

Recommended Practice

SNT-TC-1A

December 1988 Edition

American Society for Nondestructive Testing, Inc.



Documents

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

Recommended Practice **SNT-TC-1A** December 1988 Edition American Society for Nondestructive Testing, Inc.

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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 question 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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Personnel Qualification and Certification in Nondestructive Testing

Recommended Practice No. SNT-TC-1A

Personnel Qualification and Certification in Nondestructive Testing

1. Scope

- 1.1 It is recognized that the effectiveness of nondestructive testing (NDT) applications depends upon the capabilities of the personnel who are responsible for, and perform, NDT. This Recommended Practice has been prepared to establish guidelines for the qualification and certification of NDT personnel whose specific jobs require appropriate knowledge of the technical principles underlying the nondestructive tests they perform, witness, monitor, or evaluate.
- 1.2 **This document provides guidelines for the establishment of a qualification and certification program.**
- 1.3 These guidelines have been developed by The American Society for Nondestructive Testing, Inc., to aid employers in recognizing the essential factors to be considered in qualifying personnel engaged in any of the NDT methods listed in Section 3.
- 1.4 It is recognized that these guidelines may not be appropriate for certain employers' circumstances and/or applications. In developing a written practice as required in Section 5, the employer 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) Certification: written testimony of qualification.
 - (2) Certifying Agency: the employer of the personnel being certified.
 - (3) Employer: the corporate, private, or public entity which employs personnel for wages, salary, fees, or other considerations.
 - (4) Experience: work activities accomplished in a specific NDT method under the direction of qualified supervision including performing the NDT method and related activities but *not* including time spent in organized training programs.
 - (5) Outside Agency: a company or individual who provides NDT Level III services and whose qualifications to provide these services have been reviewed by the employer engaging the company or individual.
 - (6) Qualification: demonstrated skill and knowledge and documented training and experience required for personnel to properly perform the duties of a specific job.

- (7) Recommended Practice: a set of guidelines to assist the employer in developing uniform procedures for the qualification and certification of NDT personnel to satisfy the employer's specific requirements.
- (8) Shall: a verb used to express the *minimum recommended guidelines* for most employers' qualification and certification programs; this is *not* intended to express what is mandatory by law or regulation.
- (9) Should: a verb used to express the *desired guidelines* for most employers' qualification and certification programs.
- (10) Training: the organized program developed to impart the knowledge and skills necessary for qualification.

3. Nondestructive Testing Methods

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

Radiographic Testing	RT
Magnetic Particle Testing	MT
Ultrasonic Testing	UT
Liquid Penetrant Testing	PT
Electromagnetic Testing	ET
Neutron Radiographic Testing	NRT
Leak Testing	LT
Acoustic Emission Testing	AET
Visual Testing	VT

4. Levels of Qualification

- 4.1 There are three basic levels of qualification. These levels may be further subdivided by the employer for specific situations where additional levels of skills and responsibilities are deemed necessary.
- 4.2 While in the process of being trained, 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 NDT, interpret or evaluate the results of any NDT, or report NDT results.
- 4.3 The three basic levels of qualification are as follow:
 - (1) **NDT Level I.** An NDT Level I individual shall be qualified to properly perform specific calibrations, specific NDT, and specific evaluations for acceptance or rejection determinations according to written instructions

and to record results. The NDT Level I shall receive the necessary instruction or supervision from a certified NDT Level III individual or designee.

- (2) **NDT Level II.** An NDT Level II individual shall 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 shall be thoroughly familiar with the scope and limitations of the methods for which qualified and should exercise assigned responsibility for on-the-job training and guidance of trainees and NDT Level I personnel. The NDT Level II shall be able to organize and report the results of NDT.
- (3) **NDT Level III.** An NDT Level III individual shall be capable of establishing techniques and procedures; interpreting codes, standards, specifications, and procedures; and designating the particular NDT methods, techniques, and procedures to be used. The NDT Level III should be responsible for the NDT operations for which qualified and assigned and shall be capable of interpreting and evaluating results in terms of existing codes, standards, and specifications. The NDT Level III should have sufficient practical background in applicable materials, fabrication, and product technology to establish techniques and to assist in establishing acceptance criteria when none are otherwise available. The NDT Level III shall have general familiarity with other appropriate NDT methods, as demonstrated by the ASNT Level III Basic examination or other means. The NDT Level III, in the methods in which certified, should be capable of training and examining NDT Level I and II personnel for certification in those methods.

5. Written Practice

- 5.1 The employer shall establish a written practice for the control and administration of NDT personnel training, examination, and certification.
- 5.2 The employer's written practice 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 NDT shall have sufficient education, training, and experience to

ensure understanding of the principles and procedures of those NDT methods 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 Section 6.3.

- 6.3 To be considered for certification, a candidate shall satisfy one of the following criteria for the applicable NDT level:

- (1) NDT Levels I and II
Table 6.3.1 (page 7) 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.
- (2) NDT Level III
 - (a) Have graduated from a minimum four-year college or university curriculum with a degree in engineering or science, plus one year's experience in NDT testing in an assignment comparable to that of an NDT Level II in the applicable NDT method(s),
 - or:
 - (b) Have completed with passing grades at least two years of engineering or science study at a university, college, or technical school, plus two years' experience in assignments at least comparable to that of NDT Level II in the applicable NDT method(s),
 - or:
 - (c) Have four years' experience in an assignment at least comparable to that of an NDT Level II in the applicable NDT 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 by assignments at least comparable to NDT Level II in other methods listed in Section 3 of this Recommended Practice as defined in the employer's written practice.

7. Training Programs

- 7.1 Personnel being considered for initial certification shall complete sufficient organized training to become thoroughly familiar with the principles and practices of the specified NDT method related to the level of certification desired and applicable to the processes to be used and the products to be tested.
- 7.2 The training program shall include sufficient examinations to assure that the necessary information has been comprehended.
- 7.3 Recommended training course outlines for Levels I and II personnel and recommended references which may be used as technical source material follow in the Recommended Training Courses section of this Recommended Practice.

8. Examinations

8.1 An NDT Level III individual or a designated representative shall administer and grade the examinations specified in Section 8.3 through 8.8.

8.2 Vision Examinations

- (1) Near-Vision Acuity. The examination shall assure natural or corrected near-distance acuity in at least one eye such that the applicant is capable of reading a minimum of Jaeger Number 2 or equivalent type and size letter at a distance of not less than 12 inches (30.5 cm) on a standard Jaeger test chart. The ability to perceive an OrthoRater minimum of 8 or similar test pattern is also acceptable. This shall be administered annually.
- (2) Color Contrast Differentiation. The examination should demonstrate the capability of distinguishing and differentiating contrast among colors used in the method. This shall be conducted upon initial certification and at three-year intervals thereafter.

8.3 General (Written — for NDT Levels I and II)

- (1) The general examinations shall address the basic principles of the applicable method.
- (2) In preparing the examinations, the NDT Level III shall select or devise appropriate questions covering the applicable method to the degree required by the employer's written practice.
- (3) See the Appendix for example questions.
- (4) The number of questions which shall be given is as follows:

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

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

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

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

8.5 Practical (for NDT Level I and II)

- (1) The candidate should demonstrate familiarity with and ability to operate the necessary NDT equipment, record and analyze the resultant information to the degree required.
- (2) At least one selected specimen should be tested and the results of the NDT analyzed by the candidate.
- (3) The description of the specimen, the NDT procedure, including check points, and the results of the examination shall be documented.
- (4) NDT Level I Practical Examination. Proficiency shall be demonstrated in performing the applicable-NDT on one or more samples approved by the NDT Level III. At least ten (10) different checkpoints requiring an understanding of test variables and the employer's procedural requirements shall be included in this practical examination.
- (5) NDT Level II Practical Examination. Proficiency shall be demonstrated in selecting and performing the applicable NDT method and interpreting and evaluating the results on one or more samples approved by the NDT Level III. At least ten (10) different checkpoints requiring an understanding of NDT variables and the employer's procedural requirements shall be included in this practical examination.

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

Test Method	Question Booklets
Radiographic Test Method	A
Magnetic Particle Method	B
Ultrasonic Test Method	C
Liquid Penetrant Method	D
Electromagnetic (Eddy Current and Flux Leakage) Test Method	E
Neutron Radiographic Test Method	F
Acoustic Emission Test Method	G*
Leak Testing Method:	
Bubble Leak Testing	HB
Pressure Change Measurement	HP
Halogen Diode Detector Leak Testing	HH
Mass Spectrometer Test Method	HM
Visual Test Method	I*
* In course of preparation	

8.7 The written examinations shall be administered without access to reference material (closed-book) except that necessary data, such as graphs, tables, specifications, procedures, codes, etc., may be provided. All questions used for Level I and Level II examinations shall be approved by the responsible Level III.

8.8 NDT Level III Examinations

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

- (5) The employer may delete the specific examination described in 8.8(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.

8.9 Grading

- (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 actual administration and grading of Level III examinations may be performed by a designated representative of the employer.
- (2) For Level I and II personnel, a composite grade shall be determined by simple averaging of the general, specific, and practical examination results. For Level III personnel, the composite grade shall be determined by simple averaging of the basic, method, and specific examination results.
- (3) Examinations administered for qualification shall result in a composite grade of at least 80 percent, with no individual examination having a grade less than 70 percent.
- (4) When an examination is administered and graded for the employer by an outside agency and the outside agency issues grades of pass or fail only, on a certified report, then the employer may accept the pass grade as 80 percent for that particular examination.

8.10 Reexamination

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

9. Certification

- 9.1** Certification of all levels of NDT personnel is the responsibility of the employer.
- 9.2** The employer shall establish a written practice covering all phases of certification, including training, as specified in Section 5.
- 9.3** Certification of NDT personnel shall be based on demonstration of satisfactory qualification in accordance with Sections 6, 7, and 8, as modified by the employer's written practice.
- 9.4** 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 is retained by the employer.
- 9.5** The employer who purchases outside services is responsible for assuring that the training and examination services are in accordance with the employer's written practice.

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

- (1) The qualification records of the certified individuals shall be maintained by the employer and shall include the following:
 - (a) Name of certified individual.
 - (b) Level of certification and NDT method.
 - (c) Educational background and experience of certified individuals.
 - (d) Statement indicating satisfactory completion of training in accordance with the employers written practice.
 - (e) Results of the vision examinations prescribed in 8.2 for the current certification period.
 - (f) Current examination copy(ies) or evidence of successful completion of examinations.
 - (g) Other suitable evidence of satisfactory qualifications when such qualifications are used in lieu of examinations.
 - (h) Composite grade(s) or suitable evidence of grades.
 - (i) Dates of certification and/or recertification and the dates of assignments to NDT.
 - (j) Signature of employer's designated representative.

9.7 Recertification

- (1) All levels of NDT personnel shall be recertified periodically in accordance with one of the following criteria:
 - (a) Evidence of continuing satisfactory performance.

- (b) Reexamination in those portions of the examinations in Section 8 deemed necessary by the employer's NDT Level III.

- (2) Recommended maximum recertification in intervals are
 - (a) Levels I and II - 3 years
 - (b) Level III - 5 years
- (3) NDT personnel may be reexamined any time at the discretion of the employer and have their certifications extended or revoked.
- (4) The employer's written practice shall include rules covering the duration of interrupted service that requires reexamination and recertification.

10. Termination

10.1 The employer's certification shall be deemed revoked when employment is terminated.

10.2 A Level I, Level II, or Level III whose certification has been terminated may be certified to the former NDT level by a new employer based on examination, as described in Section 8, provided all of the following conditions are met to the new employer's satisfaction:

- (1) The employee has proof of prior certification.
- (2) The employee was working in the capacity to which certified within six (6) months of termination.
- (3) The employee is being recertified within six (6) months of termination.

Table 6.3.1

Recommended Initial Training and Experience Levels

	Examination Method	RT		MT		UT		PT		ET		NRT		AET		VT		LT							
	Level	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I				II			
	Technique																	BT	PCT	HDLT	MSLT	BT	PCT	HDLT	MSLT
Initial Training (Hours)	A High school graduation or equivalent	39	40	12	8	40	40	4	8	40	40	28	40	40	40	8	16	2	24	12	40	4	16	8	24
	B 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	30	40	4	4	24	40	20	40	32	40	4	8	2	16	8	28	2	12	6	16
Experience Level (Months per Level)**	Educational levels as listed above	3	9	1	3	3	9	1	2	1	9	6	24	6	18	1	2	*	1½	1½	4	½	4	4	6

BT = Bubble Test
 PCT = Pressure Change Test
 HDLT = Halogen Diode Leak Test
 MSLT = Mass Spectrometer Leak Test
 * = 2 Hours
 ** = Work Time Experience per Level

Notes:

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

Recommended Training Courses

Radiographic Testing Method

(RT — Training Course Outline — TC-1)

	Recommended Hours of Instruction	
	A*	B*
Level I		
Radiographic Equipment Operating and Emergency Instructions Course	4	4
Basic Radiographic Physics Course	20	15
Radiographic Technique Course	<u>15</u>	<u>10</u>
Total	39	29
Level II		
Film Quality and Manufacturing Processes Course	20	15
Radiographic Evaluation and Interpretation Course	<u>20</u>	<u>20</u>
Total	40	35

*A High School graduate or equivalent.

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

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

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

Recommended Training for Level I Radiographic Testing

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

- a. Wearing of monitoring badges
- b. Reading of pocket dosimeters
- c. Recording of daily dosimeter readings
- d. "Off-scale" dosimeter-action required
- e. Permissible exposure limits

2. Survey Instruments

- a. Types of radiation instruments
- b. Reading and interpreting meter indications
- c. Calibration frequency
- d. Calibration expiration - action
- e. Battery check - importance

3. Leak Testing of Sealed Radioactive Sources

- a. Requirements for leak testing
- b. Purpose of leak testing
- c. Performance of leak testing

4. Radiation Survey Reports

- a. Requirements for completion
- b. Description of report format

5. Radiographic Work Practices

- a. Establishment of restricted areas
- b. Posting and surveillance of restricted areas
- c. Use of time, distance, and shielding to reduce personnel radiation exposure
- d. Applicable regulatory requirements for surveys, posting, and control of radiation and high-radiation areas

6. Exposure Devices

- a. Daily inspection and maintenance
- b.* Radiation exposure limits for gamma-ray exposure devices
- c. Labeling
- d. Use

- e. Use of collimators to reduce personnel exposure
- f.* Use of "source changers" for gamma-ray sources

7. Emergency Procedures

- a.* Vehicle accidents with radioactive sealed sources
- b.* Fire involving sealed sources
- c.* "Source out" — failure to return to safe shielded conditions
- d.* Emergency call list

8. Storage and Shipment of Exposed Devices and Sources

- a.* Vehicle storage
- b.* Storage vault — permanent
- c.* Shipping instructions — sources
- d.* Receiving instructions — radioactive material

9. State and Federal Regulations

- a. Nuclear Regulatory Commission (NRC) and agreement states — authority
- b. License reciprocity
- c. Radioactive materials license requirements for industrial radiography
- d. Qualification requirements for radiography personnel
- e. Regulations for the control of radiation (state or NRC as applicable)
- f.* Department of Transportation regulations for radiographic-source shipment
- g. Regulatory requirements for X-ray machines (state and federal as applicable)

*Topics may be deleted if the radiography is limited to X-ray exposure devices.

Total recommended hours of instruction for this course:

Classification A — 4 hours

Classification B — 4 hours

Basic Radiographic Physics Course

1. Introduction

- a. History and discovery of radioactive materials
- b. Definition of industrial radiography
- c. Radiation protection-why?
- d. Basic math review: exponents, square root, etc.

- c. Atomic particles — properties of protons, electrons, and neutrons
- d. Atomic structure
- e. Atomic number and weight
- f. Isotope vs. radioisotope

2. Fundamental Properties of Matter

- a. Elements and atoms
- b. Molecules and compounds

3. Radioactive Materials

- a. Production
- (1) Neutron activation

- (2) Nuclear fission
 - b. Stable vs. unstable (radioactive) atoms
 - c. Curie — the unit of activity
 - d. Half-life of radioactive materials
 - e. Plotting of radioactive decay
 - f. Specific activity — curies/gram
- 4. Types of Radiation**
- a. Particulate radiation - properties: alpha, beta, neutron
 - b. Electromagnetic radiation — X-ray, gamma ray
 - c. X-ray production
 - d. Gamma-ray production
 - e. Gamma-ray energy
 - f. Energy characteristics of common radioisotope sources
 - g. Energy characteristics of X-ray machines
- 5. Interaction of Radiation with Matter**
- a. Ionization
 - b. Radiation interaction with matter
 - (1) Photoelectric effect
 - (2) Compton scattering
 - (3) Pair production
 - c. Unit of radiation exposure — the roentgen
 - d. Emissivity of commonly used radiographic sources
 - e. Emissivity of X-ray exposure devices
 - f. Attenuation of electromagnetic radiation — shielding
 - g. Half-value layers; tenth-value layers
 - h. Inverse-square law
- 6. Biological Effects of Radiation**
- a. “Natural” background radiation
 - b. Unit of radiation dose — rem
 - c. Difference between radiation and contamination
 - d. Allowable personnel — exposure limits and the banking concept
 - e. Theory of allowable dose
 - f. Radiation damage — repair concept
 - g. Symptoms of radiation injury
 - h. Acute radiation exposure and somatic injury
 - i. Personnel monitoring for tracking exposure
 - j. Organ radiosensitivity
- 7. Radiation Detection**
- a. Pocket dosimeter
 - b. Difference between dose and dose rate
 - c. Survey instruments
 - (1) Geiger-Müller tube
 - (2) Ionization chambers
 - (3) Scintillation chambers, counters
 - d. Film badge — radiation detector
 - e. TLDs (thermoluminescent dosimeters)
 - f. Calibration
- 8. Exposure Devices and Radiation Sources**
- a. Radioisotope sources
 - (1) Sealed-source design and fabrication
 - (2) Gamma-ray sources
 - (3) Beta and bremsstrahlung sources
 - (4) Neutron sources
 - b. Radioisotope exposure device characteristics
 - c. Electronic radiation sources — 500 keV and less, low-energy
 - (1) Generator — high-voltage rectifiers
 - (2) X-ray tube design and fabrication
 - (3) X-ray control circuits
 - (4) Accelerating potential
 - (5) Target material and configuration
 - (6) Heat dissipation
 - (7) Duty cycle
 - (8) Beam filtration
 - d.* Electronic radiation sources — medium- and high-energy
 - (1)* Resonance transformer
 - (2)* Van de Graaff accelerator
 - (3)* Linac
 - (4)* Betatron
 - (5)* Roentgen output
 - (6)* Equipment design and fabrication
 - (7)* Beam filtration
 - e.* Fluoroscopic radiation sources
 - (1)* Fluoroscopic equipment design
 - (2)* Direct-viewing screens
 - (3)* Image amplification
 - (4)* Special X-ray tube considerations and duty cycle
 - (5)* Screen unsharpness
 - (6)* Screen conversion efficiency
- 9. Special Radiographic Sources and Techniques**
- a.* Flash radiography
 - b.* Stereo radiography
 - c.* In-motion radiography
 - d.* Autoradiography
- *Topics may be deleted if these methods and techniques are not used by the employer.
- Total recommended hours of instruction for this course:
- Classification A — 20 hours
 - Classification B — 15 hours

Radiographic Technique Course

1. Introduction

- a. Process of radiography
- b. Types of electromagnetic radiation sources
- c. Electromagnetic spectrum
- d. Penetrating ability or “quality” of X-rays and gamma rays
- e. Spectrum of X-ray tube source
- f. Spectrum of gamma-radioisotope source
- g. X-ray tube — change of ma or kVp effect on “quality” and intensity

2. Basic Principles of Radiography

- a. Geometric exposure principles
 - (1) “Shadow” formation and distortion
 - (2) Shadow enlargement calculation
 - (3) Shadow sharpness
 - (4) Geometric unsharpness
 - (5) Finding discontinuity depth
- b. Radiographic screens
 - (1) Lead intensifying screens
 - (2) Fluorescent intensifying screens
 - (3) Intensifying factors
 - (4) Importance of screen-to-film contact
 - (5) Importance of screen cleanliness and care
 - (6) Techniques for cleaning screens
- c. Radiographic cassettes
- d. Composition of industrial radiographic film
- e. The “heel effect” with X-ray tubes

3. Radiographs

- a. Formation of the latent image on film
- b. Inherent unsharpness
- c. Arithmetic of radiographic exposure
 - (1) Milliamperage — distance-time relationship
 - (2) Reciprocity law
 - (3) Photographic density
 - (4) X-ray exposure charts — material thickness, kV, and exposure
 - (5) Gamma-ray exposure chart
 - (6) Inverse-square-law considerations
 - (7) Calculation of exposure time for gamma- and X-ray sources

- d. Characteristic Hurter and Driffield (H&D) curve
- e. Film speed and class descriptions
- f. Selection of film for particular purpose

4. Radiographic Image Quality

- a. Radiographic sensitivity
- b. Radiographic contrast
- c. Film contrast
- d. Subject contrast
- e. Definition
- f. Film graininess and screen mottle effects
- g. Penetrameters or image-quality indicators

5. Film Handling, Loading, and Processing

- a. Safe light and darkroom practices
- b. Loading bench and cleanliness
- c. Opening of film boxes and packets
- d. Loading of film and sealing cassettes
- e. Handling techniques for “green film”
- f. Elements of manual film processing

6. Exposure Techniques — Radiography

- a. Single-wall radiography
- b. Double-wall radiography
 - (1) Viewing two walls simultaneously
 - (2) Offset double-wall exposure single-wall viewing
 - (3) Elliptical techniques
- c. Panoramic radiography
- d. Use of multiple-film loading
- e. Specimen configuration

7. Fluoroscopic Techniques

- a. Dark adaptation and eye sensitivity
- b. Special scattered radiation techniques
- c. Personnel protection
- d. Sensitivity
- e. Limitations
- f. Direct screen viewing
- g. Indirect and remote screen viewing

Total recommended hours of instruction for the course:

Classification A — 15 hours

Classification B — 10 hours

Recommended Training for Level II Radiographic Testing

Film Quality and Manufacturing Processes Course

1. Review of Basic Radiographic Principles

- a. Interaction of radiation with matter
- b. Math review
- c. Exposure calculations
- d. Geometric exposure principles
- e. Radiographic-image quality parameters

2. Darkroom Facilities, Techniques, and Processing

- a. Facilities and equipment
 - (1) Automatic film processor vs. manual processing
 - (2) Safe lights
 - (3) Viewer lights
 - (4) Loading bench
 - (5) Miscellaneous equipment
- b. Film loading
 - (1) General rules for handling unprocessed film
 - (2) Types of film packaging
 - (3) Cassette-loading techniques for sheet and roll
- c. Protection of radiographic film in storage
- d. Processing of film — manual
 - (1) Developer and replenishment
 - (2) Stop bath
 - (3) Fixer and replenishment
 - (4) Washing
 - (5) Prevention of water spots
 - (6) Drying
- e. Automatic film processing
- f. Film filing and storage
 - (1) Retention-life measurements
 - (2) Long-term storage
 - (3) Filing and separation techniques
- g. Unsatisfactory radiographs — causes and cures
 - (1) High film density
 - (2) Insufficient film density
 - (3) High contrast
 - (4) Low contrast
 - (5) Poor definition
 - (6) Fog
 - (7) Lightleaks
 - (8) Artifacts

- h. Film density
 - (1) Step-wedge comparison film
 - (2) Densitometers

3. Indications, Discontinuities, and Defects

- a. Indications
- b. Discontinuities
 - (1) Inherent
 - (2) Processing
 - (3) Service
- c. Defects

4. Manufacturing Processes and Associated Discontinuities

- a. Casting processes and associated discontinuities
 - (1) Ingots, blooms, and billets
 - (2) Sand casting
 - (3) Centrifugal casting
 - (4) Investment casting
- b. Wrought processes and associated discontinuities
 - (1) Forgings
 - (2) Rolled products
 - (3) Extruded products
- c. Welding processes and associated discontinuities
 - (1) Submerged arc welding (SAW)
 - (2) Shielded metal arc welding (SMAW)
 - (3) Gas metal arc welding (GMAW)
 - (4) Flux cored arc welding (FCAW)
 - (5) Gas tungsten arc welding (GTAW)
 - (6) Resistance welding
 - (7) Special welding processes — electron beam, electroslag, electrogas, etc.

5. Radiological Safety Principles Review

- a. Controlling personnel exposure
- b. Time, distance, shielding concepts
- c. ALARA (as low as reasonably achievable) concept
- d. Radiation-detection equipment
- e. Exposure-device operating characteristics

Total recommended hours of instruction for this course:

Classification A — 20 hours

Classification B — 15 hours

Radiographic Evaluation and Interpretation Course

1. Radiographic Viewing

- a. Film-illuminator requirements
- b. Background lighting
- c. Multiple-composite viewing
- d. Penetrameter placement
- e. Personnel dark adaptation and visual acuity
- f. Film identification
- g. Location markers
- h. Film-density measurement
- i. Film artifacts

2. Application Techniques

- a. Multiple-film techniques
 - (1) Thickness-variation parameters
 - (2) Film speed
 - (3) Film latitude
- b. Enlargement and projection
- c. Geometrical relationships
 - (1) Geometrical unsharpness
 - (2) Penetrameter sensitivity
 - (3) Source-to-film distance
 - (4) Focal-spot size
- d. Triangulation methods for discontinuity location
- e. Localized magnification
- f. Film-handling techniques

3. Evaluation of Castings

- a. Casting-method review
- b. Casting discontinuities

- c. Origin and typical orientation of discontinuities
- d. Radiographic appearance
- e. Casting codes/standards — applicable acceptance criteria
- f. Reference radiographs

4. Evaluation of Weldments

- a. Welding-method review
- b. Welding discontinuities
- c. Origin and typical orientation of discontinuities
- d. Radiographic appearance
- e. Welding codes/standards — applicable acceptance criteria
- f. Reference radiographs or pictograms

5. Standards, Codes, and Procedures for Radiography

- a. ASTM E94/E142
- b. Acceptable radiographic techniques and setups
- c. Applicable employer procedures
- d. Procedure for radiograph parameter verification
- e. Radiographic reports

Total recommended hours of instruction for this course:

Classification A — 20 hours

Classification B — 20 hours

Recommended Training References

Radiographic Testing Method

- American Society for Metals. *Nondestructive Inspection and Quality Control: Metals Handbook*, Vol. 11, 8th ed. Metals Park, OH, 1976.*
- American Society for Nondestructive Testing. *Question and Answer Book A: Radiographic Test Method, Levels I, II, and III*. Columbus, OH, 1980.*
- American Society for Testing and Materials. "Metallography; Nondestructive Testing," Vol. 03.03. Philadelphia, PA, Latest Edition.*
- American Welding Society. *Welding Handbook*. Vol. 1. Miami, FL, Latest Edition.
- _____. *Welding Inspection*. Miami, FL, Latest Edition.
- British Institute of Non-Destructive Testing. *Basic Metallurgy for Non-Destructive Testing*. Essex, England: W. H. Houldershaw, Ltd., 1981.
- Bryant, Lawrence A. and Paul McIntire, eds. *Nondestructive Testing Handbook: Radiography and Radiation Testing*, Vol. 3, 2nd ed. Columbus, OH: American Society for Nondestructive Testing, 1985.*
- Halmshaw, R. *Industrial Radiology Techniques*. London: Wykeharn Publications; Ltd., New York: Springer Verlag, Inc., 1971.
- _____. *Industrial Radiology: Theory and Practice*. London and New Jersey: Applied Science Publishers, 1982.*
- _____. *Non-destructive Testing: Metallurgy and Materials Science Series*. London: Edward Arnold, 1987.*
- _____. *Physics of Industrial Radiology*. New York: American Elsevier Publishing Co., 1966.*
- Hartford Steam Boiler's Complete Radiography Workbook, 1st ed. Hartford, CT: The Hartford Steam Boiler Inspection and Insurance Co., 1983.
- Industrial Radiography/Holography*. Ridgefield Park, NJ: Agfa-Gevaert, Inc., 1986.*
- McGonnagle, Warren J. *Nondestructive Testing*, 2nd ed. New York: Gordon and Breach, 1975.
- McGuire, Stephen A., and Carol A. Peabody. *Working Safely in Gamma Radiography*, NUREG/BR-0024. Washington, DC: U.S. Government Printing Office, 1982. *
- McMaster, Robert C., ed. *Nondestructive Testing Handbook*, 1st ed. Columbus, OH: American Society for Nondestructive Testing, 1959.*
- Mix, Paul E. *Introduction to Nondestructive Testing: A Training Guide*. New York: John Wiley & Sons, 1987.*
- Moore, Harry D., ed. *Materials and Processes for NDT Technology*. Columbus, OH: American Society for Nondestructive Testing, 1981.*
- Munro, John J., III, and Francis E. Roy, Jr. *Gamma Radiography Radiation Safety Handbook*. Burlington, MA: Amersham Corp., 1986.*
- NDT Terminology*. Wilmington, DE: E.I. du Pont de Nemours and Co., 1981.
- Radiographic Testing, Classroom Training Handbook (CT-6-6)*. San Diego, CA: General Dynamics/ Convair Division, 1967.*
- Radiographic Testing, Programmed Instruction Handbook (PI-4-6)*. San Diego, CA: General Dynamics/ Convair Division, 1983.*
- Radiography in Modern Industry*, 4th ed. Rochester, NY: Eastman Kodak Co., 1980.*
- Richardson, Harry D. *NDT Radiography Training Manual*. Wilmington, DE: E.I. du Pont de Nemours and Co., 1968 reprint.*
- Sensitometric Properties of X-Ray Films*. Rochester, NY: Eastman Kodak Co., 1974.
- Thielsch, Helmut. *Defects and Failures in Pressure Vessels and Piping*. New York: Reinhold Publishing Corp., 1966. *
- _____. *The Sense and Nonsense of Weld Defects*. Morton Grove, IL: Monticello Books, 1967.*

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

Magnetic Particle Testing Method

(MT — Training Course Outline — TC-2)

	Recommended Hours of Instruction	
	A*	B*
Level I	12	8
Level II	8	4

*A High School graduate or equivalent.

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

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

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

Recommended Training for Level I Magnetic Particle Testing

1. Principles of Magnets and Magnetic Fields

- a. Theory of magnetic fields
 - (1) Earth's magnetic field
 - (2) Magnetic fields around magnetized materials
- b. 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
- c. Terminology associated with magnetic article testing

2. Characteristics of Magnetic Fields

- a. Bar magnet
- b. Ring magnet

3. Effect of Discontinuities of Materials

- a. Surface cracks
- b. Scratches
- c. Subsurface defects

4. Magnetization by Means of Electric Current

- a. 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 machined holes, slots, etc.
 - (4) Methods of inducing current flow in parts
 - (a) Contact plates
 - (b) Prods
 - (5) Discontinuities commonly discovered by circular fields
- b. 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
 - (5) Advantages of longitudinal magnetization
 - (6) Disadvantages of longitudinal magnetization

5. Selecting the Proper Method of Magnetization

- a. Alloy, shape, and condition of part
- b. Type of magnetizing current
- c. Direction of magnetic field
- d. Sequence of operations
- e. Value of flux density

6. Inspection Materials

- a. Wet particles
- b. Dry particles

7. Principles of Demagnetization

- a. Residual magnetism
- b. Reasons for requiring demagnetization
- c. Longitudinal and circular residual fields
- d. Basic principles of demagnetization
- e. Retentivity and coercive force
- f. Methods of demagnetization

8. Magnetic Particle Testing Equipment

- a. 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
- b. Manual inspection equipment
- c. Medium and heavy duty equipment
- d. Stationary equipment
- e. Mechanized inspection equipment
 - (1) Semiautomatic inspection equipment
 - (2) Single-purpose semiautomatic equipment
 - (3) Multipurpose semiautomatic equipment
 - (4) Fully automatic equipment

9. Types of Discontinuities Detected by Magnetic Particle Testing

- a. Inclusions
- b. Blowholes
- c. Porosity
- d. Flakes
- e. Cracks
- f. Pipes
- g. Laminations
- h. Laps
- i. Forging bursts
- j. Voids

10. Magnetic Particle Test Indications and Interpretations

- a. Indications of nonmetallic inclusions
- b. Indications of surface seams
- c. Indications of cracks
- d. Indications of laminations
- e. Indications of laps
- f. Indications of bursts and flakes
- g. Indications of porosity
- h. Nonrelevant indications

Total recommended hours of instruction for this course:

Classification A — 12 hours

Classification B — 8 hours

Recommended Training for Level II Magnetic Particle Testing

1. Principles

- a. Theory
 - (1) Flux patterns
 - (2) Frequency and voltage factors
 - (3) Current calculations
 - (4) Surface flux strength
 - (5) Subsurface effects
- b. Magnets and magnetism
 - (1) Distance factors vs. strength of flux
 - (2) Internal and external flux patterns
 - (3) Phenomenon action at the discontinuity
 - (4) Heat effects on magnetism
 - (5) Material hardness vs. magnetic retention

2. Flux Fields

- a. Direct current
 - (1) Depth of penetration factors
 - (2) Source of current
- b. Direct pulsating current
 - (1) Similarity to direct current
 - (2) Advantages
 - (3) Typical fields
- c. Alternating current
 - (1) Cyclic effects
 - (2) Surface strength characteristics
 - (3) Safety precautions
 - (4) Voltage and current factors
 - (5) Source of current

3. Effects of Discontinuities on Materials

- a. Design factors
 - (1) Mechanical properties
 - (2) Part use
- b. Relationship to load-carrying ability

4. Magnetization by Means of Electric Current

- a. Circular techniques
 - (1) Current calculations
 - (2) Depth-factor considerations
 - (3) Precautions — safety and overheating
 - (4) Contact prods and yokes
 - (a) Requirements for prods and yokes
 - (b) Current-carrying capabilities
 - (5) Discontinuities commonly detected
- b. Longitudinal technique
 - (1) Principles of induced flux fields
 - (2) Geometry of part to be inspected
 - (3) Shapes and sizes of coils
 - (4) Use of coils and cables
 - (a) Strength of field
 - (b) Current directional flow vs. flux field
 - (c) Shapes, sizes, and current capacities
 - (5) Current calculations
 - (a) Formulas
 - (b) Types of current required
 - (c) Current demand

- (6) Discontinuities commonly detected

5. Selecting the Proper Method of Magnetization

- a. Alloy, shape, and condition of part
- b. Type of magnetizing current
- c. Direction of magnetic field
- d. Sequence of operations
- e. Value of flux density

6. Demagnetization Procedures

- a. Need for demagnetization of parts
- b. Current, frequency, and field orientation
- c. Heat factors and precautions
- d. Need for collapsing flux fields

7. Equipment

- a. Portable type
 - (1) Reason for portable equipment
 - (2) Capabilities of portable equipment
 - (3) Similarity to stationary equipment
- b. Stationary type
 - (1) Capability of handling large and heavy parts
 - (2) Flexibility in use
 - (3) Need for stationary equipment
 - (4) Use of accessories and attachments
- c. Automatic type
 - (1) Requirements for automation
 - (2) Sequential operations
 - (3) Control and operation factors
 - (4) Alarm and rejection mechanisms
- d. Liquids and powders
 - (1) Liquid requirements as a particle vehicle
 - (2) Safety precautions
 - (3) Temperature needs
 - (4) Powder and paste contents
 - (5) Mixing procedures
 - (6) Need for accurate proportions
- e. Black-light type
 - (1) Black light and fluorescence
 - (2) Visible- and black-light comparisons
 - (3) Requirements in the testing cycle
 - (4) Techniques in use
- f. Light-sensitive instruments
 - (1) Need for instrumentation
 - (2) Light characteristics

8. Types of Discontinuities

- a. In castings
- b. In ingots
- c. In wrought sections and parts
- d. In welds

9. Evaluation Techniques

- a. Use of standards
 - (1) Need for standards and references
 - (2) Comparison of known with unknown
 - (3) Specifications and certifications
 - (4) Comparison techniques
- b. Defect appraisal

- (1) History of part
- (2) Manufacturing process
- (3) Possible causes of defect
- (4) Use of part
- (5) Acceptance and rejection criteria
- (6) Use of tolerances

10. Quality Control of Equipment and Processes

- a. Malfunctioning of equipment
- b. Proper magnetic particles and bath liquid

- c. Bath concentration
 - (1) Settling test
 - (2) Other bath-strength tests
- d. Tests for black-light intensity

Total recommended hours of instruction for this course:

Classification A — 8 hours

Classification B — 4 hours