation Area Surveys

- 3.1 Type and quantity of radiation
- 3.2 Posting
 - 3.2.1 Radiation areas
 - 3.2.2 High radiation areas
- 3.3 Establishment of time limits

4. Radioactivity

- 4.1 Radioactive components (fuel sources, etc.)
- 4.2 Induced radioactivity — due to neutron radiography
 - 4.2.1 Handling of radioactive components
 - 4.2.2 Decay of radioactive components
 - 4.2.3 Shipping of radioactive components

5. Radiation Area Safety Work Practices

- 5.1 Use of time, shielding and distance to reduce personnel radiation exposure
- 5.2 Restricted areas
- 5.3 Radioactive contamination
 - 5.3.1 Clothing requirements
 - 5.3.2 Contamination control
 - 5.3.3 Contamination cleanup
- 5.4 Specific procedures

*6. Explosive Device Safety

- 6.1 Static electricity
- 6.2 Grounding devices
- 6.3 Clothing requirements
- 6.4 Handling and storage requirements, procedures
- 6.5 Shipping and receiving procedures

7. State and Federal Regulations

- 7.1 NRC and agreement states authority
- 7.2 OSHA
- 7.3 Department of Transportation (DOT)
- *7.4 State and Federal explosive licensing requirements

Total Recommended Hours of Instruction for this Course: $\frac{1}{16 \text{ hr.}}$ $\frac{2}{8 \text{ hr.}}$ $\frac{3}{8 \text{ hr.}}$

*Required only by those personnel who will be involved in neutron radiography of explosive devices.

RECOMMENDED TRAINING FOR LEVEL I NEUTRON RADIOGRAPHER

Basic Neutron Radiography Physics Course

1. Introduction

- 1.1 History of industrial neutron radiography
- 1.2 General principles of examination of materials with penetrating radiation
- 1.3 Relationship of penetrating neutron radiation, radiography and radiometry
- 1.4 Comparison with other NDT methods, particularly with X-rays and gamma rays
- 1.5 General areas of application
 - 1.5.1 Imaging

NEUTRON RADIOGRAPHIC TESTING

- 1.5.2 Metrological
- 1.5.3 Product

2. Physical Principles

- 2.1 Sources for neutron radiography (general description)
 - 2.1.1 Isotopic
 - 2.1.2 Nuclear reactors
 - 2.1.3 Accelerators
- 2.2 Interaction between neutrons and matter
 - 2.2.1 Absorption
 - a) Thermal neutrons
 - b) Resonance neutrons
 - c) Fast neutrons
 - 2.2.2 Scatter
 - a) Elastic
 - b) Inelastic
- 2.3 Neutron radiography techniques
 - 2.3.1 Film imaging techniques
 - 2.3.2 Non-film imaging techniques
- 2.4 Glossary of terms and units of measure

3. Radiation Sources for Neutrons (specific description)

- 3.1 Reactors
 - 3.1.1 Principle of fission chain reactions
 - 3.1.2 Neutron thermalization (slowing down)
 - 3.1.3 Thermal neutron flux
- 3.2 Accelerators
 - 3.2.1 Types of accelerators
 - 3.2.2 Neutron-producing reactions
- 3.3 Isotopic sources
 - 3.3.1 Radioisotope + Be
 - a) α - Be
 - γ - Be
 - 3.3.2 Radioisotope + D
 - a) γ -D
 - 3.3.3 Spontaneous fission
 - a) ^{252}Cf

4. Personnel Safety and Radiation Protection

- 4.1 Hazard of excessive exposure
 - 4.1.1 General — beta, gamma radiation
 - 4.1.2 Specific neutron hazards
 - a) Relative biological effectiveness
 - b) Neutron activation
- 4.2 Methods of controlling radiation dose
 - 4.2.1 Time
 - 4.2.2 Distance
 - 4.2.3 Shielding
- 4.3 Specific equipment requirements
 - 4.3.1 Neutron monitoring dosimeters
 - 4.3.2 Gamma-ray monitoring dosimeters
 - 4.3.3 Radiation survey equipment
 - a) Beta/gamma
 - b) Neutron
 - 4.3.4 Recording/record keeping
- 4.4 Radiation work procedures
- 4.5 Federal, state and local regulations

Total Recommended Hours of Instruction for this Course:

$\frac{1}{15 \text{ hr.}}$

$\frac{2}{7 \text{ hr.}}$

$\frac{3}{4 \text{ hr.}}$

NEUTRON RADIOGRAPHIC TESTING

RECOMMENDED TRAINING FOR LEVEL I NEUTRON RADIOGRAPHER

Basic Neutron Radiographic Technique Course

1. Radiation Detection Imaging

- 1.1 Converter screens
 - (a) Principles of operation
 - (b) Direct-imaging screens
 - (c) Transfer-imaging screens
- 1.2 Film — principles properties and uses with neutron converter screens
 - (a) Radiation response
 - (b) Vacuum/contact considerations
 - (c) Radiographic speed
 - (d) Radiographic contrast
- 1.3 Track-etch
 - (a) Radiation response
 - (b) Vacuum/contact considerations
 - (c) Radiographic speed
 - (d) Radiographic contrast

2. The Neutron Radiographic Process: Basic Imaging Considerations

- 2.1 Definition of sensitivity (including penetrameters)
- 2.2 Contrast and definition
 - (a) Neutron energy and neutron screen relationship
 - (b) Effect of scattering in object
- 2.3 Geometric principles
- 2.4 Generation and control of scatter
- 2.5 Choice of neutron source
- 2.6 Choice of film
- 2.7 Use of exposure curves
- 2.8 Cause and correction of unsatisfactory radiographs
 - (a) High film density
 - (b) Low film density
 - (c) High contrast
 - (d) Low contrast
 - (e) Poor definition
 - (f) Excessive film fog
 - (g) Light leaks
 - (h) Artifacts
- 2.9 Arithmetic of exposure

3. Test Result Interpretation

- 3.1 Relationship between X-ray and n-ray
- 3.2 Effects on measurement and interpretation of test
- 3.3 Administrative control of test quality by interpreter
- 3.4 Familiarization with image

Total Recommended Hours of Instruction for this Course:

$$\frac{1}{15 \text{ hr.}} \quad \frac{2}{7 \text{ hr.}} \quad \frac{3}{4 \text{ hr.}}$$

RECOMMENDED TRAINING FOR LEVEL II NEUTRON RADIOGRAPHER

Neutron Radiographic Physics Course

1. Introduction

- 1.1 General principles of examination of materials with penetrating radiation
- 1.2 Relationship of penetrating neutron radiation radiography and radiometry
- 1.3 Comparison with other methods particularly with X-rays and gamma rays
- 1.4 Specific areas of application in industry

NEUTRON RADIOGRAPHIC TESTING

2. Review of Physical Principles

- 2.1 Nature of penetrating radiation (all types)
 - 2.1.1 Particles
 - 2.1.2 Wave properties
 - 2.1.3 Electromagnetic waves
 - 2.1.4 Fundamentals of radiation physics
 - 2.1.5 Sources of radiation
 - (a) Electronic
 - (b) Isotopic
 - (c) Nuclear reactors
 - (d) Accelerators
- 2.2 Interaction between penetrating radiation and matter (neutron and gamma ray)
 - 2.2.1 Absorption
 - 2.2.2 Scatter
 - 2.2.3 Other interactions
- 2.3 Glossary of terms and units of measure

3. Radiation Sources for Neutrons

- 3.1 Neutron sources — general
 - 3.1.1 Reactors
 - (a) Principle of fission chain reactions
 - (b) Fast-neutron flux: energy and spatial distribution
 - (c) Neutron thermalization
 - (d) Thermal-neutron flux: energy and spatial distribution
 - 3.1.2 Accelerators
 - (a) Types of accelerators
 - (b) Neutron-producing reactions
 - (c) Available yields and energy spectra
 - 3.1.3 Isotopic sources
 - (a) Radioisotope + Be
 - (b) Radioisotope + D
 - (c) Spontaneous fission - ^{252}Cf
 - 3.1.4 Beam design
 - (a) Source placement
 - (b) Collimator
 - (c) Filtering
 - (d) Shielding

4. Radiation Detection

- 4.1 Imaging
 - 4.1.1 Converter screens
 - (a) Principles of operations
 - (b) Types of screens
 - (1) Direct exposure
 - (2) Transfer exposure
 - (3) Track-etch process
 - (4) Spectral sensitivity (each process)
 - 4.1.2 Film — principles, properties, use with neutron converter screens
 - (a) Material examination
 - (b) Monitoring
 - 4.1.3 Fluoroscopy
 - (a) Fluorescent screen
 - (b) Image amplification
 - (c) Cine techniques
 - 4.1.4 Direct TV viewing
 - 4.1.5 Special instrumentation associated with above techniques
- 4.2 Nonimaging devices
 - 4.2.1 Solid state
 - (a) Scintillometer
 - (b) Photoresistive
 - (c) Other

NEUTRON RADIOGRAPHIC TESTING

- 4.2.2 Gaseous
 - (a) Proportional counters
 - (b) Geiger counters
 - (c) Ionization chambers
 - (d) Other
- 4.2.3 Neutron detectors
 - (a) Boron-based gas counters
 - (b) Fission counters
 - (c) Helium-3 detectors
 - (d) Lithium-based scintillators
 - (e) Instrumentation
 - (1) Rate meters
 - (2) Counters
 - (3) Amplifiers and preamplifiers
 - (4) Recording readouts
 - (5) Other

5. Personnel Safety and Radiation Protection

- 5.1 Hazard of excessive exposure
 - 5.1.1 General — beta, gamma ray
 - 5.1.2 Specific neutron hazards
 - (a) Relative biological effectiveness (RBE)
 - (b) Neutron activation of components
- 5.2 Methods of controlling accumulated radiation dose
 - 5.2.1 Time
 - 5.2.2 Distance
 - 5.2.3 Shielding
- 5.3 Specific equipment requirements
 - 5.3.1 Neutron monitoring equipment
 - 5.3.2 Gamma-ray monitoring equipment
 - 5.3.3 Survey
 - 5.3.4 Recording
 - 5.3.5 Exposure shields and/or rooms
 - (a) Operation
 - (b) Alarms
- 5.4 Operation and emergency procedures
- 5.5 Federal, state and local regulations

Total Recommended Hours of Instruction for this Course: $\frac{1}{30 \text{ hrs.}}$ $\frac{2}{14 \text{ hrs.}}$ $\frac{3}{14 \text{ hrs.}}$

RECOMMENDED TRAINING FOR LEVEL II NEUTRON RADIOGRAPHER

Neutron Radiographic Technique Course

1. The Neutron Radiographic Process

- 1.1 Basic neutron imaging considerations
 - 1.1.1 Definition of sensitivity (including penetrameters)
 - 1.1.2 Contrast and definition
 - (a) Neutron energy and neutron screen relationship
 - (b) Effect of scattering in object
 - (c) Exposure versus foil thickness
 - 1.1.3 Geometric principles
 - 1.1.4 Intensifying screens
 - (a) Fluorescent (neutron sensitive)
 - (b) Metallic (neutron sensitive)
 - 1.1.5 Generation and control of scatter
 - 1.1.6 Choice of source
 - 1.1.7 Choice of film detector

NEUTRON RADIOGRAPHIC TESTING

- 1.1.8 Use of exposure curves and process by which they are generated
- 1.1.9 Fluoroscopic inspection
 - (a) Theory of operation
 - (b) Applications
 - (c) Limitations
- 1.1.10 Film processing
 - (a) Darkroom procedures
 - (b) Darkroom equipment and chemicals
 - (c) Film processing do's and don'ts
- 1.1.11 Viewing of radiographs
 - (a) Illuminator requirements (intensity)
 - (b) Background lighting
 - (c) Judging quality of neutron radiograph
- 1.1.12 Causes and correction of unsatisfactory radiographs
 - (a) High film density
 - (b) Insufficient film density
 - (c) High contrast
 - (d) Low contrast
 - (e) Poor definition
 - (f) Excessive neutron scatter
 - (g) Fog
 - (h) Light leaks
 - (i) Artifacts
- 1.1.13 Arithmetic of exposure and of other factors affecting neutron radiographs
- 1.2 Miscellaneous applications
 - 1.2.1 Blocking and filtering
 - 1.2.2 Multifilm techniques
 - 1.2.3 Enlargement and projection
 - 1.2.4 Stereoradiography
 - 1.2.5 Triangulation methods
 - 1.2.6 Autoradiography
 - 1.2.7 Flash neutron radiography
 - 1.2.8 "In-motion" radiography and fluoroscopy
 - 1.2.9 Backscatter neutron radiography
 - 1.2.10 Neutron tomography
 - 1.2.11 Micro-neutron radiography
 - 1.2.12 Causes of "diffraction" effects and minimization of interference with test
 - 1.2.13 Determination of focal-spot size
 - 1.2.14 Panoramic techniques
 - 1.2.15 Altering film contrast and density
 - 1.2.16 Gaging and control processes

2. Test Result Interpretation

- 2.1 Basic factors
 - 2.1.1 General aspects (relationship between X-ray and neutron radiographs)
 - 2.1.2 Effects on measurement and interpretation of test
 - 2.1.3 Administrative control of test quality by interpreter
 - 2.1.4 Familiarization with image
- 2.2 Material considerations
 - 2.2.1 Metallurgy or other material considerations as it affects use of item and test results
 - 2.2.2 Materials processing effects on use of item and test results
 - 2.2.3 Discontinuities, their causes and effects
 - 2.2.4 Radiographic appearance of discontinuities
- 2.3 Codes, standards, specifications and procedures
 - 2.3.1 Thermal neutron radiography
 - 2.3.2 Resonance neutron radiography
 - 2.3.3 Other applicable codes etc.

Total Recommended Hours of Instruction for this Course:

$\frac{1}{80 \text{ hr.}}$	$\frac{2}{40 \text{ hr.}}$	$\frac{3}{40 \text{ hr.}}$
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Recommended Training References

Neutron Radiographic Testing

- Atomic Energy Review*, Vol. 15, No. 2, June 1977.
- American Society for Testing and Materials Standards and Tentative Standards Relating to Neutron Radiographic Testing*. Refer to ASTM Index of latest issue: ASTM, Philadelphia, Pennsylvania.
- Berger, H., "Neutron Radiography," *Annual Reviews of Nuclear Science*, Vol. XXI. Annual Review, Inc.: Palo Alto, California. 1971.
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- Radiography in Modern Industry*. Eastman Kodak Co.: Rochester, New York.*
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- Standards for Protection Against Radiation. Title 10: Rules and Regulations, Part 20*.
- Tyufackov, N. D. and A. S. Shtan', *Principles of Neutron Radiography*, TT76-52048. Amerind Publishing Co.: New Delhi, India, 1979.

* Available from The American Society for Nondestructive Testing

Recommended Training Course

Leak Testing Method

SUBJECT	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
G.1 Introduction	1/2	1/2	1/2			
1.1 Brief history of leak testing						
1.2 Reasons for leak testing						
1. To prevent loss of contents						
2. To prevent contamination						
3. To detect unreliable components						
4. To assure maintenance of a pressure differential						
G.2 Fundamentals of Testing	1/2	1/2	1/2	1/3	1/3	1/3
2.1 Leak testing units						
2.2 Leak conductance						
2.3 Detector sensitivity						
2.4 Leakage measurement						
G.3 Testing Standards	1/2	1/2	1/2	1/3	1/3	1/3
3.1 Calibration versus qualification						
3.2 Common types of calibrated leaks						
3.3 Calibration techniques						
G.4 Choice of Procedure for Leak Testing	1/2	1/2	1/2	1/3	1/3	1/3
4.1 Discussion						
4.2 Type of leak testing						
4.3 Leakage measurement						
4.4 Units accessible on both sides — single sealed units						
4.5 Units which may be evacuated						
4.6 Systems leaking at atmospheric pressure						
4.7 Evacuated unit testing						
4.8 Units sealed with ambient gas						
4.9 Units sealed with tracer gas						
4.10 Leak location						
Total Minimum Hours	2	2	2	1	1	1
G.5 Leak Testing Methods and Techniques						
5.1 Bubble Test (G.1, 2, 3, 4 not required)	1	1	1	1	2	2
1. Bubble testing materials and equipment						
a. Solutions						
b. Solution applicators						
c. Vacuum boxes						
2. Bubble testing practices and techniques	1	1	1	1	2	2
a. Vacuum box testing						

LEAK TESTING

	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
b. Pipe, nozzle, and pad plate testing						
c. Vessel testing						
d. Weather effects and lighting						
Total Minimum Hours	2	2	2	2	4	4
5.2 Pressure Change/Measurement Test	1	2	5	½	1	5
5.2.1 Absolute Pressure Leak Test						
1. Principles of absolute pressure testing						
a. General gas law equation						
b. Effects of temperature change						
c. Effects of water vapor pressure change						
d. Effects of barometric pressure change						
2. Terminology related to absolute pressure testing	1	1	3	½	1	5
3. Absolute pressure testing equipment	1	1½	5	½	1	5
a. Pressure measuring instruments						
b. Temperature measuring instruments						
c. Dew point measuring instruments						
d. Accuracy of equipment						
e. Calibration of equipment						
4. Pressurizing gases	¼	½	1			
5. Absolute pressure hold testing of containment liner channels, interspaces and airlocks	¾	1	4	½	1	5
a. Equation for determining pressure change						
b. Temperature measuring						
6. Absolute pressure leakage rate testing of containment vessels and airlocks	1	2	5	1½	1	9
a. Equation(s) for determining % loss						
b. Positioning of temperature and dew point sensors for mean sampling accuracy						
c. Analysis of temperature and dew point data						
7. Analysis of data for determination of accurate results	1	2	5	2¼	3	10
5.2.1 Subtotal Minimum Hours	6	10	28	5¾	8	39
5.2.2 Reference System Testing						
1. Principles of reference system testing	1½	2	5	¾	1	5
a. General gas law equation						
b. Effects of temperature change						
c. Effects of water vapor pressure						
d. Effects of barometric pressure change						
2. Terminology related to reference system testing	⅔	1		¾	1	5
3. Reference system testing equipment	2	3		¾	1	5
a. Pressure measuring instruments						
b. Temperature measuring instruments						
c. Dew point measuring instruments						
d. Reference panel instruments						
e. Reference system installation and testing						
f. Accuracy of equipment						
g. Calibration of equipment						
4. Pressurizing gases	⅓	.5	1			
5. Reference system testing of containment vessels	2⅓	3.5	10	1	2	10
a. Equation(s) for determining % loss						
b. Positioning of temperature and dew point sensors for mean sampling accuracy						

LEAK TESTING

		Recommended Instruction Period — Hours					
		Level I			Level II		
		*	**	***	*	**	***
	c. Analysis of temperature and dew point data						
6.	Analysis of data for determination of accurate results	1 1/3	2	5	2	2	15
5.2.2 Subtotal Minimum Hours		8	12	30	5 1/4	7	40
Total Minimum Hours		14	22	58	11	15	79
5.3 Halogen Diode Detector Leak Test							
1.	Principles of halogen diode detector testing	1	1	3	1	1	3
2.	Terminology related to halogen diode detector testing	2/3	1	2	1/2	1	3
3.	Halogen testing equipment	1	1	3	1/2	1	3
	a. Leak detector control unit						
	b. Gun detectors						
	c. Standard leaks						
	d. Refrigerant tracer gases						
4.	Calibration of halogen leak detectors for testing	1	1	3	1	1	3
	a. Standard leak settings						
	b. Halogen mixture percentages						
	c. Test sensitivity						
5.	Halogen “sniffer” testing techniques and practices	1	3	6	1	2	4
	a. “Sniffer” speed						
	b. Halogen background						
	c. Effects of heat on refrigerant R-12						
6.	Halogen leak detector operation and servicing	1	2	4	1	1	3
	a. Operation of gun						
	b. Replacing the sensing element						
	c. Cleaning of sensing elements						
7.	Standard leak operation and refilling	1/3	1	1			
Total Minimum Hours		6	10	22	5	7	19
5.4 Mass Spectrometer Leak Testing							
1.	Principles of mass spectrometer testing	5.8	6	6	5	5	7
	a. Vacuum and pressure technology						
	b. Outgassing of materials vs. pressure						
	c. Vacuum pumping technology						
2.	Terminology related to mass spectrometer testing	1.4	2	2			
3.	Helium mass spectrometer	7.6	8	12	4	6	24
	a. Operation						
	b. Calibration						
	c. Maintenance						
4.	Helium mass spectrometer pressure testing	2.8	6	9	2	3	12
	a. “Sniffer” speed						
	b. “Sniffer” hose diameter and length						
	c. Mixture percentage						
	d. Pressure differential						
	e. Bagging-accumulation technique						
	f. Calibration of helium mass spectrometer for “sniffer” testing						
5.	Helium mass spectrometer vacuum testing by dynamic method	2.8	6	11	1 1/4	3	12
	a. Probing						
	b. Bagging						
	c. System calibration						
	d. Helium mixture						
	e. Calculation of leakage rate						

LEAK TESTING

	Recommended Instruction Period — Hours					
	Level I			Level II		
	*	**	***	*	**	***
6. Helium mass spectrometer vacuum testing by static method	2.8	5	9	1½	3	12
a. Static equation						
b. System calibration						
c. Helium mixture						
d. System pressure						
e. Calculation of leakage rate						
7. Helium mass spectrometer testing equipment	2.8	5	9	1½	3	12
a. Mechanical vacuum pump systems						
b. Cryogenic pumps						
c. Diffusion pumps						
d. Vacuum gauges						
e. Vacuum hose						
f. Vacuum valves						
g. Standard leaks						
h. Vacuum sealing compounds						
i. Vacuum connectors						
j. “Sniffer” probes						
k. Helium probes						
Total Minimum Hours	26	38	58	15	23	79

G.6 Safety

Note: In addition to technical training, each LT Level I or II individual shall have at least 4 hours of safety training.

* Completion with a passing grade of at least 2 years of engineering or science study at a university, college, or technical school.

** High school graduation, diploma or its equivalent.

*** Grammar school graduation, or demonstrated proficiency, or additional training.

Leak Testing

General

- American Society for Testing and Materials Standards and Tentative Standards Relating to Leak Testing.* Refer to ASTM Index of latest issue. ASTM, Philadelphia, Pennsylvania.
- Guthrie, A. *Vacuum Technology.* John Wiley and Sons, Inc.: New York, 1963.
- Guthrie, A., and R. K. Wakerling. *Vacuum Equipment and Techniques.* McGraw-Hill Book Co., Inc.: New York.
- Marr, J. William. *Leakage Testing Handbook.* U.S. Government Printing Office, Clearinghouse: Springfield, Virginia.
- Pirani, M. and J. Yarwood. *Principles of Vacuum Engineering.* Reinhold Publishing Corp.: New York, 1961.
- Roehrs, Robert J. "Leak Testing on Welded Vessels." *Proceedings of the 1967 Symposium on Nondestructive Testing of Welds.* The American Society for Nondestructive Testing: Evanston, Illinois, 1968.
- Steinherz, H. A. *Handbook of High Vacuum Engineering.* Reinhold Publishing Co.: New York.
- Van Atta, C. M. *Vacuum Science and Engineering.* Hill Book Co., Inc.: New York.

Bubble Testing

- Biram, J. G. S. "Bubble Leak Detection." Atomic Energy Research Establishment, A.E.R.E.: CE/R 2066 (1957).
- Biram, J. G. S. and G. Burrows. "Bubble Tests for Gas Tightness." *Vacuum*, Vol. XIV. June, 1964, p 221-226.

Pressure Change/Measurement Testing

- "ANS 7.60 Proposed Standard for Leakage Rate Testing of Containment Structures." Latest revision. U.S. Atomic Energy Commission, Division of Safety Standards: Washington, D.C.
- American Nuclear Society. "Proposed Standard for Leakage Rate Testing of Containment Structures for Nuclear Reactors." *Nuclear Engineering Bulletin.* Vol. II. December 1964, p. 1-13.
- Herzfeld, Charles. In cooperation with AIP, ISA and NBS. *Temperature. It's Measurement and Control in Science and Industry.* Vol. III, Parts I and II. Reinhold Publishing Corp.: New York.

Safety Standards, Criteria and Guides for the Design, Location, Construction and Operation of Reactors, Part III Technical Safety Guide Reactor Containment Leakage Testing and Surveillance Requirements. Latest revision. U.S. Atomic Energy Commission, Division of Safety Standards: Washington, D.C.

Wexler, Arnold and William Wildhack. *Humidity and Moisture Measurement and Control in Science and Industry.* Reinhold Publishing Corp.: New York.

Halogen Diode Detector Testing

- American Society for Testing and Materials Standards and Tentative Standards relating to Leak Testing.* Refer to ASTM Index of latest issue. ASTM, Philadelphia, Pennsylvania.
- Instructions for Type LS-20 Leak Standard.* General Electric Publication GEJ-4251A.
- Service Manual for Types H-1, H-2, H-3, H-5P, and H-9 Leak Detector Probes and Control Unit.* Catalog No. 50-420100FAFF, General Electric Publication GEJ-4296.

Mass Spectrometer Testing

- American Society for Testing and Materials Standards and Tentative Standards Relating to Leak Testing.* Refer to ASTM Index of latest issue. ASTM, Philadelphia, Pennsylvania.
- CEC Mass Spectrometer Leak Detector Operation and Maintenance Manual.* Consolidated Electrodynamics Corporation, Subsidiary of Bell & Howell: Pasadena, California
- Panza, Jr., Prisco A. "Improved Fine and Gross Leak Test Methods for Electronic Components." Grumman Aircraft Engineering Corporation: New York, 1968. Presented at the ASNT National Conference, October, 1968.
- Veeco Mass Spectrometer Leak Detector Model MS-9A, MS-9AB, MS-9ABC Operation and Maintenance Manual.* Veeco Instruments Inc.: Plainview, New York.
- Wilson, Norman G. and Claude R. Winkelman. "An Analytical Method for Mass Spectrometer Leak Detection." LA 3955, Los Alamos Scientific Laboratory of the University of California: Los Alamos, New Mexico, 1969.

Recommended Training Course

Acoustic Emission Testing Method

	Recommended Hours of Instruction		
	1*	2*	3*
Level I			
Basic Acoustic Emission Physics Course	24	18	12
Basic Acoustic Emission Technique Course	56	42	28
Total	80	60	40
Level II			
Acoustic Emission Physics Course	12	9	5
Acoustic Emission Technique Course	73	56	30
Total	85	65	35

- *Note:
1. Grammar School Graduate
 2. High School Graduate or Equivalent
 3. Completion with passing grades of at least two years of Engineering or Science Study at a University, College, or Technical School.

RECOMMENDED TRAINING FOR ACOUSTIC EMISSION TESTING LEVEL I

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 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
 - (a) Pressure leaks
 - (b) Oxide and scale cracking
 - (c) Slag cracking
 - (d) Frictional sources
 - (e) Liquefaction and solidification

ACOUSTIC EMISSION TESTING

- (f) Loose parts, intermittent contact
- (g) Fluids and nonsolids
- (h) Crack closure
- 1.3 Wave propagation-introduction
 - 1.3.1 Attenuation
 - 1.3.2 Wave velocity in materials
 - 1.3.3 Source input vs. signal output
- 1.4 Kaiser effect
 - 1.4.1 In metals
 - 1.4.2 In composites
 - 1.4.3 In other materials
- 1.5 Terminology (refer to AE Glossary, ASTM E610-77)

2. Detection of acoustic emission

- 2.1 Sensors
 - 2.1.1 Principles of operation
 - 2.1.2 Construction
- 2.2 Sensor Attachment
 - 2.2.1 Coupling materials
 - 2.2.2 Attachment devices
- 2.3 Sensor — preamplifier transmission cables
 - 2.3.1 Cable types
 - 2.3.2 Noise susceptibility
 - 2.3.3 Impedance matching
 - 2.3.4 Connectors
 - 2.3.5 Integral electronic sensors

Total Recommended Hours of Instruction this Course: $\frac{1}{24 \text{ hr.}}$ $\frac{2}{18 \text{ hr.}}$ $\frac{3}{12 \text{ hr.}}$

Recommended Training for Acoustic Emission Testing Level I

Basic Acoustic Emission Technique Course

3. Instrumentation and signal processing

- 3.1 Signal conditioning
 - 3.1.1 Preamplifiers
 - 3.1.2 Amplifiers
 - 3.1.3 Filters
 - 3.1.4 Units of gain measurement
- 3.2 Signal processing
 - 3.2.1 Waveform characteristics
 - 3.2.2 Discrimination techniques
 - 3.2.3 Distribution techniques
 - 3.2.4 Location techniques
- 3.3 Data display and recording techniques
 - 3.3.1 Audio indicators
 - 3.3.2 X-Y and strip chart recording
 - 3.3.3 Digital counters and processors
 - 3.3.4 Oscilloscopes
 - 3.3.5 Magnetic recorders
 - 3.3.6 Others
- 3.4 Acoustic emission test systems
 - 3.4.1 Single channel systems
 - 3.4.2 Multi-channel systems
 - 3.4.3 Dedicated industrial systems

4. Acoustic emission test procedures

- 4.1 Calibration of test equipment
 - 4.1.1 Calibration signal generation techniques
 - 4.1.2 Adjustment of equipment controls

ACOUSTIC EMISSION TESTING

- 4.1.3 Discrimination technique adjustments
- 4.1.4 Recognition of severe attenuation near failure
- 4.2 Data Display and Interpretation
 - 4.2.1 Selection and display mode
 - 4.2.2 Comparison with calibration signals
 - 4.2.3 Source evaluation by other NDT methods
- 4.3 Noise Identification
 - 4.3.1 Electromagnetic noise
 - 4.3.2 Mechanical noise
- 4.4 Noise discrimination
 - 4.4.1 Electrical shielding
 - 4.4.2 Electronic techniques
 - 4.4.3 Attenuating materials and applications
 - 4.4.4 Pseudo signal identification and control
- 4.5 Response
 - 4.5.1 Purpose
 - 4.5.2 Content and structure

5. Applications of acoustic emission testing

- 5.1 Fundamental studies — introduction
- 5.2 Source detection and location
- 5.3 Other applications
 - 5.3.1 Wood and wooden structures
 - 5.3.2 Rock mechanics
 - 5.3.3 Civil structures
 - (a) Bridges
 - (b) Buildings
 - (c) Dams
 - (d) Buried pipeline
 - (e) Slopes
 - (f) Cavities
 - (g) Mines
 - 5.3.4 Leak detection
 - 5.3.5 Composite materials and structures
 - 5.3.6 Refractory structures
 - 5.3.7 Machinery analysis
 - 5.3.8 Microseismology
 - 5.3.9 Acoustic signature analysis
- 5.4 Conditions that cause poor AE applicability

Total Recommended Hours of Instruction this Course: $\frac{1}{56 \text{ hr.}}$ $\frac{2}{42 \text{ hr.}}$ $\frac{3}{12 \text{ hr.}}$

Recommended Training for Acoustic Emission Testing Level II

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 levels and frequencies
- 1.2 Sources of acoustic emission
 - 1.2.1 Sources in crystalline materials
 - (a) Dislocations — plastic deformation
 - (b) Phase transformations
 - (c) Deformation twinning
 - (d) Nonmetallic-inclusions
 - (e) Subcritical crack growth
 - (i) Subcritical crack growth under increasing load
 - (ii) Ductile tearing under increasing load

ACOUSTIC EMISSION TESTING

- (iii) Fatigue crack nucleation and growth
- (iv) Hydrogen embrittlement cracking
- (v) Stress corrosion cracking
- 1.2.2 Sources in nonmetals
 - (a) Microcracking
 - (b) Gross cracking
 - (c) Crazeing
 - (d) Other sources in nonmetals
- 1.2.3 Sources in composites
 - (a) Fiber fracture
 - (b) Matrix cracking
 - (c) Delamination, disbonding
- 1.2.4 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
- 1.3 Wave propagation
 - 1.3.1 Modes of propagation
 - 1.3.2 Mode conversion, reflection and refraction
 - 1.3.3 Attenuation
 - 1.3.4 Wave velocity in materials
 - 1.3.5 Specimen geometry effects
- 1.4 Kaiser effect
 - 1.4.1 In metals
 - 1.4.2 In composites
 - 1.4.3 In other materials
- 1.5 Terminology (refer to AE Glossary, ASTM E610-77)

2. Detection of Acoustic Emission

- 2.1 Detection 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-preamplifier transmission cables
 - 2.4.1 Cable types
 - 2.4.2 Noise susceptibility
 - 2.4.3 Impedance matching
 - 2.4.4 Connectors
 - 2.4.5 Integral electronic sensors

Total Recommended Hours of Instruction this Course: $\frac{1}{12 \text{ hr.}}$ $\frac{2}{9 \text{ hr.}}$ $\frac{3}{5 \text{ hr.}}$

Recommended Training for Acoustic Emission Testing Level II

Acoustic Emission Technique Course

1. Instrumentation and Signal Processing

- 1.1 Signal conditioning
 - 1.1.1 Preamplifiers
 - 1.1.2 Amplifiers

ACOUSTIC EMISSION TESTING

- 1.1.3 Filters
- 1.1.4 Units of gain measurement
- 1.2 Signal processing
 - 1.2.1 Waveform characteristics
 - (a) Amplitude analysis
 - (b) Pulse duration analysis
 - (c) Rise time analysis
 - (d) Event and event rate processing
 - 1.2.2 Discrimination techniques
 - 1.2.3 Distribution techniques
 - 1.2.4 Location techniques
- 1.3 Data display and recording techniques
 - 1.3.1 Audio indicators
 - 1.3.2 X-Y and strip chart recording
 - 1.3.3 Digital counters and processors
 - 1.3.4 Oscilloscopes
 - 1.3.5 Magnetic recorders
 - 1.3.6 Other techniques
- 1.4 Acoustic emission test systems
 - 1.4.1 Single channel systems
 - 1.4.2 Multi-channel systems
 - 1.4.3 Dedicated industrial systems

2. Acoustic Emission Test Procedures

- 2.1 Factors affecting test equipment selection
 - 2.1.1 Materials 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 Calibration of test equipment
 - 2.2.1 Calibration signal generation techniques
 - 2.2.2 Adjustment of equipment controls
 - 2.2.3 Discrimination technique adjustments
 - 2.2.4 Recognition of severe attenuation near failure
- 2.3 Special test procedures
 - 2.3.1 High temperature/low temperature tests
 - 2.3.2 Interrupted tests (including cyclic failure)
 - 2.3.3 Long term tests
 - 2.3.4 Tests in high noise environments
- 2.4 Data display and interpretation
 - 2.4.1 Selection of display mode
 - 2.4.2 Emission-source correlation
 - 2.4.3 Comparison with calibration signals
 - 2.4.4 Source evaluation by other NDT methods
- 2.5 Noise identification
 - 2.5.1 Electromagnetic noise
 - 2.5.2 Mechanical noise
- 2.6 Noise discrimination
 - 2.6.1 Electrical shielding
 - 2.6.2 Electronic techniques
 - 2.6.3 Attenuating materials and applications
 - 2.6.4 Pseudo signal identification and control
- 2.7 Reports
 - 2.7.1 Purpose
 - 2.7.2 Content and structure

3. Applications of Acoustic Emission

- 3.1 Fundamental studies
 - 3.1.1 Fracture mechanics
 - 3.1.2 Stress corrosion

ACOUSTIC EMISSION TESTING

- 3.1.3 Hydrogen embrittlement
- 3.1.4 Dislocation movement
- 3.1.5 Phase transformation
- 3.1.6 Phase stability
- 3.1.7 Creep
- 3.1.8 Residual Stress
- 3.1.9 Corrosion
- 3.2 Source detection and location
 - 3.2.1 Aerospace vehicles
 - 3.2.2 Pressure vessels and piping
 - 3.2.3 Nuclear reactors
 - 3.2.4 Weld monitoring
 - 3.2.5 Trusses and beams
- 3.3 Other applications
 - 3.3.1 Wood and wooden structures
 - 3.3.2 Rock mechanics
 - 3.3.3 Civil structures
 - (a) Bridges
 - (b) Buildings
 - (c) Dams
 - (d) Buried pipeline
 - (e) Slopes
 - (f) Cavities
 - (g) Mines
 - 3.3.4 Leak detection
 - 3.3.5 Composite materials and structures
 - 3.3.6 Refractory structures
 - 3.3.7 Machinery analysis
 - 3.3.8 Microseismology
 - 3.3.9 Acoustic signature analysis
- 3.4 Conditions that cause poor AE applicability

Total Recommended Hours of Instruction this Course:

$\frac{1}{73 \text{ hr.}}$	$\frac{2}{56 \text{ hr.}}$	$\frac{3}{30 \text{ hr.}}$
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Recommended Training References

Acoustic Emission Testing

- R. G. Liptai, D. O. Harris, and C. A. Tatro, eds., *Acoustic Emission — STP 505*, The American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103, 1972.
- *J. C. Spanner, *Acoustic Emission: Techniques and Applications*, Intex Publishing Company, Evanston, IL 1974, new address.
- J. C. Spanner and J. W. McElroy, eds., *Monitoring Structural Integrity by Acoustic Emission — STP 571*, The American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103, 1975.
- H. E. Boyer, ed., *Metals Handbook*, 8th Ed. Vol. 11, American Society for Metals, Metals Park, OH 44073, 1976, pp. 234-243.
- R. W. Nichols, ed., *Acoustic Emission*, Applied Science Publishers, Ltd., Ripple Road, Barking, Essex, England, 1976.
- T. F. Drouillard, *Acoustic Emission: A Bibliography with Abstracts*, Plenum Press, New York, NY, 1978.
- ASTM E569-76, "Standard Recommended Practice for Acoustic Emission Monitoring of Structures during Controlled Stimulation," Part II of the *ASTM Book of Standards*.
- ASTM E610-77, "Standard Definitions of Terms Relating to Acoustic Emission," Part II of the *ASTM Book of Standards*.

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