U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: TRAINING, QUALIFICATION, AND CERTIFICATION OF NONDESTRUCTIVE INSPECTION (NDI) PERSONNEL	Date: 4/25/03	AC No: 65-31A
	Initiated by: AFS-300	Change:

1. PURPOSE. This advisory circular (AC) contains recommendations for the experience, training, qualification, examination, and certification of nondestructive testing personnel for inspection of aircraft, engines, propellers, accessories, and other aviation components. It recommends criteria for the qualification of personnel requiring appropriate knowledge of the technical principles underlying the nondestructive tests they perform. This document applies to those individuals directly responsible for technical adequacy of the Nondestructive Inspection (NDI) methods used, as well as those persons or organizations providing training, supervision, or oversight of NDI personnel. Organizations should have a written program describing the guidelines used to train, qualify, and certify personnel. Inspection personnel qualified under this document may be eligible for Federal Aviation Administration (FAA) repairman's certification with an NDI rating.

2. CANCELLATION. Advisory Circular 65-31, Training, Qualification, and Certification of Nondestructive Inspection (NDI) Personnel, dated October 1, 2001, is canceled.

3. RELATED FEDERAL AVIATION REGULATIONS. Title 14 of the Code of Federal Regulations (14 CFR) part 145, § 145.33; part 147, Aviation Maintenance Technician Schools; and part 65, subpart E, Repairmen.

4. DISCUSSION.

a. Qualified NDI Personnel. Nondestructive testing is defined as inspections, tests, or evaluations which may be applied to a structure or component to determine its integrity, composition, electrical or thermal properties, or dimensions without causing a change in any of these characteristics. Qualified personnel are required for reliable performance of nondestructive testing. Both the performance of tests and the interpretation of results require skill and must be accomplished by trained personnel. They must know the applications and limitations of the various nondestructive testing methods used to locate defects in aircraft structure and components. Persons performing nondestructive testing, inspection, or evaluation (NDT, NDI, NDE) may be qualified in accordance with one or more of the standards listed in paragraph 6, Standards for Qualification, Certification, and Training of NDI Personnel. Other qualification documents may be used when they are included in the approved manual for the organization specified in the contractual document between the user of the NDI services and their provider. The applicable revision should be the latest unless otherwise specified. Qualification should be based on an examination and/or other demonstration of proficiency, competence, and experience, as set forth in the relevant documents.

AUTHENTICATED U.S. GOVERNMENT INFORMATION GPO

b. Records and Documentation of Administrative Practices. An organization's records should include a description of the details to be recorded for each qualified individual and identification of those responsible for developing, administering, and maintaining the organization's qualification program.

c. Requalification Requirements. Requalification requirements should include provisions for reexamination of employees. It should also include the conditions and requirements for the revocation and reinstatement of qualification of individuals and the documentation thereof.

5. DEFINITIONS. Terms included in this document are defined as follows:

a. Acceptance Criteria. The basis for acceptance of the results of an examination as noted in paragraph 10.c.

b. Calibration (instrument). The comparison or adjustment of an instrument, to known references, often traceable to the National Institute of Standards and Technology (NIST). (See **Standardization (instrument)** for inspection of product.)

c. Certification. Written testimony of qualification.

d. Certification Based On Previous Experience. Certifications acceptable to the Administrator of individuals who were certified under a previous qualification program.

e. Documentation. Written or printed record furnishing information or evidence; a legal or official record in paper or electronic form.

f. Evaluation. A determination of the significance of indications.

g. Examination. A formal, controlled, documented interrogation conducted in accordance with a procedure defined in an organization's program.

h. Examiner. A Level III or other qualified representative of the examining organization.

i. Experience. Actual performance or observation conducted in the work environment, resulting in the acquisition of knowledge and skill. This does not include classroom or laboratory training but does include on-the-job training (OJT).

j. General Examination. A written examination addressing the basic principles of the applicable NDI method.

k. Grandfathered. Qualification of individuals who are considered qualified under a prior qualification program. This option can only be used once to start a new program.

l. Indication. The observation, or evidence of an observation, occurring during a NDI or test.

m. Inspector. A qualified individual designated by an organization to provide inspection services.

n. Instructor. An individual qualified and designated, in accordance with this guidance, to provide classroom or laboratory training for NDI personnel. The instructor:

(1) Should have the necessary skills and knowledge to plan, organize, and present classroom, laboratory, or OJT programs of instruction in accordance with approved course outlines, in the method for which qualified;

(2) Should be thoroughly familiar with the theory and practical applications of the method as utilized by the organization; and

(3) Should not conduct NDIs for the acceptance of parts unless he/she is properly qualified.

o. Interpretation. The determination of whether indications are relevant or non-relevant.

p. Method. One of the disciplines of NDI, or testing (e.g., radiography or ultrasonic), within which different techniques exist.

q. On-The-Job Training (OJT). Training in the work environment. Learning objectives should include instrumentation setup, equipment operation, recognition of indications, and interpretation and should be accomplished under the technical guidance of an experienced Level II, Level III, or other designated individual.

r. Organization. A corporation or other similar entity established to provide or receive NDI services.

s. Outside Agency. An independent body under contract for NDI services which may include the training and examination of personnel to the requirements of a standard. Consultants and self-employed individuals are included in this definition.

t. Practical Examination. The hands-on examination used to demonstrate an individual's ability to practice the NDI methods that will be performed for the organization. Questions and answers do not need to be written, but observations and results should be documented.

u. Procedure. A detailed, written instruction for conducting NDIs or qualifying personnel.

v. Qualification. Demonstrated skill, training, knowledge, and experience required for personnel to properly perform the duties of a specific job.

w. Qualification Certificate. A certificate issued by the organization as evidence of qualification to NDI proficiency standards as defined in this document.

x. Qualified Personnel. Personnel qualified to perform NDIs in accordance with, and covered by, provisions of this document.

y. Specific Examination. The written examination to determine an individual's understanding of procedures, codes, standards, and specifications for a given method used by the organization.

z. Standardization (instrument). The adjustment of the equipment (instrument) to a reference value prior to use.

aa. Technique. A procedure within a method. For example: ultrasonic immersion testing used as a part of the ultrasonic method, or fluorescent penetrant inspection as a part of penetrant inspection.

bb. Trainee. An individual participating in a training program for an NDI method who is not yet qualified. Trainees should obtain work experience only under the direct supervision of a Qualified Instructor, Level II, or Level III in the same method. Trainees should not independently conduct tests; make, accept or reject decisions; or perform any other NDI functions.

cc. Training. An organized and documented program of activities designed to impart the knowledge and skills necessary for qualification. This program may be a mix of classroom, laboratory, programmed self-teaching, and OJT.

6. STANDARDS FOR QUALIFICATION, CERTIFICATION, AND TRAINING OF NDI PERSONNEL.

a. Individuals who will provide equivalent competency to ensure satisfactory maintenance as set forth in relevant aviation regulations should:

(1) Have knowledge and experience gained while attending schools with curricula developed in accordance with 14 CFR part 147;

(2) Have OJT with an appropriately certified organization; and

(3) Meet the criteria set forth in the following list of acceptable standards:

(a) AIA-NAS-410, Aerospace Industries Association, National Aerospace Standard, NAS Certification & Qualification of Nondestructive Test Personnel.

(b) ATA Specification 105, Air Transport Association, Guidelines for Training and Qualifying Personnel in Nondestructive Testing Methods.

(c) Canadian National Regulations contained in CAN/CGSB-48.9712-95, Qualification and Certification of Nondestructive Testing Personnel.

(d) International Standards Organization (ISO) document: ISO 9712, Nondestructive Testing – Qualification and Certification of Personnel.

(e) MIL-STD-410E, Military Standard, Nondestructive Testing Personnel Qualification and Certification (acceptable, although now rescinded).

b. Individuals meeting the criteria established by the following certification programs may be deemed qualified after FAA review of the specific written practice establishing certification criteria.

(1) American Society for Nondestructive Testing, Inc. (ASNT), Recommended Practice SNT-TC-1A, Personnel Qualification and Certification in Nondestructive Testing.

> **NOTE: This document is intended as a guideline for organizations to establish their own written practice for the qualification of Nondestructive Testing Personnel. It is not intended to be used as a strict specification, but may be used as one.**

(2) Certain International NDI standards accepted by other approved regulatory agencies and national qualification programs have been, and may be considered to be, acceptable standards. In particular, European standard prEN 4179, Qualification and Approval of Personnel for Nondestructive Testing, is acceptable.

c. Other standards or alternative methods of qualification and certification may be satisfactory if found acceptable by the Administrator.

d. Qualifications may be established by completing the qualification, examination, and reexamination requirements described in paragraphs 7 through 11 and Appendix A, Course Outline for NDT Methods, of this AC.

7. NONDESTRUCTIVE TESTING METHODS. Qualification of personnel in accordance with this AC should be applicable to the following methods:

a. Radiographic (RT).

b. Magnetic Particle (MT).

c. Ultrasonic (UT).

d. Liquid Penetrant (PT).

e. Eddy Current (ET).

> **NOTE: Methods other than those listed above, such as visible, acoustic emission, neutron radiography, leak testing, thermography, holography, computed tomography, or any other NDI method that can be used for inspection of aircraft, engines, accessories, or components, may be added if they become broadly applied within the organization and guidance exists as to their application. For example, if infrared or shearography become the subject of a manufacturer's Service Bulletins, the Administrator would also require assurance that only qualified individuals perform those inspections.**

8. QUALIFICATIONS.

a. Training, Experience, and Credentials. To properly perform the necessary tasks, NDI personnel should have appropriate training and experience and, when required by the qualifying organization, hold a valid and current airframe and/or powerplant mechanic certificate or repairman certificate. Instructors are not required to hold such certificates unless it's a prerequisite of the qualifying organization. Possession of an FAA airframe and/or powerplant mechanic certificate may be considered part of the required training experience.

b. Competence. NDI personnel should:

(1) Be qualified to direct and perform inspections in the method required;

(2) Be able to set up and standardize equipment (where applicable), read and interpret indications, and evaluate them with reference to applicable standards and specifications;

(3) Be thoroughly familiar with the scope and limitations of the method;

(4) Have the ability to apply detailed techniques to products or parts within the limitations of the qualifications requirements; and

(5) Be able to organize and report NDI results in a manner specified by the employing organization.

c. Certification. A certificate may be issued by the organization as evidence of qualification. This qualification certificate may define the level of qualification based on the requirements listed below. Usually there are three basic levels of personnel qualification: Level I, Level II, and Level III. These levels may be further subdivided for specific operations, when appropriate.

(1) Level I Special (Optional). Level I Special is the lowest qualification level and is task specific. Personnel may be qualified to this level to perform a specific task on a particular component. Classroom instruction and OJT may be limited to the specific requirements to perform the task. Written evidence of qualification should be limited to a specific task. An example of this level is the Eddy Current Inspection of aircraft wheels.

(2) Level I. Level I should be for a specific method. To be qualified for Level I, an individual should have the skills and knowledge to perform specific tests, specific calibrations, specific interpretations and evaluations for acceptance or rejection, and document the results in accordance with specific procedures. The individual should:

- be knowledgeable of any necessary preparation of parts before or after inspection;
- be able to follow procedures pertinent to the techniques for which he/she is qualified;
- receive the necessary guidance or supervision from a qualified Level II, Level III, or other designated individual; and
- meet the training and experience guidelines in Table 1.

TABLE 1. MINIMUM CLASSROOM TRAINING AND EXPERIENCE REQUIREMENTS

NDI METHOD	LEVELS		
	CLASSROOM INSTRUCTION (HRS)	EXPERIENCE (HRS/MO.) [3]	
	All Levels	Level I	Level II [2]
EDDY CURRENT	40	480/3 mo. [1,4]	1440/9 mo.
ULTRASONIC	40	480/3 mo. [1,4]	1440/9 mo.
MAGNETIC PARTICLE	16	160/1 mo. [1,5]	480/3 mo.
PENETRANT	16	160/1 mo. [1,5]	480/3 mo.
RADIOGRAPHY	40	480/3 mo. [1,4]	1440/9 mo.
OTHER[6]	40	480/3 mo.	1440/9 mo.

NOTES:

1. To be qualified, a trainee must complete the required classroom training and fulfill the requirements in paragraph 10, Examination.

2. A Level I may be upgraded to Level II after satisfactory completion of required experience in method.

3. Initial experience may be gained simultaneously in two or more methods if:

a. The candidate spends a minimum of 25 percent of work time on each method for which evidence of qualification is sought, and

b. The remainder of work time claimed as experience is spent in NDI-related activities defined in the employer's written practice.

4. During the first 90 days, the individual should independently accomplish only procedures for which he/she has previously been qualified by OJT. Documentation is required.

5. The experience requirements for Magnetic Particle or Penetrant can be reduced to 80 hours (2 weeks) when the inspector holds an FAA airframe or powerplant mechanic certificate.

6. The "Other" category is included as minimal guidance for anything else, such as shearography, holography, etc.

(3) Level II. In addition to the requirements specified in the Level I qualification, the individual qualified to Level II should:

(a) Have the skills and knowledge to set up and standardize equipment, conduct tests, and to interpret, evaluate, and document results in accordance with procedures in all techniques in the methods used by the organization;

(b) Be thoroughly familiar with the scope and limitations of the methods for which he/she is qualified;

(c) Be capable of providing OJT for trainees and other inspectors;

(d) Be able to organize and document NDI results;

(e) Be familiar with the codes, standards, and other regulatory documents which control the methods used by the organization; and

(f) Meet the guidelines in Table 1.

(4) Level III. In addition to the requirements specified in the Level II qualification, individuals qualified to Level III should have the skills and knowledge to interpret codes, standards, and other regulatory documents that control the methods used by the organization. A Level III may be qualified in one or more methods. Only individuals at this level should have the authority to approve procedures for the methods for which they are qualified. The individual should:

(a) Be able to select the method and technique for a specific inspection;

(b) Select and/or design equipment and reference standards;

(c) Verify the adequacy of procedures;

(d) Have general knowledge of all other NDI methods utilized by the organization; and

(e) Be capable of conducting or directing the training and examination of personnel in the methods for which they are qualified.

d. Qualification Based on Previous Experience. Personnel presently qualified to perform specific methods of NDI may request documentation citing evidence of Level I, Level II, or Level III qualification by their organization. By presenting documentation of previous training and experience as previously required by the organization for each NDI method, an individual may be deemed grandfathered to the requested level. Permanent personnel records should indicate when and to what level an individual has been qualified.

9. REQUIREMENTS FOR QUALIFICATION.

a. The organization should establish a written program for the control and administration of personnel training, examination, qualification, and documentation. This program should include a method for maintaining proficiency, including recurrent training and steps to decertify, retrain, or recertify as required.

b. The organization should provide qualified instructors who have satisfactorily completed an approved NDI program for the applicable testing method. Such individuals should have demonstrated practical experience and knowledge of the subject. At the option of the organization and as provided in their written practice, a qualified outside agency may be engaged to provide NDI training, qualification, and testing.

c. Qualified personnel should have completed sufficient organized training to become familiar with principles and practices of the applicable test method. The training program should include OJT instructions in basic principles, products, equipment, operating procedures, test techniques, and review and analysis of inspection/test data that the individual will encounter in his/her work assignment. Upon becoming qualified, personnel are entitled to notification within a reasonable amount of time.

d. Qualification of personnel should be based on demonstration of satisfactory performance as determined by procedures outlined in paragraph 10, Examination. To be considered qualified, a candidate should satisfy one or more of the following criteria for the applicable NDI skills:

(1) Level I, Special. Initial classroom hours and OJT experience should be sufficient to qualify an individual for a specific task. To be qualified, the individual must meet the requirements of the organization's written procedure.

(2) Level I/Level II. Table 1 lists the required classroom training hours and OJT/experience and testing requirements to be used in establishing written practices for initial qualification to Level I or Level II.

(3) Level III. In order to qualify for Level III, a candidate, at a minimum, should:

(a) Have graduated from a minimum four-year college or university curriculum with a degree in engineering or related science, plus one year minimum experience in NDI testing in an assignment comparable to that of an NDI Level II in the applicable NDI method(s);

(b) Have completed two years of engineering or related science study at a university, college, or technical school, plus two years' experience in assignments at least comparable to that for NDI Level II in the applicable NDI method(s); or

(c) Have four years' experience in an assignment at least comparable to that of an NDI Level II in the applicable NDI method(s).

10. EXAMINATION. This section outlines examination guidelines for Levels I, II, and III. The examination should consist of demonstrations in the following five segments to confirm physical and technical qualification:

a. Required Examinations.

(1) Physical Examination.

(a) Vision. An examination to assure near vision of at least one eye, either corrected or uncorrected, such that the individual can read Snellen equivalent of 20/20 (Jaeger #1). The examination must be on a periodic basis, not to exceed one year.

(b) Color Perception. Distinguish and differentiate between colors necessary for the inspection method for which qualification is sought.

(c) Physical Requirements. The physical requirements established by the organization as a condition of employment will normally suffice.

(2) General Skills Examination.

(a) The general examination for all skill levels should be a closed-book examination consisting of questions that cover the basic inspection/test principles relative to the applicable method and the equipment, operating procedures, and techniques that the individual may encounter in his or her assignment.

(b) In preparing the examination, the organization should select pertinent questions covering the applicable method. A minimum of 40 questions should be used for the general examination and should cover reading, interpreting findings (indications), knowledge of standards, etc.

(c) The examination should also cover the specifications and/or standards used by the organization in its NDI procedures.

(d) Relevant standards and documentation upon which the examination is based should be available in both English and the language used in the documentation for which evidence of qualification is sought. The examination should be in English.

(3) Practical Examination (Classroom). As part of the classroom training, the individual being considered for qualification should satisfactorily demonstrate that he/she is familiar with and can operate the necessary test equipment and interpret the resultant information to the degree required by the instructor.

(4) Practical Examination (OJT Shop). This experience should be accomplished in the shop area on actual components under normal working conditions. The hours of OJT are defined in the experience section of Table 1. Only personnel who have demonstrated that they possess the required knowledge and ability to meet Level I, Level II, or Level III requirements should be considered qualified. Such demonstration should include demonstration of proficiency on test samples related to tasks identified by the qualifying organization.

(5) FAA Certification. Upon satisfactory completion of the required physical, classroom training, examinations and shop OJT, as outlined in this AC, and upon receipt of a Qualification Statement by his/her organization, or by another process acceptable to the FAA Administrator, an individual may apply to the FAA for certification as a repairman with the appropriate ratings and limitations.

b. Grading of Examinations.

(1) A Level III or other qualified examiner as provided for in the organization's written program should conduct and grade or evaluate the qualification examinations for each level.

(2) Examinations administered for qualification should result in a composite grade of at least 80 percent, with no individual examination having a grade less than 70 percent.

c. Acceptance Criteria. If acceptance criteria (e.g., reference radiographs, test samples) are not included in a standard or procedure, they should be provided as a part of the examination.

d. Reexamination. Candidates failing the examinations may be given time for additional studies and be reexamined at the discretion of the organization, and as provided in the organization's written program. The reexamination should not utilize the same questions, test samples, or indications that were used in the initial examination.

11. REQUALIFICATION/RECURRENT TRAINING. Requalification examinations should consist of demonstration of proficiency in the procedure for which the applicant is being examined. Requalification should occur, at a minimum, every three years. Personnel should be required to be retrained or reexamined and their qualification certification continued or revoked in accordance with the organization's written program and at the discretion of the organization when an individual:

a. Demonstrates unsatisfactory performance, or where data indicates that performance of an individual is unsatisfactory. Unsatisfactory performance may be determined by the responsible person

from the organization who originally qualified the individual or by some other documented method approved by the organization.

b. Has been inactive in the method for a six-month period or other shorter interval as provided in the organization's written program.

c. Fails to be evaluated for compliance with performance standards by a Level III or other designated individual at an interval not to exceed three (3) years.

d. The vision examination time limits per paragraph 10a(1) have expired.

12. RECORDS. The organization should maintain appropriate personnel training records in accordance with their qualification program for as long as an inspector's qualification is in effect. Records must be available for audit by authorized personnel, and should at a minimum specify the date, time, and place of qualification, the employing organization, as well as the particular details applying to the certificate holder, such as level, special qualifications or limitations, and standards under which the holder is qualified. In addition, the records must include a copy of any FAA repairman certificates issued to the individual.

/s/ Louis C. Cusimano
for James J. Ballough
Director, Flight Standards Service

APPENDIX A. COURSE OUTLINE FOR NDT METHODS

The entire body of knowledge contained in these training outlines for the applicable method shall be covered in the training course. Each method taught shall consist of basic classroom instruction and appropriate practical demonstrations and/or on-the-job training to ensure complete understanding.

1. RADIOGRAPHIC EQUIPMENT OPERATING & EMERGENCY INSTRUCTIONS TRAINING COURSE.

NOTE 1: It is recommended that the trainee receive instruction in this course prior to performing work in radiography. This part of the training is not regulated by the Federal Aviation Administration (FAA). It must comply with the requirements of the Agreement State or NRC License.

NOTE 2: Topics so indicated (*) may be deleted if the radiography is limited to X-ray exposure devices (non-isotope inspection).

NOTE 3: The training hours for radiography can be reduced to 40 hours total, providing the trainee is seeking qualification in non-isotope methods. If the trainee is to be qualified for isotope radiography, the additional 40 hours in isotope theory and practices is recommended.

a. PERSONNEL MONITORING
- **(1)** Wearing of personnel monitoring badges
- **(2)** Reading of pocket dosimeters
- **(3)** Recording of daily dosimeter readings
- **(4)** "Offscale" dosimeter – action required
- **(5)** Permissible personnel exposure limits

b. SURVEY INSTRUMENTS
- **(1)** Types of radiation survey instruments
- **(2)** Reading and interpreting survey instrument meter indications
- **(3)** Calibration frequency
- **(4)** Calibration expiration – action
- **(5)** Battery check – importance

c. LEAK TEST OF SEALED RADIOACTIVE SOURCES
- ***(1)** Requirements for leak test
- ***(2)** Purpose of leak test
- ***(3)** Performance of leak test

d. RADIOGRAPHICAL SURVEY REPORTS
- **(1)** Requirements for completing
- **(2)** Description of report format

e. RADIOGRAPHY WORK PRACTICES
- **(1)** Establishment of restricted areas
- **(2)** Radiation exposure

(3) Use of time, distance, and shielding to reduce personnel radiation exposure

(4) Applicable regulatory requirements for surveys, posting, and control of radiation and high radiation areas

f. EXPOSURE DEVICES

(1) Daily inspection and maintenance for exposure devices

*** (2)** Radiation exposure limits for gamma ray exposure devices

(3) Labeling of exposure devices

(4) Use of exposure devices

(5) Use of collimators to reduce personnel exposure

*** (6)** Use of "Source Changer" from gamma ray sources

g. STORAGE AND SHIPMENT OF EXPOSURE DEVICES AND SOURCES

*** (1)** Vehicle accidents with radioactive sealed sources

*** (2)** Fire involving sealed sources

*** (3)** "Source Out" – failure to return to safe shielded conditions

*** (4)** Emergency call list

h. STATE AND FEDERAL REGULATIONS

(1) The NRC and agreement states – authority

(2) License reciprocity

*** (3)** Radioactive materials license requirements for industrial radiography

(4) Qualification requirements for radiography personnel

(5) Regulations for control of radiation (State/NRC as applicable)

*** (6)** Department of Transportation regulations for radiography source shipment

(7) Regulatory requirements for X-ray machines (state/federal as applicable)

2. BASIC RADIOGRAPHY PHYSICS TRAINING COURSE

a. INSTRUCTION

(1) History and discovery of radioactive materials

(2) Definition of industrial radiography

(3) Radiation protection – why it is needed

(4) Basic math review, exponents, square roots, etc.

b. FUNDAMENTAL PROPERTIES OF MATTER

(1) Elements and atoms

(2) Molecules and compounds

(3) Atomic particles, properties of protons, electrons, and neutrons

(4) Atomic structure

(5) Atomic number and weight

(6) Isotope versus radioisotope

c. RADIOACTIVE MATERIALS

*** (1)** Production of radioactive materials

(a) Neutron activation

(b) Nuclear fission

*** (2)** Stable v. unstable (radioactive) atoms

*** (3)** Curie – the unit of activity

*** (4)** Half-life of radioactive materials
*** (5)** Plotting of radioactive decay
*** (6)** Specific activity – curies/grams

d. TYPES OF RADIATION
(1) Particulate radiation properties: alpha, beta, neutron
(2) Electromagnetic radiation: X-ray, gamma ray
(3) X-ray production
(4) Gamma ray production
(5) Gamma ray energy
(6) Energy characteristics of common radioisotope sources
(7) Energy characteristics of X-ray machines

e. INTERACTION OF RADIATION WITH MATTER
(1) Ionization
(2) Radiation interaction with matter
(a) Photoelectric effect
(b) Compton scattering
(c) Pair production
(3) The unit of radiation exposure – the Roentgen
(4) Emissivity of commonly used radiography sources
(5) Emissivity of X-ray exposure devices
(6) Attenuation of electromagnetic radiation – shielding
(7) Half value layers/tenth value layers
(8) Inverse square law

f. BIOLOGICAL EFFECTS OF RADIATION
(1) "Natural" background radiation
(2) The unit of radiation dose – REM
(3) The difference between radiation and contamination
(4) Allowable personnel exposure limits and the banking concept
(5) Theory of allowable dose
(6) Radiation damage – repair concept
(7) Symptoms of radiation injury
(8) Acute radiation exposure and somatic injury
(9) Personnel monitoring for tracking exposure
(10) Organ radiosensitivity

g. RADIATION DETECTION
(1) The pocket dosimeter
(2) The difference between dose and dose rate
(3) Survey instruments
(a) Geiger muller tube
(b) Ionization chambers
(c) Scintillation chambers counters
(4) Film badge – radiation detector
(5) TLD (Thermoluminescent Dosimeters)
(6) Calibration of survey instruments

h. EXPOSURE DEVICES AND RADIATION SOURCES
- * **(1)** Radioisotope sources
  - **(a)** Sealed source design and fabrication
  - **(b)** Gamma ray sources
  - **(c)** Beta and bremsstrahlung sources
  - **(d)** Neutron sources
- * **(2)** Radioisotope exposure device characteristics
- **(3)** Electronic radiation sources – 500 key & 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

i. Final written/practical examination

TOTAL TIME (HOURS): 40

3. RADIOGRAPHY TECHNIQUE TRAINING COURSE

a. INTRODUCTION
- **(1)** The process of radiography
- **(2)** Types of electromagnetic radiation sources
- **(3)** The electromagnetic spectrum
- **(4)** Penetrating ability or quality of X-rays
- * **(5)** Penetrating ability or quality of gamma rays
- **(6)** Spectrum of X-ray tube source
- * **(7)** Spectrum of gamma radioisotope source
- **(8)** X-ray tube – change of ma or kvp effect on quality and intensity

b. BASIC PRINCIPLES OF RADIOGRAPHY
- **(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)** 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
- **(3)** Radiographic cassettes
- **(4)** Composition of industrial radiographic film
- **(5)** The “heel effect” with X-ray tubes

c. THE RADIOGRAPH
- **(1)** Formation of the latent image on film
- **(2)** Inherent unsharpness
- **(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
- **(4)** The characteristic (h and d) curve
- **(5)** Film speed and class descriptions
- **(6)** Selection of film for participation purpose

d. RADIOGRAPHIC IMAGE QUALITY
- **(1)** Radiographic sensitivity
- **(2)** Radiographic contrast
- **(3)** Film contrast
- **(4)** Subject contrast
- **(5)** Definition
- **(6)** Film graininess and screen mottle effect
- **(7)** Penetrameters or image quality indicators

e. FILM HANDLING, LOADING, AND PROCESSING
- **(1)** Safelight and darkroom practices
- **(2)** Loading bench and cleanliness
- **(3)** Opening of film boxes and packets
- **(4)** Loading of film and sealing cassettes
- **(5)** Handling techniques for "green film"
- **(6)** Elements of manual film processing

f. EXPOSURE TECHNIQUES – RADIOGRAPHY
- **(1)** Single-wall radiography
- **(2)** Double-wall radiography
  - **(a)** Viewing two walls simultaneously
  - **(b)** Offset double-wall exposure single-wall viewing
  - **(c)** Elliptical techniques
- **(3)** Panoramic radiography
- **(4)** Use of multiple film loading
- **(5)** Specimen configuration

4. FILM QUALITY & MANUFACTURING PROCESS TRAINING COURSE

a. REVIEW OF BASIC RADIOGRAPHIC PRINCIPLES
- **(1)** Interaction of radiation with matter
- **(2)** Math review
- **(3)** Exposure calculations

(4) Geometric exposure principles
(5) Radiographic image quality parameters

b. DARK ROOM FACILITIES, TECHNIQUES, AND PROCESSING
(1) Facilities and equipment
(a) Automatic film processor versus manual processing
(b) Safe lights
(c) View lights
(d) Loading bench
(e) Miscellaneous equipment
(2) Film loading
(a) General rules for handling unprocessed film
(b) Type of film packing
(c) Cassette loading techniques for sheet and roll
(3) Protection of radiographic film in storage
(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
(5) Automatic filming processing
(6) Film filing and storage
(a) Retention life measurements
(b) Long-term storage
(c) Filing and separation techniques
(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
(8) Film density
(a) Step wedge comparison film
(b) Densitometers

c. INDICATIONS, DISCONTINUITIES, AND DEFECTS
(1) Indications
(2) Discontinuities
(a) Inherent
(b) Processing
(c) Service
(3) Defects

d. RADIOLOGICAL SAFETY PRINCIPLE REVIEW
- **(1)** Controlling personnel exposure
- **(2)** Time, distance, shielding concepts
- **(3)** ALARA concept
- **(4)** Radiation-detection equipment
- **(5)** Exposure device operating characteristics

5. RADIOGRAPHIC EVALUATION & INTERPRETATION TRAINING COURSE

a. RADIOGRAPHIC VIEWING
- **(1)** Film illuminator requirements
- **(2)** Background lighting
- **(3)** Multiple-composite viewing
- **(4)** Penetrameter placement
- **(5)** Personnel dark adaptation and visual acuity
- **(6)** Film identification
- **(7)** Location markers
- **(8)** Film density measurement
- **(9)** Film artifacts

b. APPLICATION TECHNIQUES
- **(1)** Multiple film techniques
  - **(a)** Thickness variation – parameters
  - **(b)** Film speed
  - **(c)** Film latitude
- **(2)** Enlargement and projection
- **(3)** Geometrical relationships
  - **(a)** Geometrical unsharpness
  - **(b)** Penetrameter sensitivity
  - **(c)** Source film distance
  - **(d)** Focal spot size
- **(4)** Triangulation methods for discontinuity location
- **(5)** Magnification localized
- **(6)** Film handling techniques

c. EVALUATION OF WELDMENTS
- **(1)** Welding method review
- **(2)** Welding discontinuities
- **(3)** Origin and typical orientation of discontinuities
- **(4)** Radiographic appearance
- **(5)** Welding codes and standards – applicable acceptance criteria
- **(6)** Reference radiographs or pictograms

d. STANDARDS, CODES, AND PROCEDURES FOR RADIOGRAPHY\
- **(1)** ASTM E94/E142
- **(2)** Acceptable radiographic techniques and setups
- **(3)** Applicable employer procedures

(4) Procedure/radiograph parameter verification
(5) Radiographic reports

e. FINAL WRITTEN/PRACTICAL EXAMINATION

TOTAL TIME (HOURS): 40

6. MAGNETIC PARTICLE TESTING TRAINING COURSE

a. PRINCIPLES OF MAGNETS AND MAGNETIC FIELDS
(1) Theory of magnetic fields
(a) Earth's magnetic field
(b) Magnetic fields around magnetized materials
(2) Theory of magnetism
(a) Magnetic poles
(b) Law of magnetism
(c) Materials influenced by magnetic fields:
(i) Ferromagnetic
(ii) Paramagnetic
(d) Magnetic characteristics of nonferrous materials
(3) Terminology associated with magnetic particle testing

b. CHARACTERISTIC OF MAGNETIC FIELDS
(1) Bar magnet
(2) Ring magnet

c. EFFECT OF DISCONTINUITIES ON MATERIALS
(1) Surface cracks
(2) Scratches
(3) Subsurface defects

d. MAGNETIZATION BY MEANS OF ELECTRIC CURRENT
(1) Circular field
(a) Field around a straight conductor
(b) Right-hand rule
(c) Field in parts through which current flows:
(i) Long solid cylindrical regular parts
(ii) Irregularly shaped parts
(iii) Tubular parts
(iv) Parts containing critical holes
(d) Methods of inducing current flow in parts
(i) Contact plates
(ii) Prods
(e) Discontinuities commonly discovered by circular fields
(2) Longitudinal field
(a) Field produced by current flow in a coil
(b) Field direction in a current-carrying coil
(c) Field strength in a current-carrying coil
(d) Discontinuities commonly discovered by longitudinal fields

(e) Advantages of longitudinal magnetization
(f) Disadvantages of longitudinal magnetization

e. SELECTING THE PROPER METHOD OF MAGNETIZATION
(1) Alloy, shape, and condition of part
(2) Type of magnetizing current
(3) Direction of magnetic field
(4) Sequence of operations
(5) Value of flux density

f. INSPECTION MATERIALS
(1) Wet particles
(2) Dry particles

g. PRINCIPLES OF DEMAGNETIZATION
(1) Residual magnetism
(2) Reasons for requiring demagnetization
(3) Longitudinal and circular residual field
(4) Basic principles of demagnetization
(5) Retentivity and coercive force
(6) Methods of demagnetization

h. MAGNETIC PARTICLE TEST EQUIPMENT
(1) Equipment selection considerations
(a) Type of magnetizing current
(b) Location and nature of test
(c) Test materials used
(d) Purpose of test
(e) Area inspected
(2) Manual inspection equipment
(3) Medium and heavy duty equipment
(4) Stationary equipment
(5) Mechanized inspection equipment
(a) Semi-automatic inspection equipment
(b) Single-purpose semi-automatic equipment
(c) Multi-purpose semi-automatic equipment
(d) Fully automatic equipment

i. TYPES OF DISCONTINUITIES LOCATED BY MAGNETIC PARTICLE TESTING
(1) Inclusions
(2) Blowholes
(3) Porosity
(4) Flakes
(5) Cracks
(6) Pipes
(7) Laminations
(8) Laps
(9) Forging bursts
(10) Voids

j. MAGNETIC PARTICLE TEST INDICATIONS AND INTERPRETATION
- **(1)** Indications of nonmetallic inclusions
- **(2)** Indications of surface seams
- **(3)** Indications of cracks
- **(4)** Indications of laminations
- **(5)** Indications of laps
- **(6)** Indications of bursts and flakes
- **(7)** Indications of porosity
- **(8)** Nonrelevant indications

k. FINAL WRITTEN/PRACTICAL EXAMINATION

TOTAL TIME (HOURS): 16

7. ULTRASONIC TESTING TRAINING COURSE

a. FUNDAMENTAL PROPERTIES OF SOUND
- **(1)** Frequency, velocity, and wavelength
- **(2)** Definition of ultrasonic vibrations
- **(3)** General application of ultrasonic vibrations

b. PRINCIPLES OF WAVE PROPAGATION
- **(1)** Modes of vibration
- **(2)** Acoustic impedance
- **(3)** Reflection
- **(4)** Refraction and mode conversion
- **(5)** Diffraction and mode conversion
- **(6)** Fresnel and Fraunhofer effects

c. GENERATION OF ULTRASONIC WAVES
- **(1)** Piezoelectricity and types of crystals
- **(2)** Construction of ultrasonic search units
- **(3)** Characteristics of search units
  - **(a)** Frequency-crystal thickness relationships
  - **(b)** Conversion efficiencies of various crystals
  - **(c)** Damping and resolution
  - **(d)** Beam intensity characteristics
- **(4)** Care of search units

d. ULTRASONIC TESTING METHODS
- **(1)** Contact testing
  - **(a)** Straight beam
  - **(b)** Angle beam
  - **(c)** Surface wave
  - **(d)** Lamb wave
  - **(e)** Through transmission
- **(2)** Immersion testing
  - **(a)** Straight beam

(b) Angle beam
(c) Through transmission
(3) Modified immersion testing
(a) Tests employing special devices
(4) Resonance testing
(a) Contact technique
(b) Immersion technique

e. ULTRASONIC TESTING EQUIPMENT
(1) Description of basic pulse-echo instrument
(a) Time-base (synchronizer) circuit
(b) Pulser circuit
(c) Receiver or echo-amplifier circuit
(d) A-Scan display unit
(2) Special Instructions
(a) B-Scan display
(b) C-Scan display
(c) Monitors and recording devices
(3) Scanning equipment
(a) Manipulators
(b) Bridges
(c) Special scanning devices
(4) Ultrasonic bond test equipment

f. OPERATION OF SPECIFIC EQUIPMENT
(1) General operating characteristics
(2) Functional block diagram of ciruits
(3) Purpose and adjustment of external controls
(4) Care of equipment

g. SPECIFIC TESTING PROCEDURES
(1) Selection of test parameters
(a) Frequency
(b) Search unit size and type
(c) Water distance (for immersed tests)
(d) Scanning speed and index
(2) Test standardization
(a) Ultrasonic standard reference blocks
(b) Adjustment of test sensitivity
(3) Interpretation of results
(a) Acceptance standards
(b) Comparison between responses from discontinuities to those from ultrasonic reference standards
(c) Estimated length of discontinuities
(d) Location of discontinuities
(e) Zoning
(4) Equipment performance variations

h. VARIABLES AFFECTING TEST RESULTS
- **(1)** Instrument performance variations
- **(2)** Search unit performance variations
- **(3)** Inspected part variations
  - **(a)** Entry surface condition
  - **(b)** Part size and geometry
  - **(c)** Metallurgical structure
- **(4)** Discontinuity variations
  - **(a)** Size and geometry
  - **(b)** Distance location from entry surface
  - **(c)** Orientation to entry surface
  - **(d)** Type of discontinuity-reflecting characteristics

i. FINAL WRITTEN/PRACTICAL EXAMINATION

TOTAL TIME (HOURS): 40

8. LIQUID PENETRANT TRAINING COURSE

a. INTRODUCTION
- **(1)** Brief history of nondestructive testing and liquid penetrant testing
- **(2)** Purpose of liquid penetrant testing
- **(3)** Basic principles of liquid penetrant testing
- **(4)** Types of liquid penetrants commercially available

b. LIQUID PENETRANT PROCESSING
- **(1)** Preparation of parts
- **(2)** Application of penetrant to parts
- **(3)** Removal of surface penetrant
- **(4)** Developer application and drying
- **(5)** Inspection and evaluation
- **(6)** Post-cleaning

c. SELECTION OF PENETRANT TEST METHODS
- **(1)** Advantages of various methods
- **(2)** Disadvantages of various methods

d. LIQUID PENETRANT TEST EQUIPMENT
- **(1)** Liquid penetrant test units
- **(2)** Lighting for liquid penetrant inspection
- **(3)** Materials for liquid penetrant testing
- **(4)** Precautions in penetrant inspection

e. LIQUID PENETRANT INDICATIONS
- **(1)** General
  - **(a)** Reason for indications
  - **(b)** Appearance of indications
  - **(c)** Time for indications to appear
  - **(d)** Persistence of indications

(2) Factors affecting indications
(a) Penetrant used
(b) Technique used
(3) Establishing acceptance standards
(a) Lack of "standards"
(b) Standards for repetitive inspection
(4) Indication from cracks
(a) Cracks occurring during solidification
(b) Cracks occurring during processing
(c) Cracks occurring during service
(5) Indications from laminar discontinuities
(a) Cold shut or fold
(b) Forging laps
(c) Extrusion defect
(d) Seams
(6) Indications from porosity
(7) Nonrelevant indications

f. INSPECTION PROCEDURES AND STANDARDS
(1) Inspection procedures
(2) Standards

g. FINAL WRITTEN/PRACTICAL EXAMINATION

TOTAL TIME (HOURS): 16

9. EDDY CURRENT TESTING TRAINING COURSE

a. INTRODUCTION
(1) Brief history of eddy current testing
(2) Basic principles of eddy current testing

b. EDDY CURRENT THEORY
(1) Generation of eddy currents by means of an A-C field
(2) Effect of fields created by ededy currents (impedance changes)
(3) Effect of change of impedence on instrumentation
(4) Properties of eddy current
(a) Travel in circular direction
(b) Strongest on surface of test material
(c) Zero value at center of solid conductor placed in an eddy current field
(d) Strength, time relationship, and orientation as function of test system parameters and test part characteristics
(e) Have properties of compressible fluids
(f) Small magnitude of current flow
(g) Relationship of frequency and plane with current in coil
(h) Effect of irrelevant permeability variations when induced in magnetic particles
(i) Effect of discontinuity orientation
(j) Power losses

c. TYPES OF SENSING ELEMENTS
- **(1)** Probes
  - **(a)** Types of arrangement
    - **(i)** Absolute
    - **(ii)** Differential
    - **(iii)** Reflectance
  - **(b)** Lift-off
  - **(c)** Theory of operation
  - **(d)** Applications
  - **(e)** Advantages
  - **(f)** Limitations
- **(2)** Through, Encircling, or Annular Coils
  - **(a)** Types or arrangements
    - **(i)** Absolute
    - **(ii)** Differential
  - **(b)** Lift-off

j. READ-OUT MECHANISM
- **(1)** Calibrated or uncalibrated meter
- **(2)** Null meter with dial indicator
- **(3)** Oscilloscope
- **(4)** Alarm, lights, etc.
- **(5)** Sorting gates and tables
- **(6)** Strip chart recorder

k. APPLICATIONS
- **(1)** Flaw detection
- **(2)** Sorting for properties related to conductivity
- **(3)** Sorting for properties related to permeability
- **(4)** Thickness evaluation
- **(5)** Measurement of magnetic characteristic values

l. REFERENCE STANDARDS AND OPERATING PROCEDURES
- **(1)** Explanation of standards and specifications used in eddy current testing
- **(2)** Explanation of operating procedures used in eddy current testing

m. FINAL WRITTEN/PRACTICAL EXAMINATION

TOTAL TIME (HOURS): 40