

IAEA-TECDOC-628/Rev.2

***Training Guidelines in
Non-destructive Testing
Techniques:
2008 Edition***



IAEA

International Atomic Energy Agency

December 2008

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TRAINING GUIDELINES IN NON-DESTRUCTIVE TESTING TECHNIQUES

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FOREWORD

The International Atomic Energy Agency promotes industrial applications of radiation technology including non-destructive testing (NDT) through its various activities such as technical co-operation (TC) projects (national and regional projects) and co-ordinated research projects (CRPs). National programmes have been established in Member States for training and certification of NDT personnel. National certifying bodies have also been established based on International Organization for Standardization (ISO) standards.

As a part of these efforts, the IAEA has been actively involved in developing training materials. Consequently, Training Guidelines in Non-Destructive Testing were issued in 1987 as IAEA-TECDOC-407. A revised and enlarged version was issued as IAEA-TECDOC-628 in 1991, both in Spanish and English. This latter version included the development work carried out by the International Committee for Non Destructive Testing (ICNDT) and many national NDT societies. It is one of the documents referred to in ISO Standard 9712, which in turn is an internationally accepted standard for the qualification and certification of NDT personnel.

Since the issuance of IAEA-TECDOC-628 in 1991, NDT technology has experienced significant changes, which are reflected in IAEA-TECDOC-628/Rev. 1 (2002). In addition, over the last ten years, as a result of research and development activities worldwide, new NDT techniques and equipment have been introduced and accepted by the engineering community. To accommodate the latest developments, training materials need to be updated. Accordingly, revision of the existing version was considered essential to meet the demands of end user industries in the Member States.

The present publication is an updated version of IAEA-TECDOC-628/Rev. 1. The modifications were made during a consultants meeting held in Vienna from 30 October to 2 November 2006. The participating experts at the meeting were from well known international bodies active in the qualification and certification of NDT personnel.

The content of IAEA-TECDOC-628/Rev. 1 has been revised, based on the experiences of the experts, as well as comments of the end user industries. The details of the topics on each subject have been expanded to include the latest developments in the respective method.

The incorporated changes will help the end user industries to update their NDT qualification and certification schemes, and training course materials. This publication, like the previous version, will continue to play an important role towards international harmonization in the field of NDT.

The IAEA wishes to express its appreciation to all those who contributed to the production of this publication and to the governments and organizations whose support made this publication possible, especially to A.A. Khan, who revised and finalized the manuscript. The IAEA officers responsible for this publication were I. Einav and J.-H. Jin.

EDITORIAL NOTE

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1. INTRODUCTION

This publication contains a body of knowledge for non-destructive testing. It was developed to provide guidelines for trainers, training organizations and certification bodies, detailing the subject matter and the content for each level of certification. It is general in nature but the contents of the training should be adapted to the needs, procedures, materials and products of the customer. The recommended training hours are consistent with the edition of the standard ISO 9712 in effect at the time of preparation.

All formal training described in this publication contains a theoretical portion and a practical portion. Guidance is included on the range of equipment and materials needed for instruction in each method.

There is a common core of material that is required by level 3 personnel in every method. This common material has been removed from the content for the particular method and included as a separate section.

All training should end with an examination and can lead to a certification. Examination and certification are not covered by this publication, but detailed information about this can be found in ISO 9712.

This publication is applicable for the following methods:

- Eddy current testing;
- Magnetic particle testing;
- Liquid penetrant testing;
- Radiographic testing;
- Ultrasonic testing;

NDT methods are now widely used in civil engineering, especially in the evaluation of civil infrastructure. In general, the civil engineering applications are distinct and sufficiently different that training in the field of civil engineering should be addressed separately.

Radiation protection is an important topic for industrial radiography and is well-covered in a different publication available from the IAEA.

Training to this syllabus provides a general knowledge for the NDT operator. It does not represent an authorization to operate, since this remains the responsibility of the employer, and the employee may require additional specialized knowledge.

A table prior to every method description gives the recommended training hours for every area of knowledge. In the columns for level 2 and level 3 only the additional hours are stated. It is required that the candidate has completed the training in the level below.

2. GUIDELINE FOR ORGANIZING TRAINING INCLUDING ADVANCED METHODS

2.1 GENERAL

For the introduction of new methods or for training of advanced methods not fitting into the conventional certification programmes, the organizational form of a seminar can be used. It is difficult to find usable course materials or training schedules because of the fast development of advanced methods. The time horizon for such material would be typically less than a year. A number of key questions have to be answered in advance to make the seminar successful for the participants.

2.2 KEY QUESTIONS

2.2.1 Need of the customer

What are the expectations of the customer? What should the participants be able to do after the seminar? What skills are expected or what knowledge?

2.2.2 Number of potential participants

How many people will take part? This is important for lesson room size, practical working groups, number of trainers and assistants.

2.2.3 Existing applications

Which applications of the methods are used in what industries? Is it possible to visit the site, to obtain pictures, reports or to get a contribution?

2.2.4 Supplier of equipment

Who is offering equipment? Is he willing to give equipment for the seminar, practical exercises and demonstrations? Often suppliers have basic lessons about the method and the application. Is it possible to have more than one supplier?

2.2.5 Scientific background

What is the physical background of the method? Is there a university or institute working in this field? Are they willing to teach the basics? Are there books or standards available?

2.3 PREPARATION

The organization of the seminar depends on the answers to the key questions.

The first step is to form a small organizing committee. It should consist of a chairperson, a seminar organizer and some people from industries, suppliers and institutes. Their first task is to overview the sources, define the seminar targets and draft the time schedule. Trainers have to be found for the lessons. Demonstrations and practical exercises need to be defined.

The next step is to establish the date for the seminar and to design an invitation for potential participants.

The trainers are asked to deliver a written presentation in advance. These presentations are revised and coordinated in the committee to avoid double lessons and to ensure that they are meeting the seminar expectations.

2.4 ORGANISZATION

The organizer has to start action once the organizing committee sees that there are enough sources and participants to perform the seminar:

- Register the participants;
- Invite the trainers;
- Book rooms for lessons and demonstrations;
- Organize refreshments;
- Prepare a time schedule;
- Copy the course material for every participant;
- Prepare certificates of attendance;
- Organize financial affairs.

2.5 PERFORMANCE

The organizer should be available during the full seminar. He is responsible for opening the seminar, introducing the trainers, coordinating the preparation of practical exercises and demonstrations.

He answers organizational questions of the participants. An important task is to ensure that the trainers are following the time schedule.

At the end of the seminar there should be a short written evaluation with the participants and the trainers. It should be asked if the seminar fulfilled the expectation of everybody, if the conditions were good and what proposals and wishes they have for a next seminar.

2.6 POSTWORK

The organizer has to close all financial affairs. He will give away the certificates of attendance to the participants.

The organizing committee should meet again and review the evaluations for future seminars in order to improve the contents of the seminar.

If the organizing committee can see a need for more training, they have to decide to transform the seminar into a regular training programme.

I. GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3

The following table details a number of subjects which are common to Level 3 training for all methods. They have been summarized separately, however course designers must provide for the subjects and the related hours.

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE STRUCTURE	4
3. QUALITY ASSURANCE AND STANDARDIZATION -	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1 NDT
 - 1.1 Basic knowledge of at least 4 NDT methods at level 2
 - 1.1.1 Scope and limitations: comparison of different NDT methods
 - 1.1.2 Selection of methods
 - 1.2 Technology of materials
 - 1.2.1 Discontinuities and defects in materials. Classification according to location and morphology
 - 1.2.2 Properties of materials
 - 1.2.3 Nature of materials and solid state changes in materials
 - 1.2.4 Ferrous metals
 - 1.2.5 Non-ferrous metals and plastics
 - 1.2.6 Nature of manufacturing
 - 1.2.7 Casting process
 - 1.2.8 Welding process
 - 1.2.9 Plastic flow
 - 1.2.10 Millwork, forging and powder metallurgy
 - 1.2.11 Machining fundamentals
 - 1.2.12 Miscellaneous processes
 - 1.2.13 Surface finishing
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe, interpret, analyse and evaluate the defectology of metallic and non-metallic materials;
 - b) describe, interpret and analyse the main processes of fabricating materials;
 - c) describe, interpret and analyse the various types of surface finishing in metallic and non-metallic materials, including laps and adhesive bonding;
 - d) recognize various types of compound materials.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and presentation of cases for analysis and evaluation, guided discussion and solution of practical problems.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes and summaries

Films

Tables of physical constants and properties of materials

CONTENTS:

1.3 Metrology

1.3.1 Fundamental units of the International System (SI)

1.3.2 Usual derived units

1.3.3 Equivalence between units of various commonly used systems and those of the SI

SPECIFIC OBJECTIVES:

1.3 Given the instructor's explanations, the student will be able to describe and properly handle units of the SI and other widely used systems.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Course notes

CONTENTS:

- 2.1 Codes, standards, procedures and instructions
 - 2.2 Format, structure, and content of procedures
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between codes, standards, procedures and instructions;
 - b) select the information necessary to write a procedure related to codes and standards
 - 2.2 Given the instructor's explanations, the student will be able to write the table of contents of a procedure and understand what kind of information should correspond to each topic
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Films
Course notes
Example documents: Codes, standards, procedures, instructions

CONTENTS:

- 3.1 Quality assurance
 - 3.1.1 Basic principles for the application of quality assurance
 - 3.1.2 Organization of quality assurance; Quality manual; Quality control; Auditing of quality.
 - 3.1.3 Management and control of quality assurance documentation, quality control of testing
 - 3.1.4 Certification and accreditation of NDT facilities
 - 3.1.5 Reports on testing, documentation systems
 - 3.2 Standardization
 - 3.2.1 Definition of standardization, principles for writing of standards
 - 3.2.2 Standards, codes, specifications and procedures, their uses
 - 3.2.3 Procedure validation
 - 3.3 Reports and protocols
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) interpret and apply quality assurance procedures to the application of NDT at all stages;
 - b) analyse, evaluate and prepare all testing documentation in accordance with the requirements of quality assurance;
 - c) define requirements for quality assurance in the specific area of activity;.
 - d) understand the difference between certification and accreditation;
 - e) implement certification and accreditation processes.
 - 3.2 Given the instructor's explanations, the student will be able to:
 - a) define standardization and discuss basic principles for writing of standards;
 - b) discuss the benefit and applications of standards, codes, specifications and
 - c) procedures;
 - d) write reports and keep records which meet the requirements of codes and standards;.
 - e) implement procedure validations.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Films,
Course notes
Quality assurance manuals
Typical documents

CONTENTS:

4.1 Organization and administration of NDT

4.1.1 Safety:

- a) Implementation of industrial safety standards in facilities and equipment and in their operation
- b) Hazards of using toxic and inflammable materials
- c) Materials, accessories and equipment, for the protection of persons and facilities

4.1.2 Organization

- a) Equipment for work under way; Logistic provisions
- b) Testing on production lines; Flow of materials; Work shifts
- c) Maintenance of equipment and facilities

4.1.3 Costs

- a) Investments in equipment
- b) Direct and indirect staff costs
- c) Calculation and analysis of costs and profitability

4.1.4 Equipment selection and facility design

4.1.5 Operating procedures and record keeping

SPECIFIC OBJECTIVES:

4.1 Given the instructor's explanations, the student will be able to:

- a) organize and administer the performance of tests with an NDT method with proper consideration of the safety of personnel and facilities and economic factors;
 - b) organize the tasks of staff involved in NDT to ensure the operation is conducted safely and efficiently;
 - c) design a testing facility for the use of one or more NDT methods;
 - d) write operating procedures for the conduct of tests, equipment maintenance and record keeping and control of test items;
 - e) develop specifications for equipment procurement for specific testing applications.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, development from student experience and example problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Sample specifications and quotations
Sample procedures

CONTENTS:

5.1 Qualification and Certification of NDT personnel

5.1.1 National standards for the qualification and certification of personnel. Regional and international recommendations.

5.1.2 Training of NDT personnel. Organization of courses and training in NDT methods.

5.1.3 Code of ethics

SPECIFIC OBJECTIVES:

5.1 Given the instructor's explanations, the student will be able to:

- a) interpret and administer national and international standards for the qualification and certification of NDT personnel;
 - b) organize, administer and evaluate training courses for NDT personnel;
 - c) interpret and apply a code of ethics.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Applicable standards and documents

Course notes

II. INSPECTION METHOD: RADIOGRAPHIC TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	4	8	1) ¹⁾
2. PHYSICAL PRINCIPLES OF THE TEST	3	4	3
3. EQUIPMENT- RADIATION SOURCES	3	8	3
4. PHOTOGRAPHIC AND NON-PHOTOGRAPHIC RECORDING	4	8	4
5. WORK PARAMETERS AND CONDITIONS	4	8	3
6. DEFECTOLOGY	2	4	3
7. SELECTION OF TECHNIQUES	2	8	4
8. CODES, STANDARDS, SPECIFICATIONS AND PROCEDURES	2	8	9
9. PERSONAL SAFETY AND RADIATION PROTECTION	16	12	5
10. SPECIAL APPLICATIONS	-	4	3
11. RECORDING AND INTERPRETATION OF RESULTS	-	8	3
TOTAL	40	80	40 ¹⁾

¹⁾ In addition to the above 40 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once..

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology. Reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods:
 - a) Visual testing
 - b) Penetrant testing
 - c) Magnetic particle testing
 - d) Radiographic testing
 - e) Ultrasonic testing
 - f) Eddy current testing
 - g) Leak testing
 - h) Other methods
 - 1.1.4 Limitations in the application of radiographic testing
 - 1.1.5 Responsibilities of the levels of certification
- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non -destructive test;
 - b) list the characteristics of NDT technology and the reasons for using NDT;
 - c) compare the different types of NDT methods, with particular reference to the application and uses of each method.
- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity;
 - b) define the properties of materials, especially of metals;
 - c) recognize how defects affect the properties of materials.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials

CONTENTS:

- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Processing and related defects
 - a) Casting
 - b) Welding
 - c) Forging
 - d) Rolling
 - e) Heat treatment
 - f) Machining
 - g) Plating
 - 1.3.3 In-service defects
 - a) Overload
 - b) Fatigue
 - c) Corrosion
 - d) Erosion
 - e) Brittle fracture
 - f) Others

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication;
 - b) describe typical defects associated with each type of process;
 - c) describe typical defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Course notes
Samples of materials with typical defects

CONTENTS:

- 2.1 Penetrating radiation
 - 2.1.1 X rays and gamma rays
 - 2.1.2 Wavelength and energy
 - 2.1.3 X ray and gamma ray spectra
 - 2.1.4 KVp, KVc, KeV, MeV
 - 2.1.5 Inverse square law for distance/intensity
 - 2.1.6 General properties of propagation of penetrating radiation
 - 2.1.7 Units related to penetrating radiation

 - 2.2 Principles of radioactive decay
 - 2.2.1 Radioactivity
 - 2.2.2 Half-life
 - 2.2.3 Artificial and natural radioactive source
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations and a type of radiation, the student will be able to:
 - a) List its properties;
 - b) explain the characteristics of the spectrum;
 - c) calculate the variation in intensity of the radiation with distance;
 - d) recognize the basic units applied in radiographic testing.

 - 2.2 Given the instructor's explanations, the student will be able to:
 - a) distinguish between radioactive decay, radioactivity and half -life;
 - b) explain the difference between artificial and natural radioactive sources.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion and simple calculations.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Table of nuclides

CONTENTS:

- 2.3 Interaction of radiation with matter
 - 2.3.1 Absorption, dispersion, photoelectric effect, Compton effect, pair production
 - 2.3.2 Absorption coefficient, half- thickness
 - 2.4 Detection of ionizing radiation
-

SPECIFIC OBJECTIVES:

- 2.3 Given the instructor's explanations, the student will be able to:
 - a) compare the different processes of interaction of radiation with matter;
 - b) relate the attenuation of radiation to half-thickness.
 - 2.4 Given the instructor's explanations, the student will be able to:
 - a) recognize the different systems of measuring ionization
 - b) distinguish between the various radiation magnitudes;
 - c) distinguish between types of radiation measuring instruments, describing their proper application.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion and simple calculations.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials
Calculator

CONTENTS:

- 3.1 X ray equipment
 - 3.1.1 X ray generators and tubes, target material and characteristics, configuration, focus, heat dissipation
 - 3.1.2 Head, control cabinet, power source
 - 3.1.3 Accessories
 - 3.2 Gamma ray sources
 - 3.2.1 Types, spectrum, activity, shielding, collimators
 - 3.2.2 Handling
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations and a set of X ray equipment, the student will be able to:
 - a) identify the basic components and controls;
 - b) recognize the type of generator;
 - c) operate the equipment properly.
 - 3.2 Given the instructor's explanations and a source of gamma radiation, the student will be able to:
 - a) recognize the type of radioisotope;
 - b) recognize the spectrum of the radioisotope and its activity;
 - c) operate the source correctly.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion and individual practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials
X ray equipment
Radiological protection equipment (a radiation monitor and dosimeter as a minimum)
Gamma ray source

CONTENTS:

- 4.1 Photographic recording (X ray and gamma ray)
 - 4.1.1 Film, principles, properties
 - 4.1.2 Emulsions, classes, characteristic curves, radiographic quality
 - 4.1.3 Lead and fluorescent screens
 - 4.1.4 Types of film for industrial radiography
 - 4.2 Description of the fluoroscopic test
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to:
 - a) recognize the structural components of a radiographic film;
 - b) relate the code of the film to its properties (grain size, contrast, speed);
 - c) distinguish between the types of screens and their applications.
 - 4.2 Given the instructor's explanations, the student will be able to explain the nature of the fluoroscopic test and how it differs from film radiography.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion and practical laboratory work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials
Manual for various brands of film
Screens

CONTENTS:

- 5.1 Parameters and work conditions
 - 5.1.1 Image density, factors affecting it
 - 5.1.2 Geometric principles, penumbra
 - 5.1.3 Image quality, contrast and definition
 - 5.1.4 Scattered radiation, causes, control
 - 5.1.5 Use of screens, masks, filters
 - 5.1.6 Exposure curves, X rays, gamma rays, exposure calculations
 - 5.1.7 Image quality indicators, procedure
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to:
 - a) distinguish between the concepts of density, contrast, geometric penumbra and definition;
 - b) explain the effect of the various geometric factors with respect to definition of the radiographic image;
 - c) use the collimator, screens and filters to control scattered radiation;
 - d) distinguish between various types of image quality indicators in accordance with the standards and position them correctly in accordance with the test conditions;
 - e) carry out the practical radiographic work.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion, workshop on exposure calculation problems, particular work on handling procedures, practical work on handling quality indicators and performance of radiography.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available), Course notes
Samples of various materials, test procedures (written instructions for radiographic testing)
Various types of quality indicators
Test pieces, screens, filters and masks
Meter, exposure curves, calculator
Densitometer, density samples
X ray equipment, gamma ray equipment, accessories

CONTENTS:

- 5.2 Care in the handling and conservation of film
 - 5.2.1 Darkroom: equipment, chemicals, processing of the film
 - 5.3 Viewing of radiographs
 - 5.3.1 General background, lighting, viewers
 - 5.4 Evaluation of radiograph quality:
 - 5.4.1 Causes and corrections of defective radiographs
 - 5.4.2 Processing defects, high density, low density, contrast, definition, fog
 - 5.4.3 Image quality indicators
 - 5.4.4 Identification
 - 5.4.5 Density measures
-

SPECIFIC OBJECTIVES:

- 5.2 Given the instructor's explanations and an undeveloped radiographic film, the student will be able to:
 - a) verify the condition of the reagents;
 - b) handle the film correctly;
 - c) carry out the processing correctly.
 - 5.3 Given the instructor's explanations and various radiographs, the student shall demonstrate ability to interpret them, handling the viewer and film correctly.
 - 5.4 Given the instructor's explanations and various radiographs, the student will be able to:
 - a) recognize defective radiographs, identifying the various processing defects;
 - b) determine radiographic density.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including lecture, guided discussion, practical work in processing and checking of reagents, practical work in handling the viewer and viewing of radiographs.

EQUIPMENT AND RESOURCES:

Radiographic film
Darkroom
Processing equipment
Drying equipment
Viewer, reference radiographs
Writing board, sample defective radiographs

CONTENTS:

6.1 Basic relationship between image and object

6.2 Radiographic indication of defects

SPECIFIC OBJECTIVES:

6.1 Given the instructor's explanations, the student will be able to compare image size and object, explaining the variables which affect this relationship.

6.2 Given the instructor's explanations and radiographs of different work pieces, the student will be able to:

- a) recognize defect indications typical of welds and cast pieces;
 - b) relate the type of discontinuity to its radiographic image.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration includes delivery of support material, discussion and practical work in radiography, observation of radiographs.

EQUIPMENT AND RESOURCES:

Writing board
Standard radiographs
Viewer

CONTENTS:

- 7.1 Influence of properties of the material
 - 7.2 Exposure techniques according to the geometry of the object
 - 7.2.1 Single wall/single image
 - 7.2.2 Double wall/single image
 - 7.2.3 Double wall/double image
 - 7.2.4 Panoramic exposure
 - 7.2.5 Thickness compensation
 - 7.2.6 Masks
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations and work pieces of various materials, the student will be able to define the most suitable radiographic techniques, taking into account the type of material and the variables of exposure.
 - 7.2 Given the instructor's explanations and work pieces of various shapes, the student will be able to describe the most suitable radiographic technique.
-

METHODOLOGICAL STRATEGIES

Instructor's demonstration including lecture, delivery of support material, guided discussion and practical work in selection of techniques.

EQUIPMENT AND RESOURCES:

Writing board
Work pieces of various materials, codes
Work pieces of different geometry
Radiographic equipment

CONTENTS:

- 8.1 Codes, standards, specifications and procedures
 - 8.1.1 General knowledge of codes and standards as applied to radiographic testing
 - 8.1.2 General knowledge of specifications and procedures for radiographic testing
 - 8.2 Performance of tests in accordance with written instructions
 - 8.3 Identification of radiographs and recording of tests
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations, the student will be able to:
 - a) explain the significance and application of codes, standards, specifications and procedures;
 - b) recognize the structure of codes and standards;
 - c) recognize the different standards existing with respect to the application of radiographic testing;
 - d) recognize the difference between standards, specifications and procedures.
 - 8.2 Given the instructor's explanations and written instructions, the student will be able to carry out practical radiographic work, following the relevant instructions and noting the operational conditions of the test on data forms.
 - 8.3 Given the instructor's explanations and various practical examples of performing radiographs in plants, the student will be able to describe a system of codified recording, correctly identifying the radiographs.
-

METHODOLOGICAL STRATEGIES

Instructor's demonstration including lecture, delivery of support material, guided discussion and practical application of written instructions, guidelines, discussion and workshop (filling our forms)

EQUIPMENT AND RESOURCES:

Writing board
Codes, standards (ASME, ASTM, DIN, API, BTS, COVENIN, JIS)
Test procedures
Work pieces
Radiographic equipment and accessories

CONTENTS:

- 9.1 Dangers of excessive exposure to X rays and gamma rays
 - 9.1.1 Somatic and genetic effects
 - 9.1.2 Personnel monitoring
 - a) Wearing of monitoring badges
 - b) Reading of pocket dosimeters
 - c) Recording of daily dosimeter readings
 - d) "Off-scale" dosimeter-action required
 - 9.2 Maximum permissible doses
 - 9.3 Method of controlling exposure dose: time, distance, shielding
 - 9.4 Units
-

SPECIFIC OBJECTIVES:

- 9.1 Given the instructor's explanations, the student will be able to recognize the dangers of excessive exposure to X rays or gamma rays.
 - 9.2 Given the instructor's explanations and radiation protection standards, the student will be able to recognize the maximum permissible radiation doses and their effects on the organism.
 - 9.3 Given the instructor's explanations, the student will be able to relate the exposure dose to variations in time, distance or shielding.
 - 9.4 Given the instructor's explanations, the student will be able to understand the units used.
-

METHODOLOGICAL STRATEGIES

Instructor's demonstration including lecture, delivery of support material, guided discussion and problem workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Calculator
Dosimeters and monitors
Data recording forms
Radiographs in series
Examples of identification systems in radiographic testing

CONTENTS:

Specific requirements of safety for operation of X ray and gamma ray equipment

9.5.1 Survey instruments

- a) Types of radiation instruments; reading and interpreting meter indications
- b) Calibration frequency, calibration expiration action, battery check importance

9.5.2 Radiographic work practices

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

9.5.3 Exposure devices

- a) Inspection and maintenance; radiation exposure limits for gamma ray exposure devices; labeling

9.5.4 Use of Exposure device

- a) Use of collimators to reduce personnel exposure
- b) Use of “source changers” for gamma ray sources

9.6 Operational and emergency procedures

- a) Vehicle accidents with radioactive sealed sources; fire involving sealed sources
- b) Failure of source to return to safe shielded conditions; emergency call list

9.7 Storage and transportation of exposure devices and sources

- a) Vehicle storage; storage vault — permanent; shipping instructions; receiving instructions
- b) Labeling

9.8 Regulations

- a) Regulatory authorities
- b) Radioactive materials license requirements for industrial radiography
- c) Qualification requirements for radiographic source shipment

SPECIFIC OBJECTIVES:

9.5 Given the instructor’s explanations, the student will be able to:

- a) define the safety conditions under which X ray and gamma ray equipment should be operated and the radiation detection equipment required;
- b) handle warning systems.

9.6 Given the instructor’s explanations and examples of emergency situations, the student will be able to explain the possible solutions to such emergencies.

METHODOLOGICAL STRATEGIES

Instructor's demonstration including lecture, guided discussion and practical emergency work.

EQUIPMENT AND RESOURCES:

Writing board

X ray and gamma ray equipment

Monitors

Dosimeters

Bunker warning system

Collimators

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods: VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects:
 - a) Casting processes and associated discontinuities: ingots, blooms, and billets; sand casting; centrifugal casting; investment casting
 - b) Wrought processes and associated discontinuities: forgings; rolled products; extruded products
 - c) Welding processes and associated discontinuities: submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas etc.
- 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures: corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 The nature of penetrating radiation
 - 2.1.1 Atomic structure
 - 2.1.2 Corpuscular and electromagnetic radiation
 - 2.1.3 X rays and gamma rays
 - 2.1.4 Wavelength and energy
 - 2.1.5 X ray and gamma ray spectra
 - 2.1.6 Inverse square law for distance/ intensity
 - 2.1.7 General properties of the propagation of penetrating radiation
 - 2.1.8 Units related to penetrating radiation
 - 2.2 The elements of radioactive decay, radioactivity, half life, natural and artificial sources
 - 2.2.1 Intensity and concept of specific emission (R/Ci-h at 1 m, Gy/Bq-h at 1 m)
 - 2.3 Alpha and beta particles, neutrons
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations and a type of radiation, the student will be able to:
 - a) list its properties;
 - b) determine the characteristics of the spectrum;
 - c) determine the variation in intensity of radiation with distance;
 - d) apply properly the units related to radiographic testing.
 - 2.2 Given the instructor's explanations, the student will be able to:
 - a) distinguish between radioactive decay, radioactivity and half-life;
 - b) distinguish between natural and artificial radioactive sources;
 - c) know the units of specific emission.
 - 2.3 Given the instructor's explanations, the student will be able to distinguish between alpha and beta particles and neutrons.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and simple calculations.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies

CONTENTS:

- 2.4 Interaction of radiation with matter
 - 2.4.1 Absorption, dispersion, photoelectric effect, Compton effect, pair production
 - 2.4.2 Absorption coefficient
 - 2.4.3 Half-value thickness and tenth value thickness
 - 2.4.4 Use of tables for calculating attenuation of gamma and X radiations

 - 2.5 Measurement of ionization and units
 - 2.5.1 Detection of radiation by ionization
 - 2.5.2 Exposure, absorbed dose, equivalent dose
 - 2.5.3 Dose intensity

 - 2.6 Principles of X and gamma ray detection
 - 2.6.1 Film, fluorescent material, electronics
 - 2.6.2 Accuracy of measurements
 - 2.6.3 Limits of application
-

SPECIFIC OBJECTIVES:

- 2.4 Given the instructor's explanations, the student will be able to:
 - a) analyse the various mechanisms of the interaction of radiation with matter;
 - b) explain the absorption and attenuation of radiation;

 - 2.5 Given the instructor's explanations, the student will be able to explain the measurement of ionization and the units used.

 - 2.6 Given the instructor's explanations, the student will be able to describe the detection and measurement of X and gamma rays.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and problem workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies

CONTENTS:

- 3.1 X ray equipment
 - 3.1.1 Generators and X ray tubes, material and target characteristics, configuration, focus, heat dissipation
 - 3.1.2 Head, control cabin, power source
 - 3.1.3 Auxiliaries
 - 3.1.4 Equipment design, emission, work cycle
 - 3.1.5 Determination of focus length
 - 3.1.6 Linear accelerators, betatrons and other high energy sources
 - 3.2 Gamma ray sources, production of radioisotopes
 - 3.2.1 Radioisotopes used in gamma radiography, energy, spectra, half-life, emission factors, range
 - 3.2.2 Different types of gamma cameras, shielding, collimators, handling
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations and a set of X ray equipment, the student will be able to:
 - a) identify its basic elements and controls;
 - b) recognize the type of generators;
 - c) operate the equipment correctly;
 - d) recognize the various designs of conventional and other equipment.
 - 3.2 Given the instructor's explanations and a source of gamma radiation, the student will be able to:
 - a) recognize the type of isotope and camera;
 - b) describe the physical parameters of radioisotopes;
 - c) describe the applicable range of penetration in different materials for different sources;
 - d) operate the source correctly.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and individual practical exercises.

EQUIPMENT AND RESOURCES:

Transparencies
X ray equipment
Radiation protection equipment (radiation monitor and dosimeter as a minimum)
Gamma ray source in camera

CONTENTS:

- 4.1 Photographic recording (Gamma ray, X ray)
 - 4.1.1 Films used in radiography, principles, properties, types of emulsions, granularity, influence of radiation energy, characteristic curves
 - 4.1.2 Radiographic quality, density, contrast, definition, sharpness
 - 4.1.3 Lead and fluorescent screens
 - 4.1.4 Types of film for industrial radiography
 - 4.1.5 Use of sensitometric curves
 - 4.1.6 Exposure curves
 - 4.1.7 Brightness and penumbra responses of fluorescent screens

 - 4.2 Description of fluoroscopy test
 - 4.2.1 Image intensifiers
 - 4.2.2 TV systems
 - 4.2.3 Xero radiography
 - 4.2.4 Digital radiography
 - 4.2.5 CCD systems, Scintillation screens
 - 4.2.6 Digital direct image recording
 - 4.2.7 Digital image analysis and enhancement
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to:
 - a) recognize the constituent parts of a radiographic film;
 - b) relate the film code to its properties (grain size, contrast, speed);
 - c) distinguish between the types of screens and their applications;
 - d) describe sensitometric and exposure curves for various materials.

 - 4.2 Given the instructor's explanations, the student will be able to:
 - a) explain fluoroscopy, image intensification, TV systems etc, based on digital radiography;
 - b) explain the differences between fluoroscopy, conventional radiography and digital radiography.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, laboratory practical work and problem workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Manuals for different makes of film
Sensitometric curves
Screens
Fluoroscopy systems
Film scanner
Digital radiography system

CONTENTS:

- 5.1 Parameters and working conditions
 - 5.1.1 Image density, factors which affect it
 - 5.1.2 Geometrical principles, penumbra
 - 5.1.3 Image quality, contrast and definition
 - 5.1.4 Scattered radiation, cause, control
 - 5.1.5 Use of screens, masks, filters
 - 5.1.6 Exposure curves, X rays, gamma rays, exposure calculations
 - 5.1.7 Image quality indicators, positioning
 - 5.1.8 Interpretation of test instructions
 - 5.1.9 Choice of films
 - 5.1.10 Preparation of exposure curves
 - 5.1.11 Choice of screens
 - 5.1.12 Magnification and distortion of the projected image
 - 5.1.13 Fluoroscopy, evaluation of sensitivity, selection of KVp
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to:
 - a) distinguish between the concepts of density, contrast, geometrical penumbra and definition, types of evaluation;
 - b) explain the action of various geometrical factors with respect to definition of the radiographic image;
 - c) use screens, collimators and filters for controlling scattered radiation;
 - d) distinguish between image quality indicators in accordance with the standards and explain their positioning in accordance with the test conditions;
 - e) choose the correct film type and prepare their exposure curves.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, workshop on exposure calculation problems, practical exercise on handling procedures and practical exercises on handling quality indicators.

EQUIPMENT AND RESOURCES:

Writing board, test procedures
Various types of quality indicators
Sample work pieces
Screens, filters and masks
Meter, exposure curves
Calculator, densitometer
Density samples
X ray equipment
Accessories
Slides

CONTENTS:

- 5.2 Film processing
 - 5.2.1 Principle of image formation
 - 5.2.2 Processing in darkroom
 - 5.2.3 Equipment and reagents
 - 5.2.4 Care to be taken in handling and conserving the film
 - 5.2.5 Safety lamps
 - 5.2.6 Checking on the use of reagents, temperatures, processing time
 - 5.2.7 Special situations

 - 5.3 Viewing of the radiographs
 - 5.3.1 General information, lighting, viewer
 - 5.3.2 Influence of the observation conditions on the detection of defects
 - 5.3.3 Checking the lighting in the viewer
 - 5.3.4 Brightness requirements
-

SPECIFIC OBJECTIVES:

- 5.2 Given the instructor's explanations and an undeveloped radiographic film, the student will be able to:
 - a) verify the conditions of the reagents and the darkroom;
 - b) handle the film correctly;
 - c) carry out the process correctly.

 - 5.3 Given the instructor's explanations and various radiographs, the student will be able to evaluate them, using the viewer and film correctly.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, practical exercises on procedure, control of reagents and viewing of radiographs.

EQUIPMENT AND RESOURCES:

Radiographic film
Darkroom
Processing equipment
Drying equipment
Viewer
Reference radiographs

CONTENTS:

- 5.4 Evaluation of radiographic quality
 - 5.4.1 Causes and correction of defective radiographs
 - 5.4.2 Processing defects, high density, low density, contrast, definition, fog
 - 5.4.3 Image quality indicators
 - 5.4.4 Identification
 - 5.4.5 Density measurement
 - 5.4.6 Systematic control of radiographic quality
-

SPECIFIC OBJECTIVES:

- 5.4 Given the instructor's explanations and various radiographs, the student will be able to:
 - a) distinguish between defective radiographs, recognizing the various processing defects;
 - b) identify the image quality indicator;
 - c) determine the density of the radiographs.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical exercises on viewing of defective and good radiographs.

EQUIPMENT AND RESOURCES:

Writing board
Sample radiographs
Viewer
Densitometers
Slides
Film scanner
Image intensifier (CCTV systems)

CONTENTS:

- 6.1 Basic factors
 - 6.1.1 Relation between image and object
 - 6.2 General information on the nature of discontinuities in radiography
 - 6.3 Interpretation of radiographic images
 - 6.3.1 Use of reference radiographs (welding, casting, corrosion, etc.).
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanations, the student will be able to make comparisons between image size and object, determining the values affecting this relationship.
 - 6.2 Given radiographs of different work pieces, the student will be able to:
 - a) recognize the indications of typical defects of welding and cast pieces, etc
 - b) relate the type of discontinuity to its radiographic image.
 - 6.3 Given the instructor's explanations and reference radiographs, the student will be able to evaluate various degrees of defect seriousness in accordance with references.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including delivery of support material, guided discussion, practical exercises on viewing of radiographs and practical exercises on interpretation and evaluation of radiographs.

EQUIPMENT AND RESOURCES:

Writing board
Standard reference radiographs
Sample radiographs
Viewer
Densitometers
Standards
Slides

CONTENTS:

- 7.1 Influence of the properties of the material
 - 7.1.1 Compound materials

 - 7.2 Exposure techniques depending on the geometry and accessibility of the object
 - 7.2.1 Single wall/single image
 - 7.2.2 Double wall/single image
 - 7.2.3 Double wall/double image
 - 7.2.4 Panoramic exposure
 - 7.2.5 Thickness compensation
 - 7.2.6 Masks

 - 7.3 Detection probability depending on type, size, position and orientation of the defect
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations and various work pieces of different materials, the student will be able to select the most suitable radiographic techniques, taking into account the density of the material and the variables of exposure.

 - 7.2 Given the instructor's explanation and various work pieces of different shape, the student will be able to select the most suitable radiographic technique.

 - 7.3 Given the instructor's explanations, the student will be able to analyse the range and limitations of defect detection by radiography.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and practical exercises on technique selection.

EQUIPMENT AND RESOURCES:

Writing board
Work pieces of various materials (steel, aluminium, etc.)
Codes
Work pieces of different geometry
Standards
Transparencies
Slides

CONTENTS:

- 8.1 General knowledge of codes and standards
 - 8.1.1 General knowledge of specifications and procedures
 - 8.1.2 Interpretation of procedures and compilation of test instructions
 - 8.2 Performance of test in accordance with written instructions
 - 8.2.1 Recording of operating conditions on test forms
 - 8.2.2 Evaluation of tasks carried out by level 1 operators
 - 8.3 Instructions for testing in special situations
 - 8.3.1 Range of application of the test, equipment and technique
 - 8.3.2 Standards, codes, and procedures for radiography
 - a) ASTM E-94, E-142 and other applicable standards
 - b) Radiographic techniques and setups
 - c) Applicable employer procedures
 - d) Procedure for radiograph parameter verification
 - e) Radiographic reports
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations and testing procedures, the student will be able to:
 - a) demonstrate understanding of the significance and application of codes, standards, specifications and procedures;
 - b) recognize the various standards existing for the application of radiographic testing;
 - c) prepare instructions for testing.
 - 8.2 Given the instructor's explanation, the student will be able to establish and evaluate tasks for level 1 personnel.
 - 8.3 Given the instructor's explanations, the student will be able to formulate instructions for testing under special conditions.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, practical exercises on interpretation of procedures and compilation of instructions.

EQUIPMENT AND RESOURCES:

Writing board
Codes
Standards (ASME, ASTM, DIN, API, BSI, COVENIN, JIS)
Test procedures and examples of instructions
Work pieces (steel, aluminium, etc.)
Equipment and accessories
Radiographs
Slides

CONTENTS:

- 9.1 Dangers of excessive exposure to X rays and gamma rays
 - 9.1.1 Somatic and genetic effects
 - 9.1.2 Personnel monitoring
 - 9.2 Maximum permissible exposure limits
 - 9.3 Methods of monitoring exposure dose, time, distance and shielding
 - 9.4 Specific safety requirements for the operation of X ray and gamma ray equipment
 - 9.4.1 Monitoring records
 - 9.4.2 Shielding or exposure, bunkers
 - 9.4.3 Operation of warning systems
 - 9.4.4 Calculations of shielding and distances
 - 9.5 Operational and emergency procedures
 - 9.5.1 Accident reports
-

SPECIFIC OBJECTIVES:

- 9.1 Given the instructor's explanations, the student will be able to recognize the dangers of excessive exposure to X rays or gamma rays.
 - 9.2 Given the instructor's explanations and standards of radiation protection, the student will be able to recognize the maximum permissible doses of radiation and their effects on the organism.
 - 9.3 Given the instructor's explanations, the student will be able to explain the variation of exposure dose with variation in time, distance or shielding.
 - 9.4 Given the instructor's explanations, the student will be able to:
 - a) recognize the safety conditions under which X ray and gamma ray equipment as well as equipment for the detection of radiation should be operated;
 - b) handle warning systems;
 - c) calculate shielding and distances.
 - 9.5 Given the instructor's explanations and examples of emergency procedures and situations, the student will be able to describe the possible solutions in such emergencies.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Calculator

X ray and gamma ray equipment

Monitors

Dosimeters

Bunkers

Warning system

CONTENTS:

- 10.1 Multiple film techniques
 - 10.2 Projection and magnification techniques
 - 10.3 Panoramic exposure
 - 10.4 Determination of depth of defects
 - 10.5 Radiography of non-metallic materials (plastics, ceramics, compounds, etc.)
-

SPECIFIC OBJECTIVES:

- 10.1 Given the instructor's explanations, the student will be able to use multiple film techniques.
 - 10.2 Given the instructor's explanation, the student will be able to explain techniques of projection and magnification in radiography.
 - 10.3 Given the instructor's explanations, the student will be able to describe panoramic exposure techniques.
 - 10.4 Given the instructor's explanations, the student will be able to measure the depth of defects.
 - 10.5 Given the instructor's explanations, the student will be able to describe radiography of non-metallic materials.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Course notes
Writing board
Transparencies
Examples
Slides
DIR and CT systems

CONTENTS:

- 11.1 Radiographic viewing
 - 11.1.1 Film-illuminator requirements, background lighting, multiple-composite viewing, dark adaptation and visual acuity
 - 11.1.2 Film identification, location markers, IQ placement
 - 11.1.3 Film-density measurement
 - 11.1.4 Film artifacts
 - 11.2 Radiographic evaluation
 - 11.2.1 Evaluation of castings: casting method review; casting discontinuities; origin and typical orientation of discontinuities; radiographic appearance; casting codes/standards; applicable acceptance criteria; reference radiographs
 - 11.2.2 Evaluation of weldments: welding method review; welding discontinuities; origin and typical orientation of discontinuities; radiographic appearance; welding codes/standards; applicable acceptance criteria; reference radiographs or pictograms
 - 11.3 The recording of tests and test documentation
 - 11.4 Evaluation of results according to standards and applicable codes
-

SPECIFIC OBJECTIVES:

- 11.1 Given the instructor's explanations and the various practical examples of making radiographs in the plant, the student will be able to:
 - a) present a codified recording system, correctly identifying the radiographs;
 - b) document the tests.
 - 11.2 Given the instructor's explanations and various radiographs for a practical case, the student will be able to:
 - a) present a model report;
 - b) describe the cases of acceptance, repair or rejection.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, guided discussion, report and evaluation of radiographs.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Example radiographs
Applicable standards and colours

INSPECTION METHOD: RADIOGRAPHIC TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Nature of ionizing radiation
 - 2.1.1 Corpuscular and electromagnetic radiation
 - 2.1.2 X rays and gamma rays and their spectra
 - 2.1.3 Wavelength and energy

 - 2.2 Radioactive decay
 - 2.2.1 Radioactivity, half -life
 - 2.2.2 Artificial and natural sources
 - 2.2.3 Alpha and beta particles, neutrons
 - 2.2.4 Measurement of intensity, concept of specific emissions (R/Ci.h at 1 m, Gy.Bq.h at 1 m)

 - 2.3 Interaction of radiation with matter
 - 2.3.1 Absorption, scattering, photoelectric effect, Compton effect, pair production
 - 2.3.2 Absorption coefficient; half- thickness
 - 2.3.3 Calculation of attenuation coefficient for simple materials and compounds
 - 2.3.4 Radiographic equivalents

 - 2.4 Measurement of ionization and units
 - 2.4.1 Detection of radiation by ionization, scintillation, etc.
 - 2.4.2 Exposure, absorbed dose, equivalent dose, dose intensity
 - 2.4.3 Calculations relating to radiation dosimetry

 - 2.5 Principles of detection by means of film, fluorescent material or electric and electronic systems in radiographic testing
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to describe the spectral characteristics and nature of ionizing radiation.

- 2.2 Given the instructor's explanations, the student will be able to explain the concepts and parameters relating to the radioactive sources used in the testing.

- 2.3 Given the instructor's explanations, the student will be able to:
 - a) describe various mechanisms for the interaction of radiation with matter and its application in radiographic testing;
 - b) explain the absorption and attenuation of radiation in materials.

- 2.4 Given the instructor's explanations, the student will be able to solve problems relating to radiation detection and dosimetry.

- 2.5 Given the instructor's explanations, the student will be able to explain the principles applied in various detection systems.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and problem solving.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Chart of radionuclides and radioactive decay

CONTENTS:

- 3.1 Industrial radiation sources
 - 3.1.1 X ray generators, linear accelerators, betatrons
 - 3.1.2 Equipment for gamma radiation and neutron generators
 - 3.1.3 Purchase, acceptance, operation and maintenance
 - 3.1.4 Shielding, filtering and collimation
 - 3.2 Facilities for industrial radiography
 - 3.3 Accessories
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) explain the principles of designing equipment and accessories.
 - 3.2 Given the instructor's explanations, the student will be able to:
 - a) design facilities for industrial radiography.
 - 3.2 Given the instructor's explanations, the student will be able to:
 - a) design collimators;
 - b) design and evaluate radiographic viewers and lighting systems.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
X ray equipment
Radiation protection equipment (one radiation monitor and one dosimeter as a minimum)

CONTENTS:

4.1 Photographic recording

4.1.1 Films used in radiography, principles, properties, types of emulsions (granularity), influence of radiation, energy, characteristic curves

4.1.2 Radiographic quality, density, contrast, definition, sharpness

4.1.3 Types of films for industrial radiography

4.1.4 Sensitometric curves

4.1.5 Exposure curves

4.1.6 Lead and fluorescent screens

4.2 Radiography in real time

4.2.1 Testing by fluoroscopy

4.2.2 Image intensities for image transmission by TV

4.3 Xero radiography

4.4 Direct digital radiology, real time digital radiography, computed tomography

SPECIFIC OBJECTIVES:

4.1 Given the instructor's explanations, the student will be able to:

a) evaluate structural characteristics of radiographic film;

b) describe the behaviour and application of various types of radiographic film, including paper and special types;

c) compare and evaluate the various types of screens and their applications.

4.2 Given the instructor's explanations, the student will be able to conduct operation with real time radiographic systems.

4.3 Given the instructor's explanations, the student will be able to carry out tests using xeroradiography, real time radiography, digital radiography and get acquainted with CT systems.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, laboratory practical work and problem workshop.

EQUIPMENT AND RESOURCES:

Transparencies

Slides

Writing board

Manuals for different makes of films

Sensitometric curves

Screens

CONTENTS:

- 5.1 Operating parameters and image quality in radiographic testing
 - 5.1.1 Radiographic sensitivity

 - 5.2 Operating techniques for real-time fluoroscopy and direct digital image recording
 - 5.2.1 Testing sensitivity, fluctuation and resolution

 - 5.3 Film processing, equipment, facilities and reagents
 - 5.3.1 Handling and conservation
 - 5.3.2 Special situations
 - 5.3.3 Influence of the observations conditions in defect detection
 - 5.3.4 Lighting control in viewers
 - 5.3.5 Brightness requirements
 - 5.3.6 Causes of defective radiographs and correction there of
 - 5.3.7 Processing defects
 - 5.3.8 Systematic control of radiographic quality

 - 5.4 Conditions for observing radiographs
 - 5.4.1 Lighting and perceptibility
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to select, design and evaluate testing procedures as a function of operating specifications and techniques.

 - 5.2 Given the instructor's explanations, the student will be able to apply and evaluate real time fluoroscopy.

 - 5.3 Given the instructor's explanations, the student will be able to design and evaluate film processing facilities.

 - 5.4 Given the instructor's explanations, the student will be able to design and evaluate the conditions for film viewing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and review of radiographs.

EQUIPMENT AND RESOURCES:

Radiographic film
Darkroom
Processing equipment
Viewers
Demonstration radiographs
Standard reference radiographs
Slides

CONTENTS:

- 6.1 Radiographic indication of defects
 - 6.1.1 Relation between image and object
 - 6.1.2 Types of defects and their formation
 - 6.1.3 Casting, welding, heat treatment, forging, lamination, corrosion, etc.
 - 6.2 Discontinuities in radiography
 - 6.2.1 Standard reference radiographs (IIW, ASTM, etc.)
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanations, the student will be able to analyse and evaluate radiographic findings and relate them to defectology.
 - 6.2 Given the instructor's explanations and reference radiographs, the student will be able to analyse and evaluate the reliability of the radiographic information.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and supervised student practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Standard reference radiographs
Viewers
Densitometers
Slides

CONTENTS:

- 7.1 Influence of the properties of materials
 - 7.1.1 Compound materials
 - 7.2 Exposure technique depending on the geometry and accessibility of the object
 - 7.2.1 Single wall/single image
 - 7.2.2 Double wall/single image
 - 7.2.3 Double wall /double image
 - 7.2.4 Panoramic exposure
 - 7.2.5 Compensation for thickness
 - 7.2.6 Masks
 - 7.3 Probability of detection according to type, size, position and orientation of the defect
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations, the student will be able to design and evaluate techniques for various types of materials.
 - 7.2 Given the instructor's explanations, the student will be able to select radiographic techniques as a function of specimen geometry and accessibility.
 - 7.3 Given the instructor's explanations, the student will be able to analyse and discuss the validity of the results.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and supervised practical work in selection of techniques.

EQUIPMENT AND RESOURCES:

Writing board
Work pieces of various materials and geometries (steel, aluminium, etc.)
Transparencies
Slides

CONTENTS:

- 8.1 National and international codes and standards for radiographic testing
 - 8.2 Specifications for radiographic testing
 - 8.3 Radiographic procedure writing as per given reference codes.
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations and a review of applicable codes and standards, the student will be able to develop procedures and evaluate results in compliance with these standards.
 - 8.2 Given national and international standards and specific inspection requirements, the student will be able to develop and evaluate specifications for radiographic testing.
 - 8.3 Procedure writing exercises.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, review of standards, specifications and procedures and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
National and international codes and standards
Typical specifications

CONTENTS:

- 9.1 Radiation and its effects
 - 9.1.1 Biological effects of radiation
 - 9.1.2 International regulations and recommendations for radiation protection
 - 9.2 Equipment and facilities
 - 9.2.1 Design and calculation of shielding for equipment and facilities
 - 9.2.2 Design of packaging for the transport of radioactive sources
 - 9.2.3 Verification of radiation of leaks from X ray and gamma ray equipment
 - 9.3 Operational procedures
 - 9.3.1 Safety in equipment and facilities for industrial radiography
 - 9.3.2 Maintenance of equipment for scintiscanning
 - 9.4 Radiation safety conditions for work in the field
-

SPECIFIC OBJECTIVES:

- 9.1 Given the instructor's explanations and international regulations, the student will be able to develop radiation protection procedures and manuals for the use and maintenance of equipment and facilities.
 - 9.2 Given the instructor's explanations, the student will be able to design and calculate shielding and packaging for the safe transport of radioactive sources.
 - 9.3 Given the instructor's explanations, the student will be able to devise and evaluate radiation protection conditions in facilities for industrial radiography.
 - 9.4 Given the instructor's explanations, the student will be able to plan, conduct and evaluate field operating procedures to ensure adequate protection of personnel.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, calculation exercises and problem solving.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Writing board
Typical documents
Course notes
International regulations and recommendations
Installation plans
Comparative tables
Monitors
Dosimeters

CONTENTS:

- 10.1 Special film techniques
 - 10.1.1 Multiple film, projection and enlargement
 - 10.1.2 Panoramic exposure
 - 10.1.3 Defect depth determination techniques
 - 10.2 Radiography of non-metallic materials (plastics, ceramics, compounds, etc.)
 - 10.3 Application of radiographic techniques in non-conventional areas
 - 10.3.1 Aeronautics and aerospace
 - 10.3.2 Offshore structures
 - 10.3.3 Others
-

SPECIFIC OBJECTIVES:

- 10.1 Given the instructor's explanations, the student will be able to develop procedures to apply special film techniques.
 - 10.2 Given the instructor's explanations, the student will be able to develop and evaluate procedures for testing non-metallic materials.
 - 10.3 Given the instructor's explanations, the student will be able to develop and evaluate procedures to apply radiographic testing in particular industries and environments.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations, problem-solving and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Slides
Test pieces
Demonstration radiographs

CONTENTS:

- 11.1 Comparison and application of imaging techniques including film, fluoroscopic and scintillation counting
 - 11.2 Treatment of the image including image analysis, enhancement, reconstruction, storage, transmission and evaluation
 - 11.3 Factors involved in valid interpretation of results
-

SPECIFIC OBJECTIVES:

- 11.1 Given the instructor's explanations, the student will be able to compare and evaluate various means of recording the radiographic test.
 - 11.2 Given the instructor's explanations, the student will be able to evaluate and select appropriate means of handling the radiographic images once recorded.
 - 11.3 Given the instructor's explanations and his own experience, the student will be able to evaluate the validity of the interpretation of test results, with respect to specifications, the nature of the specimen and the parameters of the test.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and supervised problem solving and practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Various types of imaging equipment
Sample test reports and radiographs

III. INSPECTION METHOD: ULTRASONIC TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	4	8	¹⁾
2. TERMINOLOGY, PHYSICAL PRINCIPLES AND FUNDAMENTALS OF ULTRASONICS	8	8	5
3. TESTING TECHNIQUES AND THEIR LIMITATIONS	4	8	5
4. EQUIPMENT AND ACCESSORIES	4	6	6
5. CALIBRATION OF THE TESTING SYSTEM	8	12	3
6. SPECIFIC APPLICATIONS	4	12	4
7. CODES, STANDARDS, SPECIFICATIONS AND PROCEDURES	4	10	9
8. RECORDING AND EVALUATION OF RESULTS	4	10	2
9. SPECIAL TECHNIQUES	-	6	6
TOTAL	40	80	40 ¹⁾
¹⁾ ¹⁾ In addition to the above 40 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once..			

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE STRUCTURE	4
3. QUALITY ASSURANCE AND STANDARDIZATION -	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology. Reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods:
 - a) Visual testing
 - b) Liquid penetrant testing
 - c) Magnetic particle testing
 - d) Radiographic testing
 - e) Ultrasonic testing
 - f) Eddy current testing
 - g) Leak testing
 - 1.1.4 Limitations in the application of ultrasonic testing
 - 1.1.5 Responsibilities of the levels of certification
- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - b) define the nature of a non -destructive test;
 - c) list the characteristics of NDT technology and the reasons for using NDT;
 - d) compare the different types of NDT, with particular reference to the application and uses of each method.
- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity;
 - b) define the properties of materials, especially of metals;
 - c) recognize how defects affect the properties of materials.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials

CONTENTS:

- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) Casting
 - b) Welding
 - c) Forging
 - d) Rolling
 - e) Heat treatment
 - f) Machining
 - g) Plating
 - 1.3.2 In-service defects
 - a) Overload
 - b) Fatigue
 - c) Corrosion
 - d) Erosion
 - e) Brittle fracture
 - f) Others

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication;
 - b) describe typical defects associated with each type of process;
 - c) describe typical defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Course notes
Samples of materials with typical defects

CONTENTS:

- 2.1 General concepts
 - 2.1.1 Definition of ultrasonics
 - 2.1.2 History of ultrasonic testing
 - 2.1.3 Applications of ultrasonic energy
 - 2.1.4 Properties of sound and propagation of mechanical waves
- 2.2 Concepts relating to frequency, amplitude, wave length and speed of propagation
- 2.3 Acoustic impedance
- 2.4 Influence of wave type on the test method
 - 2.4.1 Longitudinal waves and transverse waves
 - 2.4.2 Surface waves and Lamb waves (Level 2 and 3)
- 2.5 Reflection and refraction
 - 2.5.1 Modes conversion
 - 2.5.2 Attenuation
 - 2.5.3 Snell's law and critical angles

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to list the properties of ultrasonic waves.
- 2.2 Given the instructor's explanations, the student will be able to:
 - a) define frequency, amplitude, length, speed of propagation;
 - b) state the mathematical expression relating speed of propagation, wavelength and frequency.
- 2.3 Given the instructor's explanations, the student will be able to define acoustic impedance, stating the corresponding mathematical expressions.
- 2.4 Given the instructor's explanations, the student will be able to:
 - a) define longitudinal and transverse waves, specifying their characteristics;
 - b) state the relationship between wave type and application of test.
- 2.5 Given the instructor's explanations, the student will be able to:
 - a) define reflection and refraction;
 - b) represent graphically the possible mode conversions when the beam is incident at non-zero angle with respect to normal;
 - c) state the causes of attenuation.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and exercise workshop.

EQUIPMENT AND RESOURCES:

Transparencies

Slides

Visual animations

CONTENTS:

- 2.6 Ultrasonic wave transfer from one medium to another
 - 2.6.1 Generation of ultrasonic waves
 - 2.6.2 Ultrasonic losses in different media
- 2.7 Piezoelectric effect, characteristics and types of crystals
- 2.8 Sonic field influence of speed of sound and transducer size
- 2.9 Types of sensors; normal; emitter-receiver; angular
- 2.10 The sonic path; near field; far field; beam divergence

SPECIFIC OBJECTIVES:

- 2.6 Given the instructor's explanations, the student will be able to:
 - a) state the principle of conservation of energy;
 - b) list the energies involved in ultrasonic testing, describing the way in which the energies change.
- 2.7 Given the concept of piezoelectricity, the student will be able to:
 - a) define its nature;
 - b) list the materials which exhibit this property and which are currently used in ultrasonics.
- 2.8 Given the instructor's explanations, the student will be able to:
 - a) define sonic field;
 - b) explain the relationship between transducer size, frequency and tested material on sonic field.
- 2.9 Given the instructor's explanations and a sensor, the student will be able to:
 - a) recognize its type and structural characteristics;
 - b) compare it with the other types of sensors, stating the basic differences between them;
 - c) describe its use or application.
- 2.10 Given the instructor's explanations and the concepts of near field and far field the student will be able to:
 - a) state the characteristics of each and the main differences between them;
 - b) state the mathematical relationship which limits them;
 - c) represent graphically the sonic field for a transducer, indicating the near and the far field;
 - d) correctly interpret the beam shape for different transducers.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, lecture, practical exercises and problem workshop

EQUIPMENT AND RESOURCES:

Writing board

Transparencies and slides

Various types of sensors and calculators

CONTENTS:

- 3.1 Pulse- echo technique:
 - 3.1.1 By direct contact
 - 3.1.2 Immersion
 - a) Transducers in water
 - b) Water column, wheels
 - c) Submerged test part
 - d) Sound-beam path — transducer to water path length
 - e) Focused transducers
 - f) Curved surfaces
 - g) Comparison of contact and immersion methods
 - 3.1.3 Pitch catch transducers
- 3.2 Transmission technique
- 3.3 Resonance technique
- 3.4 Methods of coupling
- 3.5 Testing with automatic systems and on the production line

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) state the basic principle of the pulse- echo technique;
 - b) list the applications and limitations of the technique.
- 3.2 Given the instructor's explanations, the student will be able to:
 - a) describe the nature of the transmission technique;
 - b) list the applications and limitations of the transmission technique.
- 3.3 Given the instructor's explanations, the student will be able to describe the resonance technique.
- 3.4 Given the instructor's explanations, the student will be able to:
 - a) define coupling;
 - b) define the characteristics of a good couplant;
 - c) list five different substances which can be used as couplants;
 - d) relate the different techniques to the method of coupling.
- 3.5 Given the instructor's explanations, the student will be able to:
 - a) list the characteristics of an automatic testing system;

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides

CONTENTS:

- 4.1 Description of the basic testing equipment with display of the information in a representation (A-scan)
 - 4.2 Basic B-C-D scan and computerized systems.
 - 4.3 Analog and digital equipment for thickness measurements
 - 4.4 Controls and Functions
 - 4.4.1 Functions
 - 4.4.2 Use
 - 4.4.3 Recorders
 - 4.4.4 Alarms
 - 4.4.5 Automatic and semi-automatic systems
 - 4.4.6 Electronic distance/amplitude correction
 - 4.4.7 Transducers — materials
 - 4.4.8 Piezoelectric effect
 - 4.4.9 Types of crystals
 - 4.4.10 Frequency (crystal-thickness relationships)
 - 4.4.11 Beam spread
 - 4.4.12 Sensitivity, resolution and damping
 - 4.4.13 Couplants
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations and a set of ultrasonic (A-scan) equipment, the student will be able to recognize the controls and describe the specific function of each.
 - 4.2 Given the instructor's explanations and ultrasonic equipment for thickness measurements, the student will be able to:
 - a) recognize the type of equipment;
 - b) recognize each of the controls and its function;
 - c) operate the equipment correctly.
 - 4.3 Given the instructor's explanations and a set of ultrasonic equipment, the student will be able to explain the use of the monitor.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, delivery of support materials and practical work.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Ultrasonic equipment with analogue and digital displays

Sensors

CONTENTS:

- 5.1 Distance calibration for normal single and double crystal sensors (transmitter/receiver)
 - 5.2 Angular transducers of transverse waves
 - 5.2.1 Sonic path calibration
 - 5.2.2 Projected distance, pulse echo variables, transmission factors
 - 5.2.3 Shortened projected distance
 - 5.3 Checking the calibration: consideration of differences in speed of propagation between calibration block and test piece, comparison with reference blocks
 - 5.4 Variable effects, transmission accuracy
 - 5.5 Calibration requirements and reflectors
 - 5.6 Inspection calibration
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to:
 - a) perform the calibration correctly at a distance with normal sensors (single and double crystals);
 - b) explain the difference in the calibration of the two graphs obtained for the two types of sensors;
 - c) state the applications, advantages and limitations for each of the calibration systems with different sensors.
 - 5.2 Given the instructor's explanations and the procedures, the student will be able to:
 - a) perform the calibration correctly with an angular sensor;
 - b) distinguish between calibration techniques for angular sensors;
 - c) locate the beam exit point and verify the angle.
 - 5.3 Given the instructor's explanations and a calibration, the student will be able to adjust the calibration to compensate for the difference in speed of ultrasonic propagation between the calibration block and the test piece.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, lecture and practical demonstration.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials
Written instructions for ultrasonic testing
Ultrasonic equipment
Normal sensors (single and double crystals)
Test pieces of simple geometry
Calibration units
Couplant
Normal sensors (different angles)
Sample work pieces

CONTENTS:

- 6.1 Testing of specimens of simple geometries
 - 6.1.1 Examination of sheets
 - 6.1.2 Examination of billets
 - 6.1.3 Examination of castings.
 - 6.2 Thickness measurements
 - 6.2.1 Influence of material type
 - 6.2.2 Geometry
 - 6.2.3 Influence of surface condition
 - 6.3 Detection of corrosion
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanations, the student will be able to list the possible flaws which occur in work pieces of simple geometry.
 - 6.2 Given the instructor's explanations, the student will be able to relate the speed of sound propagation to the type of material.
 - 6.3 Given the instructor's explanations, the student will be able to describe the difficulties in detecting corrosion.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, delivery of support materials, problem workshop and practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials
Calculator
Ultrasonic equipment
Accessories
Test pieces

CONTENTS:

- 7.1 General knowledge
 - 7.2 Codes and standards
 - 7.3 Performance of tests in accordance with written instructions, selection of parameters
 - 7.4 Recording of results
 - 7.5 Preparation of test reports
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations, the student will be able to recognize the different codes and standards which exist for the application of ultrasonic testing.
 - 7.2 Given the instructor's explanations, the student will be able to recognize the different codes and standards which exist for the application of ultrasonic testing.
 - 7.3 Given the instructor's explanations and the written procedural instructions, the student will be able to carry out a test, correctly interpreting the instructions and terms used.
 - 7.4 Given the instructor's explanations and requisite forms, the student will be able to record the results of the test in proper format.
 - 7.5 Given the instructor's explanations and requisite forms, the student will be able to prepare the test report completing all of its requirements.
-

METHODOLOGICAL STRATEGIES

Instructor's presentation including lecture, guided discussion and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board
Codes and standards ASME, ASTM, DIN, API, COVENIN, JIS, BSI, IRAM
Ultrasonic equipment and accessories
Test pieces of simple geometry

CONTENTS:

- 8.1 Recording of the test results
 - 8.1.1 Position of defects
 - 8.1.2 Echo amplitude
 - 8.1.3 Defect dimensions (average value, length)
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations and the test procedure for a work piece, the student will be able to note correctly on the recording form the results of the test with respect to the position and size of the reflector, as detected by the average value technique.
-

METHODOLOGICAL STRATEGIES

Instructor's presentation including guided discussion and practical work.

EQUIPMENT AND RESOURCES:

Procedures
Recording sheets
Ultrasonic equipment and accessories

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods, VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - d) define non-destructive testing;
 - e) describe the basic principles and the method of application of the common NDT methods;
 - f) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - c) describe the structure, physical and mechanical properties of metallic materials
 - d) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

1.3 Processing and defects

1.3.1 Primary processes and related defects

1.3.2 Manufacturing processes and related defects:

- a) Casting processes and associated discontinuities: ingots, blooms, and billets; sand casting; centrifugal casting; investment casting
- b) Wrought processes and associated discontinuities: forgings; rolled products; extruded products
- c) Welding processes and associated discontinuities: submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.

1.4 Materials in service

1.4.1 Behaviour of materials in service

1.4.2 Service conditions leading to defects and failures: corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others

1.4.3 Concepts of rupture development in metals

SPECIFIC OBJECTIVES:

1.3 Given the instructor's explanations, the student will be able to:

- c) describe the common primary metallurgical processes and the related defects;
- d) describe the common manufacturing processes and the related defects.

1.4 Given the instructor's explanations, the student will be able to:

- c) describe basic mechanisms giving rise to defects when the component is in service;
 - d) describe defects that could arise during service and the general significance of each.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

CONTENTS:

- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports
-

SPECIFIC OBJECTIVES:

- 1 5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and review of examples.

EQUIPMENT AND RESOURCES:

Transparencies
Films
Slides
Writing board
Course notes
Typical documents, i.e. codes

CONTENTS:

- 2.1 The nature of ultrasonic waves
 - 2.2 Characteristics of wave propagation
 - 2.2.1 Frequency
 - 2.2.2 Amplitude
 - 2.2.3 Wave length
 - 2.2.4 Velocity
 - 2.2.5 Acoustic impedance
 - 2.2.6 Acoustic pressure
 - 2.2.7 Acoustic energy
 - 2.2.8 Acoustic intensity
 - 2.3 Types of ultrasonic waves and their applications
 - 2.3.1 Longitudinal wave
 - 2.3.2 Transverse wave
 - 2.3.3 Surface wave
 - 2.3.4 Lamb wave
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to describe the nature of ultrasonic waves.
 - 2.2 Given the instructor's explanations, the student will be able to:
 - a) define frequency, amplitude, length, velocity, impedance, acoustic pressure and intensity;
 - b) determine the corresponding mathematical relationships.
 - 2.3 Given the instructor's explanations, the student will be able to:
 - a) define longitudinal waves, surface waves and lamb waves and describe their characteristics;
 - b) explain the relationship between the type of wave and its application.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and guided discussion.

EQUIPMENT AND RESOURCES:

Course notes
Writing board
Transparencies
Slides

CONTENTS:

- 2.4 Behaviour of ultrasonic waves: normal incidence; angular incidence; reflection and refraction; mode conversion
 - 2.5 Transfer of energy from one medium to another
 - 2.5.1 Generation of ultrasonic waves
 - 2.5.2 Energy losses in various media
 - 2.6 Piezoelectric and magnetostrictive effect on the crystal
 - 2.7 Characteristics of the sound beam
 - 2.7.1 Far field and near field
 - 2.7.2 Influence of sound velocity and transducer size
 - 2.7.3 Field divergence
 - 2.8 Attenuation of sound: Cause and effect; principles of measurement of attenuation
-

SPECIFIC OBJECTIVES:

- 2.4 Given the instructor's explanations, the student will be able to:
 - a) distinguish between normal and angular incidence;
 - b) define reflection and refraction;
 - c) explain mode conversion.
- 2.5 Given the instructor's explanations, the student will be able to:
 - a) describe the characteristics of energy transfer from one medium to another;
 - b) explain the generation of ultrasonic waves and the cause of energy loss in various media.
- 2.6 Given the instructor's explanations, the student will be able to:
 - a) explain the piezoelectric and magnetostrictive effects;
 - b) compare the advantages and disadvantages of various crystal materials.
- 2.7 Given the instructor's explanations of the concepts of near and far field. The student will be able to:
 - a) identify the characteristics of near and far fields and differentiate between them;
 - b) state the limiting mathematical relationship;
 - c) illustrate graphically the sonic field for a transducer, indicating the near and far fields;
 - d) interpret correctly the sonogram for different sensors.
- 2.8 Given the instructor's explanations, the student will be able to define ultrasonic attenuation

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and problem solving.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Ultrasonic instruments
Various transducers
Calibration blocks

CONTENTS:

- 3.1 Test methods: transmission method; pulse- echo method; resonance method; automatic and semi- automatic methods
 - 3.2 Sensors: normal incidence sensors; angular incidence sensors; special sensors
 - 3.3 Techniques: tandem techniques; focused sensor technique; double-crystal sensor technique; surface- wave sensor technique; immersion techniques
 - 3.4 Limitations in the application of the ultrasonic test method.
 - 3.5 Defect sizing techniques: maximum amplitude; 6db drop; 20db drop; distance gain size (DGS)
 - 3.6 Discontinuity detection:-
 - 3.6.1 Sensitivity to reflections
 - 3.6.2 Resolution
 - 3.6.3 Determination of discontinuity size
 - 3.6.4 Location of discontinuity.
 - 3.7 Setting test sensitivity
 - 3.7.1 Distance amplitude correction (DAC)
 - 3.7.2 DGS
 - 3.7.3 Attenuation and transfer correction.
 - 3.8 Echo classification systems: pattern responses 1,2,3a,3b,4 (BS 3923); planar defects; volumetric defects; discrete reflectors; diffuse reflectors
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) explain the principle of each of the methods;
 - b) list the applications and limitations of the methods.
- 3.2 Given the instructor's explanations, the student will be able to:
 - a) distinguish between the various types of sensors;
 - b) perform the calculation for obtaining the angle of incidence.
- 3.3 Given the instructor's explanations, the student will be able to:
 - a) explain each of the techniques;
 - b) list the applications and limitations of each technique.
- 3.4 Given the instructor's explanations, the student will be able to list the limitations which restrict the use of the ultrasonic test method.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Specimen sensors

CONTENTS:

- 4.1 Construction and mode of operation of ultrasonic equipment
 - 4.1.1 Functions of the electronic elements in a typical instrument
 - 4.1.2 Types of instrumentation:
 - a) portable
 - b) laboratory
 - c) digital
 - d) automated installations
- 4.2 Characteristics of equipment and system controls
 - 4.2.1 Properties of vertical and horizontal amplifiers
 - 4.2.2 Correlation between resolving power and frequency, transmitting power, damping
 - 4.2.3 Linearity
 - 4.2.4 Saturation and amplifier threshold
- 4.3 Signal presentation: echo amplitude and its control; A-scan; B-scan; C-scan; correlation of digital and analogue signals
- 4.4 Recording instrumentation
 - 4.4.1 Automatic monitors
 - 4.4.2 Computer interfacing
 - 4.4.3 Recorders, printers and colour markers

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, practical exercises and demonstrations, the student will be able to explain the functions of the ultrasonic instrument and recognize a malfunction of a component.
- 4.2 Given several types of ultrasonic instrumentation and the instructor's demonstration and explanation, the student will be able to explain the different functions of each, calibrate each type and identify malfunctions.
- 4.3 Given several types of instrumentation and the instructor's explanations, the student will be able to explain the significant characteristics of each and to select the appropriate instrument for each inspection problem.
- 4.4 Given the instructor's explanations and demonstration, the student will be able to operate various types of recording instrumentation in conjunction with an ultrasonic instrument.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, demonstrations and practical exercises.

EQUIPMENT AND RESOURCES:

Ultrasonic equipment
Recording equipment
Transparencies
Slides
Writing board

CONTENTS:

- 5.1 Calibration of equipment
 - 5.1.1 Horizontal linearity
 - 5.1.2 Vertical linearity
 - 5.2 Verification of the sensor
 - 5.2.1 Calibration blocks V1 and V2
 - 5.2.2 Sensor sensitivity
 - 5.2.3 Sensor resolution
 - 5.2.4 Verification of an angular sensor
 - 5.3 Calibration in curved work pieces
 - 5.4 Construction of distance- amplitude correction (DAC)
 - 5.5 DGS method
 - 5.6 Coupling medium
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the necessary equipment and calibration blocks, the student will be able to test the horizontal and vertical linearity of the equipment.
 - 5.2 Given the instructor's explanations and the necessary equipment, the student will be able to:
 - a) test the sensor to determine its sensitivity and resolution;
 - b) determine the exit point and angle of incidence for an angle sensor.
 - 5.3 Given an explanation of the procedures and the necessary equipment, the student will be able to perform calibration using curved work pieces.
 - 5.4 Given the instructor's explanation of the procedures, the student will be able to construct a DAC curve.
 - 5.5 Given the instructor's explanations, the student will be able to make evaluations with DGS curves.
 - 5.6 Given the instructor's explanations, the student will be able to explain the advantages of various types of coupling media.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board, sample written procedures, calibration blocks, coupling materials, equipment
Sample DGS curves

CONTENTS:

- 6.1 Methods of examination
 - 6.1.1 Cast work pieces
 - 6.1.2 Welded work pieces
 - 6.1.3 Components and systems
 - 6.1.4 Austenitic materials
 - 6.1.5 Forged work pieces
 - 6.1.6 Non-metallic materials (ceramics, plastics, etc.)
 - 6.1.7 Bonded structures
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanation and demonstrations, the student will be able to:
 - a) explain how the test should be performed, the type of sensor to be used, the frequency, probe angle and scanning direction;
 - b) describe the manufacturing processes, geometries and possible types of discontinuities in each case.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Demonstration work pieces
Ultrasonic equipment and materials

CONTENTS:

7.1 Codes, standards and specifications specifically related to ultrasonic testing

7.2 Testing procedures:

7.2.1 Selection of equipment

7.2.2 Position and direction of scan

7.2.3 Calibration

7.2.4 Comparison procedures

a) Standards and references

b) Amplitude area and distance relationship

c) Application of results of other NDT methods

7.2.5 Object appraisal

a) History of part

b) Intended use of part

c) Interpretation to code/specification

d) Type and location of discontinuity.

SPECIFIC OBJECTIVES:

7.1 Given a collection of standards and specifications relating to ultrasonic testing and the instructor's explanation, the student will be able to distinguish between and relate findings to them.

7.2 Given the instructor's presentation of a specific case, the student will be able to:

a) define the test procedure;

b) prepare a report based on the procedure.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and guided discussion

Writing board

Transparencies

Slides

Typical codes, standards, specifications and procedures

CONTENTS:

- 8.1 Response of the equipment to various types of defects
 - 8.2 Evaluation of discontinuities in accordance with specifications, standards and codes
 - 8.3 Recording and reporting the results of a test
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations, the student will be able to identify the various types of defects.
 - 8.2 Given the instructor's demonstration and the sample work piece, the student will be able to recognize and evaluate discontinuities in accordance with a specific code.
 - 8.3 Given the instructor's explanations and the results of an evaluation of a sample work piece, the student will be able to record and report on the test.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Ultrasonic equipment
Test pieces
Procedures
Report forms
Course notes

CONTENTS:

- 9.1 Special inspection problems and techniques used to solve them
 - 9.2 Automated and semi- automated testing techniques
 - 9.3 Special techniques for data processing
 - 9.4 Time of flight diffraction
 - 9.5 Automatic UT (P scan)
 - 9.6 Phased array
 - 9.7 And scan (portable C scan)
 - 9.8 Corrosion mapping and detection (T scan)
 - 9.9 Guided waves.
-

SPECIFIC OBJECTIVES:

- 9.1 Given the instructor's demonstrations and explanations, the student will be able to identify special inspection problems and select appropriate approaches.
 - 9.2 Given the instructor's demonstrations and explanations, the student will be able to understand the use of automated and semi- automated testing techniques.
 - 9.3 Given the instructor's demonstrations and explanations, the student will be able to understand the special techniques used for data processing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including demonstration.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film
Samples

INSPECTION METHOD: ULTRASONIC TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Nature of ultrasonic waves
 - 2.2 Characteristics of ultrasonic wave propagation. Frequency, wavelength, velocity, acoustic impedance, acoustic energy, acoustic intensity, amplitude.
 - 2.3 Types of ultrasonic waves and their applications:
 - 2.3.1 Longitudinal wave
 - 2.3.2 Transverse wave
 - 2.3.3 Surface wave
 - 2.3.4 Lamb wave
 - 2.4 Behaviour of ultrasonic waves
 - 2.4.1 Normal incidence
 - 2.4.2 Angular incidence
 - 2.4.3 Reflection and refraction
 - 2.4.4 Methods of mode conversion
 - 2.4.5 Snell's law
 - 2.4.6 Modes of sound wave propagation.
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to discuss the nature of ultrasonic waves.
- 2.2 Given the instructor's explanations, the student will be able to:
 - a) define frequency, amplitude, length, velocity, impedance, acoustic pressure and intensity;
 - b) apply the corresponding mathematical relationships;
- 2.3 Given the instructor's explanations, the student will be able to:
 - a) define longitudinal waves, surface waves and Lamb waves and describe their characteristics;
 - b) determine the relationship between the type of the wave and its applications;
- 2.4 Given the instructor's explanations, the student will be able to:
 - a) distinguish between normal and angular incidence;
 - b) explain reflection and refraction; mode conversion.

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides

CONTENTS:

- 2.5 Transfer of energy from one medium to another, generation of ultrasonic waves, energy losses in various media.
 - 2.6 Piezoelectric effect and magnetostrictive effect in crystals
 - 2.7 Far field and near field, influence of the speed of sound and the size of the transducer, divergence of the field, Fresnel and Fraunhofer zones.
 - 2.8 Attenuation of sound, cause, effect, principles of measurement
-

SPECIFIC OBJECTIVES:

- 2.5 Given the instructor's explanations, the student will be able to:
 - a) explain the energy transfer from one medium to another;
 - b) explain ultrasonic waves and the cause of energy loss in various media;
 - 2.6 Given the instructor's explanations, the student will be able to:
 - a) explain the differences between the piezoelectric effect and the magnetostrictive effect;
 - b) describe the advantages and disadvantages of various crystals;
 - 2.7 Given the instructor's explanations, the student will be able to sketch near field and far field indicating:
 - a) the characteristics of each and the essential differences;
 - b) the mathematical relationship limiting them;
 - c) the sonic field for a transducer, with indication of the near field and the far field;
 - d) the sonogram for different sensors.
 - 2.8 Given the instructor's explanations, the student will be able to explain attenuation of sound.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides

CONTENTS:

- 3.1 Testing methods:
 - 3.1.1 Transmission method
 - 3.1.2 Pulse-echo method
 - 3.1.3 Resonance method
 - 3.1.4 Automatic and semi- automatic methods
 - a) Time of flight diffraction
 - b) Phased array
 - c) And scan (Portable C scan)
 - d) Guided wave
 - e) Corrosion Mapping (T scan)

 - 3.2 Sensors:
 - 3.2.1 Normal incidence sensors
 - 3.2.2 Angular incidence sensors
 - 3.2.3 Special sensors

 - 3.3 Techniques:
 - 3.3.1 Tandem technique
 - 3.3.2 Focalized sensor technique
 - 3.3.3 Double crystal technique
 - 3.3.4 Surface -wave sensor technique
 - 3.3.5 Immersion techniques
 - a) Transducer in water
 - b) Water column, wheels etc
 - c) Submerged test part
 - d) Sound beam path — transducer to part
 - e) Testing of curved surfaces.

 - 3.4 Limitations to the application of ultrasonic testing
-

SPECIFIC OBJECTIVES:

- 3. Given the instructor's explanations, the student will be able to:
 - a) explain the principle of each of the techniques, its application and limitations;
 - b) distinguish between the different types of sensors and perform the calculation to obtain the angles;
 - c) describe the various operational techniques and determine their applications and limitations;
 - d) determine the limits of ultrasonic testing for each type of application.

METHODOLOGICAL STRATEGIES:

Instructor' s demonstration including guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Sample transducers
Film

CONTENTS:

- 4.1 Construction and mode of operation of ultrasonic equipment
 - 4.1.1 Functions of the electronic elements in a typical instrument
 - 4.1.2 Types of instrumentation:
 - a) portable
 - b) laboratory
 - c) digital
 - d) automated installations
 - 4.2 Characteristics of equipment and system controls
 - 4.2.1 Properties of vertical and horizontal amplifiers
 - 4.2.2 Correlation between resolving power and frequency, transmitting power, damping
 - 4.2.3 Linearity
 - 4.2.4 Saturation and amplifier threshold
 - 4.3 Signal presentation: Echo amplitude and its control; A-scan; B-scan; C-scan; P-scan; T-scan; correlation of digital and analogue signals
 - 4.4 Recording instrumentation
 - 4.4.1 Automatic monitors
 - 4.4.2 Computer interfacing
 - 4.4.3 Recorders, printers and colour markers
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, practical exercises and demonstrations, the student will be able to explain the functions of the ultrasonic instrument and recognize a malfunction of a component.
- 4.2 Given several types of ultrasonic instrumentation and the instructor's demonstration and explanation, the student will be able to explain the different functions of each. calibrate each type and identify malfunctions.
- 4.3 Given several types of instrumentation and the instructor's explanations, the student will be able to explain the significant characteristics of each and to select the appropriate instrument for each inspection problem.
- 4.4 Given the instructor's explanations and demonstration, the student will be able to operate various types of recording instrumentation in conjunction with an ultrasonic instrument.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, demonstrations and practical exercises.

EQUIPMENT AND RESOURCES:

Ultrasonic equipment
Recording equipment
Transparencies
Slides
Writing board

CONTENTS:

- 5.1 Calibration and adjustment of the equipment:
 - 5.1.1 Calibration of equipment electronics
 - a) variable effects,
 - b) transmission accuracy
 - 5.1.2 Accessories
 - 5.1.3 Control of calibration
- 5.2 Calibration of the sensitivity of the test, different geometric conditions.
 - 5.2.1 Reference reflectors for calibration
 - a) Balls, side drilled and flat bottomed holes
 - b) Area amplitude blocks
 - c) Distance amplitude blocks
 - d) Notches
 - e) Special blocks, I.I.W and others
 - 5.2.2 Design and preparation of calibration units
 - 5.2.3 Various calibration criteria (D.A.C., D.G.S., etc.) and selection of suitable reflectors
 - 5.2.4 Exact measurement of speed of propagation, use of interferometers.
- 5.3 Transmission of ultrasonic energy across the surface being explored
 - 5.3.1 Condition of surface, curvature
 - 5.3.2 Precautions against excitation
 - 5.3.3 Crystal diameter and coupling medium

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to establish procedures for the calibration of equipment.
- 5.2 Given the instructor's explanations, the student will be able to establish procedures for the calibration and sensitivity of the test.
- 5.3 Given the instructor's explanations, the student will be able to establish suitable procedures for optimizing the transmission of energy across the surface being explored.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion, demonstrations and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Test equipment, sensors and calibration blocks

CONTENTS:

- 6.1 Methods of examination
 - 6.1.1 Cast work pieces
 - 6.1.4 Welded work pieces
 - 6.1.5 Components and systems
 - 6.1.4 Austenitic materials
 - 6.1.5 Forged work pieces
 - 6.1.8 Non-metallic materials (ceramics, plastics, etc.)
 - 6.1.9 Bonded structures
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanation and demonstrations, the student will be able to:
 - a) explain how the test should be performed, the type of sensor to be used, the frequency, probe angle and scanning direction
 - b) describe the manufacturing processes, geometries and possible types of discontinuities in each case.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Equipment and supplies
Samples containing discontinuities

CONTENTS:

- 7.1 Examination specifications
 - 7.1.1 Function of design engineering
 - 7.1.2 Design and building codes
 - 7.1.3 ASME Code

- 7.2 Standards for ultrasonic testing
 - 7.2.1 Specific standards for testing with ultrasonics (ASTM, JIS, EN)
 - 7.2.2 Interpretation of specifications, codes and standards

- 7.3 Test procedures
 - 7.3.1 Drafting of test procedures
 - 7.3.2 General and specific procedures — Specific applications to be considered
 - a) Detection of flaws
 - b) Thickness assessment
 - c) Bond evaluation
 - d) Fluid flow measurements
 - e) Material properties measurements
 - f) Computer control and defect analysis
 - g) Liquid level setting
 - h) Process control
 - i) Field inspection
 - 7.3.3 Safety and health consideration: electric shock; mechanical hazards; pneumatic hazards; chemical contamination

SPECIFIC OBJECTIVES:

- 7.1. Given the instructor's explanations and the results of practical exercises, the student will be able to interpret, analyse and explain examination specifications developed by design engineers or specified in codes.

- 1.2. Given the instructor's explanation, the student will be able to analyse, interpret and discuss the validity of testing procedures in relation to the applicable specifications, codes and standards.

- 7.3. Given the instructor's explanation and the results of practical work, the student will be able to analyse, evaluate and draft complete testing procedures for whatever type of specimen is to be examined and for whatever ultrasonic technique is required, with interpretation of results.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, discussion of examples, guided discussion and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Examples of design specifications
Applicable codes and standards
Examples of general and specific procedures

CONTENTS:

- 8.1 Response of the equipment to the various types of defect
 - 8.2 Evaluation of discontinuities, in accordance with specifications, standards and codes
 - 8.3 Recording and reporting on the test
-

SPECIFIC OBJECTIVES:

- 8.1 Given an ultrasonic instrument, a test piece containing one or more discontinuities and the instructor's explanations, the student will be able to recognize various types of defects by the instrument's response.
 - 8.2 Given the instructor's explanations, the student will be able to recognize and evaluate discontinuities in accordance with a specific code.
 - 8.3 Given the instructor's explanations, the student will be able to:
 - a) interpret and discuss the test results;
 - b) establish the conditions for preparing the report.
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Equipment
Test pieces
Codes
Procedures

CONTENTS:

- 9.1 Special techniques
 - 9.1.1 Ultrasonic holography
 - 9.1.2 Ultrasonic spectroscopy
 - 9.1.3 Automated and semi- automated testing techniques
 - 9.1.4 Special techniques for data processing
-

SPECIFIC OBJECTIVES:

- 9.1 Given the instructor's explanations, the student will be able to:
 - a) state the principles of applying each special technique;
 - b) evaluate the possible application of each special technique to industrial problems.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and practical exercises.

EQUIPMENT AND RESOURCES:

Writing board
Slides
Transparencies
Equipment and test samples

IV. INSPECTION METHOD: MAGNETIC PARTICLE TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	4	5	1) ¹⁾
2. PHYSICAL PRINCIPLES AND FUNDAMENTALS OF MAGNETIC PARTICLES	3	3	2
3. METHODS AND TECHNIQUES	4	4	3
4. EQUIPMENT AND ACCESSORIES	2	3	3
5. CODES, STANDARDS, SPECIFICATIONS AND PROCEDURES	1	3	8
6. PRESENTATION AND RECORDING OF RESULTS	2	2	2
7. INTERPRETATION OF RESULTS LIMITATIONS	-	4	2
TOTAL	16	24	20¹⁾
¹⁾ In addition to the above 20 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once.			

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION -	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology, reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods:
 - a) Visual testing
 - b) Liquid penetrant testing
 - c) Magnetic particle testing
 - d) Radiographic testing
 - e) Ultrasonic testing
 - f) Eddy current testing
 - g) Leak testing
 - 1.1.4 Limitations in the application of magnetic particle testing
- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non-destructive test;
 - b) list the characteristics of NDT technology and the reasons for using NDT;
 - c) compare the different types of NDT, with particular reference to the application and uses of each method.
- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity;
 - b) define the properties of materials, especially of metals;
 - c) recognize how defects affect the properties of materials.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Film (if available)
Course notes
Samples of various materials

CONTENTS:

- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) Melting
 - b) Pouring
 - c) Cooling
 - 1.3.2 Processing and related defects
 - a) Casting
 - b) Welding
 - c) Forging
 - d) Rolling
 - e) Heat treatment
 - f) Machining
 - g) Plating
 - h) Other processes
 - 1.3.3 Service and related defects
 - a) Overload
 - b) Fatigue
 - c) Corrosion
 - d) Brittle fracture
 - e) Others

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication and bonding;
 - b) describe the possible defects associated with each type of process;
 - c) describe the possible defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Course notes
Samples of materials with typical defects

CONTENTS:

- 2.1 Electricity (General principles)
 - 2.1.1 Current, 2.1.2 Voltage, 2.1.3 Resistance
 - 2.1.4 Alternating current, 2.1.5 Direct current

 - 2.2 Magnetism (general principles)
 - 2.2.1 Magnetic poles; permanent magnets; temporary magnets
 - 2.2.2 Permeability
 - 2.2.3 Ferromagnetic, paramagnetic and diamagnetic materials
 - 2.2.4 Magnetic fields; lines of force; magnetic fields around the conductor
 - 2.2.5 Solenoid, electromagnet, 2.2.6 Magnetic flux, 2.2.7 Magnetization force
 - 2.2.8 Reluctance, 2.2.9 Hysteresis

 - 2.3 Visible and ultraviolet light

 - 2.4 Method of testing by magnetic particles
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) define the key terms such as current, voltage and resistance and to relate them to each other;
 - b) explain the fundamental differences between alternating and direct current.

- 2.2 Given the demonstrations and explanations in class, the student will be able to:
 - a) define terms used in magnetic testing such as magnet, magnetic poles, magnetic fields, lines of force and magnetic flux;
 - b) distinguish between:
 - i) permanent and temporary magnets
 - ii) ferro-, para-, and dia-magnetic materials
 - c) in the hysteresis curve, recognize and define:
 - i) the magnetization force, ii) magnetic flux, iii) reluctance
 - d) illustrate the magnetic field around a conductor, solenoid and electromagnet.

- 2.3 Given an explanation of the concepts involved, the student shall be able to explain the difference between ultraviolet and visible light.

- 2.4 Given the instructor's explanations, the student will be able to recognize the terms and observations most commonly used in magnetic testing.

METHODOLOGICAL STRATEGIES:

Instructor's explanations using lecture method, guided discussion and demonstrations of magnetic field using magnets and iron particles.

EQUIPMENT AND RESOURCES:

Magnets
Magnetizable particles
Transparencies
Slides and writing board
Samples of types of lights
Light meters
Demonstration equipment

CONTENTS:

3.1 Methods of magnetization:

3.1.1 Longitudinal

3.1.2 Circular

3.1.3 Vertical

3.2 Magnetization techniques:

3.2.1 Permanent magnets

3.2.2 Electromagnets

3.2.3 Coils

3.2.4 Passage of current

3.2.5 Central conductor

SPECIFIC OBJECTIVES:

3.1 Given various magnetized work pieces, the student will be able to:

- a) find the direction of the magnetic field and current in each of them;
- b) explain the relationship between field direction and the orientation of discontinuities which may be detected;
- c) list the characteristics of the longitudinal and circular magnetic fields and distinguish between them.

3.2 Given a demonstration and explanation of magnetization techniques, the student will be able to:

- a) define the applications and limitations of each technique;
 - b) determine the type of magnetization produced in each technique;
 - c) measure the direction of the magnetic field produced in each technique.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations using lecture method, demonstrations, guided discussion and a problem workshop.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Basic equipment for magnetization

Magnetic ink

Magnetizable test pieces

CONTENTS:

- 3.3 Inspection techniques
 - 3.3.1 Remnant fields
 - 3.3.2 Continuous field
 - 3.3.3 Wet method
 - 3.3.4 Dry method
 - 3.3.5 Verification of magnetic fields
 - 3.3.6 Retentivity and coercive force
 - 3.4 Demagnetization
 - 3.4.1 Reasons for requiring demagnetization
 - 3.4.2 Demagnetization techniques and verification of remnant fields
-

SPECIFIC OBJECTIVES:

- 3.3 Given a background in the theory of magnetic particles and the means of application, the student will be able to:
 - a) distinguish between continuous and remnant magnetization and recognize the characteristics of the materials to be tested by each technique;
 - b) explain the difference between wet and dry methods and identify the characteristics of the particles to be used in each case;
 - c) verify the presence of a magnetic field.
 - 3.4 Given the explanations and demonstrations, the student will be able to:
 - a) describe the principles on which magnetization is based;
 - b) list the methods for demagnetization;
 - c) verify the remnant field.
 - d) explain the reasons for demagnetization
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations using lecture method, demonstrations, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Samples
Writing board
Transparencies
Slides
Equipment for magnetization
Magnetic ink
Magnetizable test pieces
Gaussmeter and/or indicator

CONTENTS:

4.1 Knowledge of equipment:

- 4.1.1 Permanent magnets, 4.1.2 Magnetic yokes, 4.1.3 Portable and stationary equipment
4.1.4 Types of current, 4.1.5 Test current capacity, 4.1.6 Demagnetization equipment

4.2 Conditions of use:

- 4.2.1 Equipment operation, 4.2.2 Equipment maintenance, 4.2.3 Safety

4.3 Accessories

- 4.3.1 Contact points
4.3.2 Vessels for checking inspection baths
4.3.3 Field indicator (Berthold test piece)
4.3.4 Calibration test pieces (JIS, ASTM, EN, MIL)
4.3.5 Magnetic field measurement equipment
4.3.6 Ultraviolet lamps
4.3.7 Coloured and fluorescent powders
4.3.8 Colour for increasing contrast
-

SPECIFIC OBJECTIVES:

- 4.1 Given a demonstration and explanation of the use of the equipment, the student will be able to:
- a) recognize the main types of magnetization equipment;
 - b) identify the test capacity of each type of equipment;
 - c) identify the type of current used in each type of equipment;
 - d) identify the type of field generated by each type of equipment;
 - e) recognize demagnetization equipment.
- 4.2 Given a demonstration and explanation of equipment operations, the student will be able to:
- a) recognize the different controls and identify their function;
 - b) operate the different types of equipment properly and safely;
 - c) state the maintenance procedures for each type of equipment.
- 4.3 Given a demonstration and explanation of accessories, the student will be able to:
- a) distinguish between the types of contact points and their application;
 - b) recognize magnetic field measurement equipment, test pieces for calibration and control vessels for wet bath concentration;
 - c) recognize lamps for ultraviolet light and describe their proper use.

METHODOLOGICAL STRATEGIES:

Instructor's explanations using lecture method, demonstrations, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Equipment for magnetization
Particles
Magnetizable test pieces
Equipment for demagnetization
Accessories including various types of contact points
Graduated test vessel
Field indicators
Ultraviolet lamps
Protective hoods

CONTENTS:

5.1 Interpretation of written instructions for application of tests by different techniques

5.2 Wet suspension of coloured and fluorescent particles

5.2.1 Preparation

5.2.2 Standards

SPECIFIC OBJECTIVES:

5.1 Given a set of written instructions, the student will be able to:

- a) interpret the instructions correctly, perform the test on the appropriate work piece;
- b) explain the differences between the techniques of wet and dry methods in relation to the conditions of application, size and form of the particles and the sensitivity of the test.

5.2 Given the demonstration and explanation and the liquids and particles, the student will be able to:

- a) prepare coloured and fluorescent particle suspensions in the appropriate concentrations;
 - b) compare these concentrations to standards or recommended practices.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations and demonstrations, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Examples of written instructions for magnetic particle testing

Different types of equipment and work samples of different geometrical shapes and dimensions

Fluorescent and coloured particles

Water and oil suspension vehicles

Vessel for measuring bath concentration

Ultraviolet lamp

Safety hoods

Slides

CONTENTS:

5.3 Working with magnetic field

5.3.1 Magnetic field test

5.3.2 Measurement of magnetic field

5.3.3 Demagnetization of work pieces

5.4 Codes, standards, specifications and procedures

5.4.1 General knowledge of codes and standards

5.4.2 General knowledge of specifications and procedures

SPECIFIC OBJECTIVES:

5.3 Given the necessary test conditions and equipment, the student will be able to:

- a) determine the existence and direction of the magnetic field, using field indicators;
- b) determine the existence of a remnant field;
- c) perform demagnetization using various systems in each case, checking afterwards for the presence of a remnant field.

5.4 Given the instructor's explanation and a selection of documents, the student will be able to recognize the different specifications and standards which govern the application of magnetic testing.

METHODOLOGICAL STRATEGIES:

Instructor's explanations and demonstrations guided discussion and practice.

EQUIPMENT AND RESOURCES:

Magnetization and demagnetization equipment

Work pieces of different sizes and shapes

Field indicators

Field measuring instruments

Slides

CONTENTS:

- 6.1 Presentation of results on test forms
 - 6.2 Recording of indications:
 - 6.2.1 To locate and identify them with reference to the test piece
 - 6.2.2 By photography
 - 6.3 Recognition of findings
 - 6.3.1 Indications of defects
 - 6.3.2 Spurious (false) indications
-

SPECIFIC OBJECTIVES:

- 6.1 Given an explanation and a number of practical examples, the student will be able to correctly complete the appropriate test report forms.
 - 6.2 Given the results of a magnetic particle test, the student will be able to:
 - a) make a permanent record of the indications using photography;
 - b) enter the results obtained on the appropriate report form.
 - 6.3 Given the results of magnetic particle tests, the student will be able to make a preliminary evaluation of the findings in accordance with the criteria contained in a written procedure.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations, guided discussion, practical exercises and written procedures.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Selection of forms
Samples
Test equipment
Work pieces containing discontinuities
Measuring equipment
Photographic camera
Adhesive tape
Slides

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods: VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects
 - a) Casting processes and associated discontinuities, ingots, blooms, and billets; sand casting; centrifugal casting; investment casting
 - b) Wrought processes and associated discontinuities: forgings; rolled products; extruded products
 - c) Welding processes and associated discontinuities: submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.
- 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures, corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 Electricity
 - 2.1.1 Current, voltage and resistance; alternating current; direct current
 - 2.2 Magnetism; magnetic poles; permanent magnets; temporary magnets
 - 2.2.1 Ferro-,para-, and dia-magnetic materials
 - 2.2.2 Magnetic fields; lines of force; magnetic field around a conductor; solenoid; electromagnet; magnetic flux; magnetization force; reluctance; hysteresis
 - 2.3 Magnetic field characteristics; remanence; permeability; saturation; normal and tangential components of the magnetic field
 - 2.4 Terminology and abbreviations
 - 2.5 Electromagnetic waves
 - 2.6 Visible and ultraviolet light
-

SPECIFIC OBJECTIVES:

- 2.1 Given the student's background knowledge and the instructor's explanation, the student will be able to:
 - a) explain the concepts of current, voltage and resistance; b) relate these concepts to each other through Ohm's Law; c) distinguish between alternating current, direct current and half wave rectified current, with specific reference to their applications in magnetic particle testing.
- 2.2 Given the instructor's explanation and demonstrations, the student will be able to:
 - a) distinguish between ferromagnetic, paramagnetic and diamagnetic materials; b) explain the concept of magnetism; c) distinguish between temporary and permanent magnets; d) explain the concepts of magnetic field, lines of force, magnetic poles and field distortion; e) define magnetic flux, magnetization force, reluctance and capacitive force with respect to a given hysteresis curve; f) illustrate magnetic field around a magnetic conductor, non magnetic conductor and a solenoid, explain heat effects on magnetism; g) explain material hardness vs. magnetic retention.
- 2.3 Given the instructor's explanation and a specific hysteresis curve, the student will be able to determine the type of material to which it relates (high or low permeability).
- 2.4 Given the student's general understanding and the instructor's explanations, the student will be able to:
 - a) list the terms relating to electricity, magnetism, electromagnetism and to testing by magnetic particles, indicating the related abbreviations; b) determine the saturation point, describing its characteristics; c) measure the variation in permeability along the

curve; d) identify the point of maximum permeability; e) determine the normal and tangential components of a vectorial representation of the magnetic field.

2.5 Given the student's background knowledge and the instructor's explanation, the student will be able to describe the characteristics of electromagnetic waves

2.6 Given the instructor's explanations, the student will be able to:

a) distinguish between visible and ultraviolet light; b) explain the concept of fluorescence.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Transparencies

Writing board

Samples

Course notes

Slides

CONTENTS:

- 3.1 Methods of magnetization
 - 3.1.1 Longitudinal
 - 3.1.2 Circular
 - 3.2 Magnetization techniques
 - 3.2.1 Permanent magnets
 - 3.2.2 Electromagnets
 - 3.2.3 Coils
 - 3.2.4 By passage of current
 - 3.2.5 By induction
 - 3.3 Work methods
 - 3.3.1 Remnant field
 - 3.3.2 Continuous field
 - 3.3.3 Dry method
 - 3.3.4 Wet method
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanation and demonstration, the student will be able to:
 - a) distinguish between the methods of magnetization, determining direction of field and detectable defects;
 - b) explain the basic principle of magnetization.
 - 3.2 Given the instructor's explanation and demonstrations, the student will be able to:
 - a) distinguish between field direction and distribution of the field in ferro- and paramagnetic materials when testing with passage of current;
 - b) compare the technical differences, describing the limitations of each technique.
 - 3.3 Given the instructor's explanation and demonstration, the student will be able to explain the difference between:
 - a) permanent and remnant magnetism;
 - b) testing by wet and dry methods.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes

Test pieces of different properties and dimensions

Equipment and accessories for applying the test

CONTENTS:

- 3.4 Testing techniques
 - 3.4.1 For work pieces of differing alloy or, shape and condition
 - 3.4.2 With various types of current
 - 3.4.3 Field direction for some specific cases
 - 3.4.4 Appropriate field intensity
 - 3.4.6 Test sequences
 - 3.4.7 Safety precautions

 - 3.5 Miscellaneous field practices
 - 3.5.1 Preparation of the wet and dry suspension for coloured and fluorescent particles
 - 3.5.2 Techniques for checking field sensitivity
 - a) field indicators for calibration test pieces
 - b) work pieces for evaluating the sensitivity of the test
 - c) work pieces for evaluating magnetic particles
 - 3.5.3 Reasons for demagnetization
 - a) operating conditions
 - b) testing the effectiveness of demagnetization
-

SPECIFIC OBJECTIVES:

- 3.4 Given work pieces of different composition and dimensions, the student will be able to:
 - a) select the most appropriate magnetization technique in each case, supporting this choice and specifying type of magnetization, method of applying the particles, type of current, field direction and calculation of current requirements
 - b) determine the logical sequence of tests;
 - c) carry out a magnetic test
 - d) be aware of the safety requirements

- 3.5 Given the particles and the transport medium, the student will be able to:
 - a) obtain the correct concentration both for coloured and fluorescent magnetic particles, considering the reasons for the difference with respect to the percentage of particles to be used;
 - b) apply and compare the methods for checking sensitivity of a magnetic particle test, explaining the limitations of each;
 - c) evaluate the magnetic properties of the particles used in the test;
 - d) determine the conditions for and verification of demagnetization.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes

Test pieces of different properties and dimensions

Equipment and accessories for applying the test and for demagnetization

CONTENTS:

- 4.1 Knowledge of equipment
 - 4.1.1 Permanent magnets; magnetic yoke; portable and stationary equipment; types of current and concepts of testing capacity; demagnetization equipment; maintenance and use of equipment
 - 4.2 Accessories
 - 4.2.1 Contact points; vessels for checking bath concentration; field indicators (Berthold test pieces); calibration pieces (JIS,ASTM,EN,MIL); magnetic field measurement equipment (Gaussmeter); ultraviolet lamps; coloured and fluorescent powders; colour for increasing contrast; morphology of the particles
 - 4.3 Selection of equipment appropriate to the nature of the test
 - 4.4 Special equipment
 - 4.4.1 Portable equipment; stationary installations; automated equipment
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanation and various types of magnetization equipment, the student will be able to:
 - a) prepare a table comparing the equipment on the basis of testing capacity, type of current used, type and range of magnetic field, field of application, demagnetization capacity, particular structural characteristics, ease of use, handling and maintenance;
 - b) correctly perform adjustment and calibration of equipment.
- 4.2 Given the instructor's explanation and demonstration, the student will be able to:
 - a) recognize the types of contact points used, relating them to the work pieces in which they can be used;
 - b) use the various accessories correctly, including the vessels for checking bath concentration;
 - c) recognize the limitations on application of indicators and field measuring equipment;
 - d) compare coloured with fluorescent powders;
 - e) operate ultraviolet lamps properly, comparing the various types available;
 - f) determine the intensity requirements for ultraviolet lamps, describing how measurements are made.
- 4.3 Given the instructor's explanation, demonstration and a particular work piece, the student will be able to select the most suitable equipment for performing the test, depending on the characteristics of the work piece and type of defect to be detected.
- 4.4 Given the instructor's explanation and demonstration, the student will be able to compare portable and stationary equipment, identifying the advantages and limitations in each case and the conditions which must be met for using each type.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Course notes
Test pieces of different properties and dimensions
Equipment and accessories for applying the test

CONTENTS:

- 5.1 Interpretation of procedures for the application of tests using various techniques
 - 5.2 Composition of test procedures including instructions for various methods and techniques for use with work pieces of various materials and shapes, selection of equipment, field detection, intensity, type of current, selection of inspection medium, types of particles, sequence of testing, demagnetization
 - 5.3 Standards
 - 5.3.1 Qualification and certification of personnel
 - 5.3.2 Internal specifications and corresponding standards
 - 5.3.3 Codes and standards
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanation and a written test procedure, the student will be able to perform the test properly, interpreting the indications resulting from the procedure.
 - 5.2 Given the instructor's explanation, the student will be able to:
 - a) interpret a procedure which would involve all the conditions under which the test must be carried out (equipment, current, field direction and intensity, type of particles);
 - b) determine the logical sequence for carrying out the test and the sequence for demagnetization;
 - c) compile instructions with sufficient detail for a level 1 operator to successfully carry out a magnetic particle test.
 - 5.3 Given the instructor's explanations and the appropriate documents, the student will be able to distinguish between codes and standards used in NDT, especially in magnetic particle testing, both for performing the test and for the qualification and certification of personnel conducting the test.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Transparencies
Writing board
Course notes
Test pieces of various dimensions
Equipment and accessories for applying the test
Written test procedures
Codes and standards relating to the tests
Codes and standards relating to NDT qualification and certification

CONTENTS:

- 6.1 Preparation of reports on the testing
 - 6.2 Preparation and completion of the report form
 - 6.3 Documentation of the findings
 - a) to locate the indication within the component
 - b) by the use of sketching and photography
 - c) knowledge of documentation systems
 - d) management and control of complete documentation
-

SPECIFIC OBJECTIVES:

- 6.1 Given the results of the test he has conducted, the student will be able to present a report showing all aspects of the inspection process and the results obtained.
 - 6.2 Given the instructor's explanation, the student will be able to design and complete an inspection report sheet in accordance with requirements and the inspection results.
 - 6.3 Given the instructor' explanation, the student will be able to:
 - a) distinguish between the different means of recording information and compare their limitations and applications;
 - b) record the results of his own inspection using each of the different recording systems.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Transparencies
Writing board
Slides
Course notes
Test pieces of various dimensions
Equipment and accessories for applying the test
Written test procedures, codes and standards relating to the tests
Photographic camera
Adhesive tape
Other recording media

CONTENTS:

- 7.1 Presentation of results
- 7.2 Interpretation of findings with reference to the manufacturing process:
 - a) evaluation of results according to the criteria of the procedure and specifications;
 - b) additional possibilities for making the results more conclusive
- 7.3 Sensitivity and limitations
- 7.4 Applications of magnetic testing and other methods of testing for surface and subsurface flaws
- 7.5 Safety, implementation of industrial safety standards in facilities and equipment and in their operation; hazards of using toxic and inflammable materials; materials, equipment and accessories for the protection of persons and facilities

SPECIFIC OBJECTIVES:

- 7.1 Given a work piece of known characteristics and the corresponding procedure, the student will be able to:
 - a) choose an appropriate procedure and determine the thresholds of the inspection;
 - b) carry out the inspection of the work piece interpreting correctly the results obtained and determining whether the findings correspond to real discontinuities or whether they are spurious indications;
 - c) evaluate the findings in accordance with the inspection criteria.
- 7.2 Given the instructor's explanation and the samples provided, the student will be able to relate the findings to defects inherent in the process of fabricating the test piece.
- 7.3 Given the instructor's explanation, the student will be able to determine the application and limitation magnetic particle testing.
- 7.4 Given the instructor's explanation, the student will be able to compare magnetic particle testing to other methods for detecting surface and subsurface flaws.
- 7.5 Given the instructor's explanations, the student will be able to:
 - a) organize and administer the performance of tests with an NDT method with proper consideration of the safety of personnel and facilities;
 - b) organize the tasks of staff involved in NDT to ensure the operation is conducted safely and efficiently.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes

Test pieces of various dimensions

Equipment and accessories for applying the test

Written test procedures

Codes and standards relating to the tests

Codes and standards relating to NDT qualification and certification

INSPECTION METHOD: MAGNETIC PARTICLE TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Magnetism
 - 2.1.1 Theory and characteristics of the magnetic fields
 - 2.1.2 Demagnetizing effect
 - 2.1.3 Separation of the magnetic field

- 2.2 Magnetic induction in materials
 - 2.2.1 Permeability in ferromagnetic and non-ferromagnetic materials
 - 2.2.2 Film effect

- 2.3 Magnetic fields
 - 2.3.1 Generation of magnetic fields
 - 2.3.2 Basis for the calculation on of magnetization systems

- 2.4 Measurement of
 - 2.4.1 Magnetic fields
 - 2.4.2 Electromagnetic fields

- 2.5 Electromagnetic radiation
 - 2.5.1 Visible light
 - 2.5.2 Field radiation
 - 2.5.3 Physical concepts, measurements and equipment
 - 2.5.4 Conditions for visual observation
 - 2.5.5 Luminance thresholds
 - 2.5.6 Visual acuity

SPECIFIC OBJECTIVES:

- 2. Given the instructor's explanations, the student will be able to:
 - a) analyse and evaluate the theory of magnetic fields and magnetic induction in relation to the test method;
 - b) make appropriate use of the laws of magnetism to perform the calculations required in applying the test;
 - c) define the theoretical conditions required for the test in relation to the various techniques and the state of the specimen;
 - d) determine and evaluate the conditions for the test;
 - e) represent and calculate the magnetic field as a function of current and permeability and geometrical relations.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, delivery of support material, instructions explanations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Slides
Support material
Course notes

CONTENTS:

- 3.1 Magnetization
 - 3.1.1 Magnetization methods
 - 3.1.2 Magnetization techniques
 - a) Types of magnetic field application
 - b) Intensity and type of current
 - c) Combined magnetization
 - d) Individual cases
 - e) Incremental permeability
- 3.2 Modes of operation
 - 3.2.1 Continuous field, conditions for application of the inspection medium.
 - 3.2.2 Remnant field
- 3.3 Indicating medium
 - 3.3.1 Physical and chemical conditions necessary for the particles and suspension vehicles, wet and dry methods, fluorescent particles.
 - 3.3.2 Conditions for applying the indicating medium

SPECIFIC OBJECTIVES:

- 3. Given the instructor's explanations, the student will be able to:
 - a) determine and discuss various testing techniques;
 - b) evaluate the applicability of the magnetization method in relation to defectology;
 - c) select and evaluate field intensity;
 - d) determine conditions for the use and calculate currents for the various techniques;
 - e) calculate current for magnetization by induction;
 - f) calculate current for magnetization by yokes and coils;
 - g) understand the effect of the air gap in yokes and permanent magnets and coil magnetization;
 - h) select the suitable demagnetization technique;
 - i) determine the suitability and effectiveness of demagnetization.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, delivery of support material, guided discussion and practical work in performance of the test.

EQUIPMENT AND RESOURCES:

Writing board
Slides Transparencies
Course notes
Work pieces of varying characteristics and dimensions

CONTENTS:

- 3.4 Evaluation
 - 3.4.1 Verification of the sensitivity of the test. Determination of the applicability of the various field indicators
 - 3.4.2 Verification of visibility conditions and requirements for existing fluorescence
 - 3.4.3 Correlation between defectology, the test findings and the technique applied
 - 3.5 Demagnetization
 - 3.5.1 Reasons for demagnetizing
 - 3.5.2 Evaluation of remnant magnetic fields
 - 3.5.3 Requirements and conditions for demagnetization in accordance with the technique of the test use and the material examined
-

SPECIFIC OBJECTIVES:

- 3. Given the instructor's explanations, the student will be able to:
 - a) determine and discuss various testing techniques;
 - b) evaluate the applicability of the magnetization method in relation to defectology;
 - c) select and evaluate field intensity;
 - d) determine conditions for the use and calculate currents for the various techniques;
 - e) calculate current for magnetization by induction;
 - f) calculate for magnetization by yokes and coils;
 - g) know the effect of the air gap in yokes and permanent magnets and coil magnetization;
 - h) select the suitable demagnetization technique;
 - i) determine the stability and effectiveness of demagnetization.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, delivery of support material, guided discussion and practical work in performance of the test.

EQUIPMENT AND RESOURCES:

Writing board
Slides
Transparencies
Course notes
Work pieces of varying characteristics and dimensions

CONTENTS:

- 4.1 Equipment
 - 4.1.1 Selection for purchase
 - 4.1.2 Conditions of use and maintenance of equipment for magnetization and demagnetization, portable, permanently installed or automated
 - 4.1.3 Design basis of systems for testing
- 4.2 Accessories
 - 4.2.1 Design, selection and use of accessories for various testing techniques
 - 4.2.2 Field indicators
 - a) Analysis and comparison of the various field indicators (Berthold, ASME, BS, JIS, etc.)
 - b) Method of application and evaluation of application
 - 4.2.3 Instruments for magnetic field measurement, use of the Gaussmeter
 - 4.2.4 Various types of field radiation lamps and UV meters
- 4.3 Methods of indication
 - 4.3.1 Magnetizable particles
 - a) Chemical and physical characteristics
 - b) Morphology and dimensions
 - c) Various types: coloured and fluorescent
 - 4.3.2 Suspension vehicles for tests by wet methods
 - 4.3.3 Preparation and evaluation of indication media for test by wet and dry methods
- 4.4 AC and DC demagnetization equipment. Demagnetization equipment based on the oscillatory discharge of condensers.

SPECIFIC OBJECTIVES:

- 4. Given the instructor's explanations, the student will be able to:
 - a) select and evaluate the equipment and accessories required for the various techniques;
 - b) make a comparative analysis of the magnetization capacity of the equipment;
 - c) evaluate the applicability of the various field measurement accessories in relation to the technique applied;
 - d) select and evaluate the means of indication, determining the conditions for their appropriate use;
 - e) select and evaluate demagnetization equipment;
 - f) design components and accessories for the application of magnetization current in unusual situations;
 - g) design and direct the installation and adjustment of test systems for production line monitoring.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, delivery of support material, teacher's explanations, guided discussions, demonstration, practice in selection and checking equipment.

EQUIPMENT AND RESOURCES:

Transparencies

Slides

Various magnetization equipment

Test pieces

Field measurement instruments

UV measurements, standards and codes

CONTENTS:

- 5.1 Specifications of the examination, function of design engineering, design and building codes, ASME code.
 - 5.2 Standards
 - 5.2.1 Specific standards for tests with magnetic particles (ASTM, JIS, BS, DIN)
 - 5.2.2 Interpretation of specifications, codes and standards
 - 5.3 Procedures
 - 5.3.1 Formulation of test procedures
 - 5.3.2 General and specific procedures
-

SPECIFIC OBJECTIVES:

- 5. Given the instructor's explanations, (and performance of the assigned exercises) the student will be able to:
 - a) interpret, analyse and explain examination specifications produced by design engineers or laid down by codes;
 - b) analyse, evaluate and formally complete test procedures, considering the type of specimen to be examined and the magnetic particle technique required, interpreting the specifications involved;
 - c) analyse, interpret and discuss the validity of the procedures in relation to applicable specifications, codes and standards.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical assignment including the use of specifications and standards, discussion and analysis of procedures and formulation of test procedures.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Samples of design specifications
Standards and codes
Samples of general and specific procedures

CONTENTS:

- 6.1 Preparation of reports of the test
 - 6.2 Preparation and completion of the report form
 - 6.3 Documentation of the findings:
 - a) to locate the indication within the component
 - b) knowledge of documentation systems
 - c) management and control of complete documentation
-

SPECIFIC OBJECTIVES:

- 6.1 Given the results of the test he has conducted, the student will be able to develop a report showing all aspects of the inspection process and the results obtained.
 - 6.2 Given the instructor's explanation, the student will be able to design and complete an inspection report sheet in accordance with requirements and the inspection results.
 - 6.3 Given the instructor's explanation, the student will be able to:
 - a) distinguish between the different means of recording information and compare their limitations and applications;
 - b) record the results of his own inspection using each of the different recording systems.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Transparencies
Writing board
Slides
Course notes
Test pieces of various dimensions
Equipment and accessories for applying the test
Written test procedures, codes and standards relating to the tests
Photographic camera
Adhesive tape
Other recording media

CONTENTS:

- 7.1 Presentation of results
 - 7.2 Thresholds of detection
 - a) evaluation of results according to the criteria of the procedure and specifications
 - b) additional possibilities for making the results more conclusive
 - 7.3 Interpretation of findings with reference to the manufacturing process
 - 7.4 Applications of magnetic particle testing and other methods of testing for surface and subsurface flaws
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanation and the results of the inspection, the student will be able to present the results obtained in an ordered and logical manner.
 - 7.2 Given a work piece of known characteristics and the corresponding procedure, the student will be able to:
 - a) choose an appropriate procedure;
 - b) determine the thresholds of the inspection;
 - c) carry out the inspection of the workpiece interpreting correctly the results obtained and determining whether the findings correspond to real discontinuities or whether they are spurious indications;
 - d) evaluate the findings in accordance with the inspection criteria.
 - 7.3 Given the instructor's explanation and the samples provided, the student will be able to relate the findings to defects inherent in the process of fabricating the test piece.
 - 7.4 Given the instructor's explanation, the student will be able to determine the application and limitation of testing by magnetic particles and to compare magnetic particle testing to other methods for detecting surface and subsurface flaws.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes

Test pieces of various dimensions

Equipment and accessories for applying the test

Written test procedures

Codes and standards relating to the tests

Codes and standards relating to NDT qualification and certification

V. INSPECTION METHOD: LIQUID PENETRANT TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	4	5	1 ¹⁾
2. PHYSICAL PRINCIPLES OF THE TEST	3	3	2
3. PROCESSING	4	4	3
4. TEST EQUIPMENT AND MATERIALS	2	3	3
5. CODES, STANDARDS, PROCEDURES AND SAFETY	1	3	8
5 PRESENTATION AND RECORDING OF RESULTS	2	2	2
6. INTERPRETATION OF RESULTS LIMITATIONS	-	4	2
TOTAL	16	24	20 ¹⁾
¹⁾ In addition to the above 20 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once.			

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION -	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1. Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology, reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods:
 - a) visual testing, b) liquid penetrant testing, c) magnetic testing, d) radiographic testing, e) ultrasonic testing, f) eddy current testing, g) leak testing
 - 1.1.4 Limitations in the application of liquid penetrant testing

- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects

- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) melting, b) pouring, c) cooling
 - 1.3.2 Processing and related defects
 - a) casting, b) welding, c) forging, d) rolling, e) heat treatment, f) machining, g) plating, h) other processes
 - 1.3.3 Service related defects
 - a) overload, b) fatigue, c) corrosion, d) brittle fracture, e) others

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non-destructive test;
 - b) list the characteristics of NDT technology and the reasons for using NDT;
 - c) compare the different types of NDT, with particular reference to the application and uses of each method.

- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity;
 - b) define the properties of materials, especially of metals;
 - c) recognize how defects affect the properties of materials.

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication and bonding;
 - b) describe the possible defects associated with each type of process;
 - c) describe the possible defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Film (if available)

Course notes

Samples of various materials with typical defects

CONTENTS:

- 2.1 Description of the method
 - 2.2 Properties of penetrating liquids
 - 2.2.1 Wettability (expansion of the drop)
 - 2.2.2 Penetration
 - 2.2.3 Bleeding
 - 2.2.4 Influence of the state of the surface, contamination and temperature
 - 2.3 Concepts of solutions and dispersions
 - 2.3.1 Solvents
 - 2.3.2 Dispersive agents
 - 2.3.3 Emulsifiers
 - 2.4 Concepts relating to the mechanism of development
 - 2.4.1 Powder granulometry
 - 2.4.2 Suspension
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) define the physical principles on which the test is based;
 - b) list the stages of application of the liquid penetrant method.
- 2.2 Given the instructor's explanations, the student will be able to:
 - a) list the properties which must be met by liquid penetrants;
 - b) indicate the influence exerted on the properties of the penetrating liquids by the surface state of the work piece, contamination, temperature of the work piece and the liquid.
- 2.3 Given the concepts of solution, dispersion and emulsification, the student will be able to:
 - a) distinguish between them;
 - b) list some substances which are used as solvents, dispersive agents and emulsifiers in penetrating liquids.
- 2.4 Given the instructor's explanations, the student will be able to:
 - a) define the nature of the development processes with respect to penetrating liquids;
 - b) list the forms of developer penetration and the granulometry of the powder in each case.

METHODOLOGICAL STRATEGIES:

Instructor's explanation including lecture, guided discussion and practical demonstration.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Chemical products
Penetrants
Work pieces

CONTENTS:

- 2.5 Basic concepts relating to colour and fluorescence
 - 2.5.1 Dyes
 - 2.5.2 Fluorescent pigments
 - 2.5.3 UV and light radiation (black light)
 - 2.6 Composition of oily and non-oily penetrating liquids
 - 2.7 Composition and/or properties of removers
 - 2.7.1 Organic solvents
 - 2.7.2 Emulsifiers
 - 2.8 Composition and state of developers
 - 2.8.1 Dry developers
 - 2.8.2 Wet developers
-

SPECIFIC OBJECTIVES:

- 2.5 Given the instructor's explanations, the student will be able to:
 - a) define the coloured and fluorescent penetrants, determining the basic difference between them;
 - b) indicate the difference in wavelength and the characteristics between white light and UV radiation.
 - 2.6 Given the instructor's explanations, the student will be able to recognize the difference in composition of liquids with an oily base and those with a non-oily base.
 - 2.7 Given the instructor's explanations, the student will be able to:
 - a) list the types of excess penetrant removers which are used in accordance with the techniques employed;
 - b) recognize the composition and properties of the different types of removers.
 - 2.8 Given the instructor's explanations, the student will be able to list the various types of developer applications, in accordance with the technique used, stating in each case its composition and state.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including lecture and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Examples of penetrant materials

CONTENTS:

- 3.1 Preparation of the specimen
 - 3.1.1 Treatment
 - 3.1.2 Identification
 - 3.1.3 Temperature

 - 3.2 Cleaning prior to inspection
 - 3.2.1 Solvents
 - 3.2.2 Types and techniques of use
 - 3.2.3 Detergent solutions
 - 3.2.4 Chemical action solutions (acids, alkalis, removers)
 - 3.2.5 Inhibition and rinsing
 - 3.2.6 Use of ultrasonic agitation
 - 3.2.7 Mechanical media, brushing, grinding, sandblasting, etc.
 - 3.2.8 Conditions and limitations on their use

 - 3.3 Drying
 - 3.3.1 Drying requirements
 - 3.3.2 Cold and hot air
 - 3.3.3 Temperature and time
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations and a work piece, the student will be able to:
 - a) perform a visual inspection to determine its surface state;
 - b) identify the work piece in accordance with instructions;
 - c) report on temperature.

- 3.2 Given the instructor's explanations, the student will be able to:
 - a) list the various cleaning systems explaining in each case the type of impurity or contaminant which they can remove;
 - b) list the mechanical cleaning media, stating the conditions which permit their use and the limitations of these media;
 - c) perform the cleaning of work pieces, following written instructions.

- 3.3 Given the instructor's explanations, the student will be able to:
 - a) list the forms of drying;
 - b) recognize the time and temperature limits in accordance with the standards;
 - c) carry out drying of a work piece in accordance with the instructions.

METHODOLOGICAL STRATEGIES:

Instructor's explanations including guided discussion and practical work.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Work pieces with different surface states and contaminants

Work pieces with various contaminants (dust, fat, oil, oxides, scale, etc.)

Different types of cleaners

Work pieces which have previously been cleaned

Cold and hot air dryers

CONTENTS:

- 3.4 Application of the penetrant; various modes of application; penetration time; temperature
 - 3.5 Removal of excess penetrant
 - 3.5.1 Various methods of removal depending on type of penetrant; water-dispersible; water-soluble; solvent-soluble; post-emulsifiable; drying
 - 3.6 Application of the developer
 - 3.6.1 Various techniques for application of the developer
 - 3.6.2 Previous treatment of the developer
-

SPECIFIC OBJECTIVES:

- 3.4 Given the instructor's explanations, the student will be able to:
 - a) describe the types of penetrant applications;
 - b) define penetration times in accordance with standards;
 - c) perform the correct application of a penetrant to a clean and dry work piece;
 - d) select the established penetration temperature and time, in accordance with penetration time and temperature written instructions.
 - 3.5 Given the instructor's explanations, the student will be able to:
 - a) list the systems for removal of excess penetrant, explaining the relationship with the type of penetrant used;
 - b) perform the removal of excess penetrant properly, applying the precautions and fulfilling the requirements necessary to avoid overwashing or insufficient removal, following a written procedure;
 - c) perform subsequent drying of the work piece if required by the procedure.
 - 3.6 Given the instructor's explanations, the student will be able to:
 - a) list the various types of developer application;
 - b) list the characteristics of a good developer;
 - c) explain the importance of developer distribution;
 - d) carry out the correct application of the developer, following a written procedure.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including guided discussion and practical work.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Written instructions for liquid penetrant testing

Work piece

Penetrant and accessory equipment

Drying material

Work pieces (from which the excess penetrant has been removed)

CONTENTS:

- 3.7 Observation of indications
 - 3.7.1 Conditions for the observation of coloured and fluorescent penetrating liquids
 - 3.7.2 Lighting requirements
 - 3.7.3 Observation sequence and time
 - 3.7.4 False or irrelevant indications
 - 3.8 Final cleaning
 - 3.9 Recording of the findings
 - 3.9.1 Test forms
 - 3.9.2 Transfer of findings
 - 3.9.3 Diagrams
 - 3.9.4 Photography
-

SPECIFIC OBJECTIVES:

- 3.7 Given the instructor's explanations and written instructions, the student will be able to:
 - a) determine the conditions for observation, differentiating between them on the basis of whether the liquids are coloured or fluorescent;
 - b) observe the indications following the observation sequence;
 - c) list the causes of false and/or irrelevant indications.
 - 3.8 Given the instructor's explanations, the student will be able to explain the procedure and importance of final cleaning.
 - 3.9 Given written instructions, the student will be able to note on the recording forms, the indications obtained in the test, showing graphically their location on a diagram of the work piece
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including guided discussion and practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Written instructions for liquid penetrant testing

CONTENTS:

- 4.1 Evaluation of the materials for testing
 - 4.1.1 Characteristic properties
 - 4.1.2 Behaviour properties
 - 4.1.3 Content of halogen, sulphur and other specific contaminants
- 4.2 Cleaning equipment
 - 4.2.1 Ultrasonics
 - 4.2.2 Degreasing steam
- 4.3 Pulverizers and aerosols
- 4.4 Installations for processing by immersion
- 4.5 Lighting
 - 4.5.1 Measuring equipment and units
- 4.6 Ultraviolet radiation lamps (black light)
 - 4.6.1 Efficiency types and characteristics
 - 4.6.2 Measurements of ultraviolet radiation intensity
 - 4.6.3 Units (micro watts/cm²)

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations and a sample work piece, the student will be able to:
 - a) list the parameters which are checked in order to ensure the suitability of the materials used in the test, describing how this check is performed;
 - b) compare the sensitivity of the test, carrying out every stage.
- 4.2 Given the systems of cleaning, the student will be able to recognize their proper state and operation.
- 4.3 Given various types of pulverizers and aerosols, the student will be able to test the effectiveness of the system and proper condition of the equipment.
- 4.4 Given the instructor's explanations, the student will be able to:
 - a) distinguish between portable equipment and stationary equipment for immersion;
 - b) recognize each of the sections of the equipment and its use.
- 4.5 Given the instructor's explanations, the student will be able to:
 - a) recognize various types of lighting equipment;
 - b) explain positioning and measurement.

- 4.6 Given various ultraviolet lamps, the student will be able to:
- a) recognize the type of lamp and its efficiency characteristics.
 - b) measure the intensity of ultraviolet radiation, using a suitable measuring instrument.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including guided discussion and practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Penetrants
Removers
Developers
Sample of work pieces
Ultrasonic cleaning equipment and degreasing steam
Aerosols
Lighting equipment
Tanks
Accessories and materials
Measurement devices for lighting
Ultraviolet lamps

CONTENTS:

- 5.1 General knowledge
 - 5.1.1 National, regional and international codes and standards
 - 5.1.2 General knowledge of specifications
 - 5.2 Industrial safety standards
 - 5.3 Instructions for the test
 - 5.3.1 Interpretation
-

SPECIFIC OBJECTIVES:

- 5.1 Given the various classification of liquid penetrants processes in accordance with standards, the student will be able to prepare a table classifying the techniques in accordance with various standards, explaining the relationship between them.
 - 5.2 Given the instructor's explanations, the student will be able to describe the safety conditions under which the test with liquid penetrants should be carried out.
 - 5.3 Given written instructions, the student will be able to:
 - a) perform the test, properly interpreting the instructions for it;
 - b) fill out the test forms and note the results.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Codes covering liquid penetrants
Procedures
Equipment
Work pieces

CONTENTS:

- 6.1 Presentation of results on test forms
 - 6.2 Recording of indications
 - 6.2.1 To locate and identify them with reference to the test piece
 - 6.2.2 By photography
 - 6.3 Recognition of findings
 - 6.3.1 Indications of defects
 - 6.3.2 Spurious (false) indications
-

SPECIFIC OBJECTIVES:

- 6.1 Given an explanation and a number of practical examples, the student will be able to correctly complete the appropriate test report forms.
 - 6.2 Given the results of a penetrant test, the student will be able to:
 - c) make a permanent record of the indications using photography;
 - d) enter the results obtained on the appropriate report form.
 - 6.3 Given the results of penetrant tests, the student will be able to make a preliminary evaluation of the findings in accordance with the criteria contained in a written procedure.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations, guided discussion, practical exercises and written procedures.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Selection of forms
Samples
Test equipment
Work pieces containing discontinuities
Measuring equipment
Photographic camera
Adhesive tape
Slides

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods: VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - b) define non-destructive testing;
 - c) describe the basic principles and the method of application of the common NDT methods;
 - d) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects:
 - a) Casting processes and associated discontinuities: Ingots, blooms, and billets; Sand casting; Centrifugal casting; Investment casting
 - b) Wrought processes and associated discontinuities: forgings; rolled products; extruded products
 - c) Welding processes and associated discontinuities: submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.
 - 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures: corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
 - 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports
-

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 General description of the method
 - 2.2 Properties of liquid penetrants
 - 2.2.1 Viscosity, surface tension, angle of contact between liquid and solid, capillarity
 - 2.2.2 Behaviour of liquid penetrants, wettability, penetrability, washability, retention and bleeding
 - 2.2.3 Influence of the surface state of the sample, contamination and temperature
 - 2.3 Solutions and dispersions, solvents and dispersive agents
 - 2.3.1 Lipophilic and hydrophilic emulsifiers
 - 2.4 Mechanism of development
 - 2.4.1 Granulometry of powders
 - 2.4.2 Types and phenomena of fine powder aggregation
 - 2.4.3 Suspension of powders in liquids
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to list the stages involved in application of the method.
 - 2.2 Given the instructor's explanations, the student will be able to:
 - b) identify the properties determining the behaviour of liquids in contact with solids; explain the behaviour of liquid penetrants in various stages of the process;
 - c) explain the factors affecting the behaviour of the liquids during the test;
 - 2.3 Given the instructor's explanations, the student will be able to state the characteristics of solutions and emulsions;
 - 2.4 Given the instructor's explanations, the student will be able to explain the differences in behaviour between lipophilic and hydrophilic emulsifiers.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, experiments to demonstrate physical phenomena involved in the test, practical demonstration of the various stages of the test under supervision and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Work pieces illustrating different surface states and different materials

Work pieces with calibrated fissures

Penetrants for the various techniques for applying the test

Course notes

CONTENTS:

- 2.5 Luminous and ultraviolet spectrum
 - 2.5.1 Colour and fluorescence
 - 2.5.2 Colours
 - 2.5.3 Absorption of light
 - 2.5.4 Beer's law
 - 2.5.5 Fluorescent pigments

 - 2.6 Basic formulation of penetrating liquids with oily and non-oily base
 - 2.6.1 Additives and conditioners

 - 2.7 Removers used in the process
 - 2.7.1 Basic formulations and properties
 - 2.7.2 Emulsifiers
 - 2.7.3 Lipophilic and hydrophilic agents

 - 2.8 Composition and state of developers
 - 2.8.1 Granulometry
 - 2.8.2 Developers in the dry state and in liquid suspension
-

SPECIFIC OBJECTIVES:

- 2.5 Given the instructor's explanations, the student will be able to:
 - a) explain the mechanism of development and the behaviour of development powders in the dry state and in liquid suspension;
 - b) explain the phenomena of colour and fluorescence;
 - c) describe the behaviour of fluorescent dyes and pigments in solutions.

- 2.6 Given the instructor's explanations, the student will be able to list the basic components of liquid penetrants and describe the influence of formulation on their behaviour.

- 2.7 Given the instructor's explanations, the student will be able to:
 - a) list the various types of removers and explain their behaviour;
 - b) list the various types of emulsifiers and explain the mechanisms of emulsification.

- 2.8 Given the instructor's explanations, the student will be able to explain the composition, granulometry and behaviour of the developers.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Samples of penetrant and cleaning materials

CONTENTS:

- 3.1 Preparation of the work piece, treatment, identification and protection of the areas not to be examined
- 3.2 Cleaning prior to inspection
 - 3.2.1 Various techniques applicable
 - a) Solvents
 - b) Vapour degreasing
 - c) Detergent solutions
 - d) Solutions having a chemical action (acid and alkali removers, etc .)
 - e) Ultrasonic cleaning
 - f) Mechanical means (grinding, sandblasting, brushing)
 - 3.2.2 Conditions and limitations of the different cleaning techniques
 - 3.2.3 Comparison of the effectiveness of the different techniques in relation to the surface state of the specimen
- 3.3 Conditions and requirements for the different drying stages
 - 3.3.1 Use of cold and hot air
 - 3.3.2 Temperature and time

SPECIFIC OBJECTIVES:-

- 3.1 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to state the requirements for treatment and identification of the work pieces to be tested.
- 3.2 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to explain the operating conditions required for the materials used in the proper application of the various techniques involving liquid penetrants, including the stage of precleaning.
- 3.3 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to describe the use of various drying procedures.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical application of the test to selected work pieces for teaching purposes, analysis and discussion of the test results and practice in writing reports.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Laboratory for testing with penetrating liquids equipped for applying the 6 standardized techniques

CONTENTS:

- 3.4 Inspection process
 - 3.4.1 Application of the penetrating agent
 - a) application techniques, b) temperature, c) penetration time
 - 3.4.2 Removal of excess penetrating agent
 - a) various methods of removal depending on type of penetrant, water-dispersable, water-soluble, solvent-soluble, post emulsifiable; b) conditions for the application of lipophilic and hydrophilic emulsifiers; c) drying; d) requirements and precautions in the removal stage
 - 3.4.3 Application of the developer
 - a) various techniques, b) previous treatment of the developer
 - 3.5 Observation of the findings
 - 3.5.1 Lighting conditions for coloured liquids and UV radiation for fluorescent liquids
 - 3.5.2 Sequence and time of observation
 - 3.5.3 Interpretation of the findings and identification of the type of defects
 - 3.5.4 Spurious or non-relevant findings
 - 3.6 Recording of findings
 - 3.6.1 Test forms
 - 3.6.2 Localization schemes
 - 3.6.3 Transfer of findings
 - 3.6.4 Photographic techniques
 - 3.6.5 Writing reports
 - 3.7 Testing techniques for detection of leaks by means of liquid penetrants
-

SPECIFIC OBJECTIVES:

- 3.4 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to explain the application of liquid penetrants to carry out a valid inspection.
- 3.5 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to describe the conditions required for the observation, interpretation and recording of the indications.
- 3.6 Given the instructor's explanations and performance of the appropriate practical exercises, the student will be able to interpret, evaluate and record the findings of the test in accordance with the written procedures.
- 3.7 Given the instructor's presentation, the student will be able to explain liquid penetrant methods for leak detection.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and supervised practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Penetrant equipment and supplies
Samples
Photographic equipment
Report forms

CONTENTS:

- 4.1 Evaluation of the materials used in the test
 - 4.1.1 Penetrating agents
 - a) Characteristic properties, viscosity, density, surface tension, ignition point, halogen and sulphur content, colour, fluorescence
 - b) Behaviour, drop expansion, washability, corrosion, preservation, stability under light and UV radiation
 - 4.1.2 Removers
 - a) Characteristic properties and behaviour
 - b) Granulometry and apparent volume
 - c) Sedimentation and compaction
 - 4.1.3 Emulsifiers characteristic properties and behaviour
 - 4.1.4 Developers
 - a) Characteristic properties and behaviour
 - b) Granulometry and apparent volume
 - c) Sedimentation
 - d) Evaluation of processes
 - e) Use of standardized work pieces
 - 4.2 Cleaning equipment
 - 4.2.1 Degreasing vapour
 - 4.2.2 Ultrasonic
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations and performance of practical tasks, the student will be able to:
 - a) explain the requirements for evaluation of materials used in the tests;
 - b) state the main properties which have to be evaluated and describe the methods applicable;
 - 4.2 Given the instructor's explanations and supervised practice, the student will be able to describe the use of ultrasonic cleaners and vapour degreasing equipment.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Brochures and diagrams of facilities and equipment
Instrumentation for measuring and sample work pieces

CONTENTS:

- 4.3 Compressed air equipment
 - 4.3.1 Air filters
 - 4.3.2 Supply of cold and hot air
 - 4.3.3 Compressed air pistols
 - 4.3.4 Electrostatic pulverizers
 - 4.3.5 Aerosols

 - 4.4 Stationary installations for processing by immersion
 - 4.4.1 Automatic installations

 - 4.5 Light sources and light meters
 - 4.5.1 Ultraviolet radiation sources (black light) and meters for measuring UV radiation intensity
 - 4.5.2 Checking the efficiency of ultraviolet lamps
 - 4.5.3 Cabinets for observation of fluorescent penetrating liquids

 - 4.6 Standardized work pieces for evaluating processes and qualifying procedures
 - 4.6.1 ASTM, MIL, JIS, IRAM test pieces
 - 4.6.2 Non-standardized test pieces for checking penetrability
 - 4.6.3 Equipment for checking fluorescence and efficiency of UV lamps
-

SPECIFIC OBJECTIVES:

- 4.3 Given the instructor's explanations, the student will be able to describe the various means of coupling developer materials.
 - 4.4 Given the instructor's explanations and performance of practical tasks, the student will be able to describe the facilities and equipment in common use and the procedures applicable for their verification and maintenance.
 - 4.5 Given the instructor's explanations, the student will be able to describe the types of light sources used and the equipment used to verify them.
 - 4.6 Given the instructor's explanations, the student will be able to state the characteristics and conditions for the use of standardized work pieces for evaluating test procedures.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slide
Equipment and test pieces

CONTENTS:

- 5.1 Standards applicable to liquid penetrant testing
 - 5.1.1 Test methods
 - 5.1.2 Materials for the test (ASTM, DIN, MIL, IRAM)
 - 5.1.3 ASME code
- 5.2 Test specifications and procedures
 - 5.2.1 Interpretation
 - 5.2.2 Formulation of instructions for the test
- 5.3 National standards for liquid penetrant testing and testing personnel
 - a) quality control of the test and procedure for its administration, b) quality assurance requirements
- 5.4 Problems of industrial safety in the use of chemical and inflammable products
 - 5.4.1 Applicable safety standards
 - 5.4.2 Safety conditions required for the use of UV light
 - 5.4.3 Drafting of safety instructions for the personnel involved
 - 5.4.4 Safety factors applicable to the test
 - 5.4.4 Environmental protection

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations and the performance of practical exercises, the student will be able to: a) state classification systems of the techniques for application of liquid penetrants according to the standards in force, b) explain the criteria for application of liquid penetrants according to the standards in force;
- 5.2 Given the instructor's explanations and the performance of practical exercises, the student will be able to: a) interpret general and specific test procedures for liquid penetrants; b) develop test instructions for level 1; c) formulate the information required for documenting the test and presenting reports.
- 5.3 Given the instructor's explanations and the performance of practical exercises, the student will be able to recognize the qualification and certification standard for NDT personnel in force in his respective country;
- 5.4 Given the instructor's explanations and discussion of the subjects, the student will be able to: a) describe the risks inherent in the use of chemical and inflammable products; b) describe the risks involved in using UV radiation; c) list the applicable safety standards; d) prepare safety instructions for application of the test; e) describe the risks of environmental contamination

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, supervised practice and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Samples of standards and codes
Comparative tables
Course notes
Safety equipment

CONTENTS:

- 7.1 Presentation of results
 - 7.2 Interpretation of findings with reference to the manufacturing process
 - a) evaluation of results according to the criteria of the procedure and specifications
 - b) additional possibilities for making the results more conclusive
 - 7.3 Sensitivity and limitations
 - 7.4 Applications of penetrant testing and other methods of testing for surface flaws
 - 7.5 Safety: Implementation of industrial safety standards in facilities and equipment and in their operation; hazards of using toxic and inflammable materials; materials, equipment and accessories for the protection of persons and facilities
-

SPECIFIC OBJECTIVES:

- 7.1 Given a work piece of known characteristics and the corresponding procedure, the student will be able to:
 - a) choose an appropriate procedure and determine the thresholds of the inspection;
 - b) carry out the inspection of the work piece interpreting correctly the results obtained and determining whether the findings correspond to real discontinuities or whether they are spurious indications;
 - c) evaluate the findings in accordance with the inspection criteria.
- 7.2 Given the instructor's explanation and the samples provided, the student will be able to relate the findings to defects inherent in the process of fabricating the test piece.
- 7.3 Given the instructor's explanation, the student will be able to determine the application and limitation of testing by penetrant particles.
- 7.4 Given the instructor's explanation, the student will be able to compare penetrant testing to other methods for detecting surface flaws.
- 7.5 Given the instructor's explanations, the student will be able to:
 - a) organize and administer the performance of tests with and NDT method with proper consideration of the safety of personnel and facilities;
 - b) organize the tasks of staff involved in NDT to ensure the operation is conducted safely and efficiently.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Course notes

Test pieces of various dimensions

Equipment and accessories for applying the test

Written test procedures

Codes and standards relating to the tests

Codes and standards relating to NDT qualification and certification

INSPECTION METHOD: LIQUID PENETRANT TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Review of physical, chemical and physico-chemical principles for applying the method. Liquid- solid interface phenomena
 - 2.2 Solutions and dispersions, solvents and dispersing agents, lipophilic and hydrophilic emulsifiers
 - 2.3 Physicochemical mechanisms determining penetration, emulsification and developing
 - 2.4 General spectrum of electromagnetic radiation, luminaries spectrum, ultraviolet and infra- red radiation, wood radiation (black light), measurement and units
 - 2.5 Colour and fluorescence, light absorption phenomena, Beer's law, absorption spectrometry, fluorescent emission spectra
 - 2.5 Mechanism of vision, conditions for visual observations, perception of light, colour and contrast, systems of weighing units and thresholds
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to explain the mechanisms involved in the phenomena of the liquid -solid interface;
- 2.2 Given the instructor's explanations, the student will be able to analyse, evaluate and apply knowledge of the properties and mechanisms involved in every stage of the application of the method;
- 2.3 Given the instructor's explanations, the student will be able to analyse, evaluate and compare the various techniques for application of the method depending on the parameters of the products used and the material being tested;
- 2.4 Given the instructor's explanations, the student will be able to describe, analyse and evaluate the lighting conditions required for observation of the indications correlating lighting sources with the properties of heat and visual sensitivity;
- 2.5 Given the instructor's explanations, the student will be able to analyse, evaluate and determine the requirements for excitation with ultraviolet radiation for the use of fluorescent penetrating liquids.
- 2.6 Given the instructor's explanations, the student will be able to define the conditions for proper viewing of results.

METHODOLOGICAL STRATEGIES:

Instructor's explanations including analysis of the graphic expression of the laws and principles of application, guided discussion and laboratory experiments.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Tables and graphs

Laboratory material for demonstration of physicochemical principles

Course notes

CONTENTS:

- 3.1 Selection of the test techniques in relation to the type of specimen and design specifications
- 3.2 Treatment and preparation of the specimen
 - 3.2.1 Protection of areas not being examined
 - 3.2.2 Selection of techniques for preparation and preliminary cleaning; 3.2.3 Systems of cleaning, design and monitoring; 3.2.4 Intermediate drying, conditions and requirements for the various techniques
- 3.3 Application of the penetrating agent
 - 3.3.1 Comparison of the various techniques
 - 3.3.2 Determination of special conditions depending on the examination requirements; 3.3.3 Acceptable temperature intervals; 3.3.4 Special cases of high and low temperature
 - 3.3.5 Penetration time
- 3.4 Removal of the excess penetrating agent
 - 3.4.1 Removal techniques for the various systems
 - 3.4.2 Design and monitoring of the removal stage
 - 3.4.3 Post- emulsification
 - 3.4.4 Lipophilic and hydrophilic emulsifiers
- 3.5 Techniques of development
 - 3.5.1 Treatment of the specimens prior to development; 3.5.2 Various types of developer; 3.5.3 Treatment, selection and control
- 3.6 Observation of the indications
 - 3.6.1 Lighting conditions and Wood radiation requirements, depending on the applicable techniques and characteristics of the specimen; 3.6.2 Method, time and sequence of the observations; 3.6.3 Methods and media for recording indications

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to select test techniques in accordance with the design specifications and the state and type of specimen to be tested;
- 3.2 Given the instructor's explanations, the student will be able to analyse, evaluate and determine the requirements for the identification, treatment and precleaning of the specimens to be tested;
- 3.3 Given the instructor 's explanations, the student will be able to evaluate, settle and apply various methods of applying the penetrant to specimens of different configurations.

- 3.4 Given the instructor's explanations, the student will be able to select and evaluate effective penetrant removal systems.
- 3.5 Given the instructor's explanations, the student will be able to select and evaluate various developer systems.
- 3.6 Given the instructor's explanations, the student will be able to define and evaluate the necessary conditions for proper inspection and adequate interpretation of results.

METHODOLOGICAL STRATEGIES:

Instructor's explanations including practical testing work on selected specimens, guided discussion of all stages of application of the test and the results.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Laboratory equipment and accessories for testing
Products for the various testing techniques
Specimens for testing

CONTENTS:

- 3.7 Evaluation of test sensitivity
 - 3.7.1 Test pieces for comparison
 - 3.7.2 Detection thresholds
 - 3.7.3 Interpretation of indications depending on fabrication process
 - 3.7.4 False, spurious or irrelevant indications
 - 3.7.5 Evaluation of indications according to specifications, codes or tolerance criteria
 - 3.8 Classification of the application techniques
 - 3.8.1 Criteria for classification and selection
 - 3.8.2 Applications according to specimens and operational conditions
 - 3.9 Test techniques for detecting leaks by means of penetrating liquids
 - 3.9.1 Evaluation of areas of applications and sensitivity
-

SPECIFIC OBJECTIVES:

- 3.7 Given the instructor's explanations, the student will be able to define and evaluate the sensitivity of the technique applied;
 - 3.8 Given the instructor's explanations, the student will be able to define and evaluate operating conditions for the application of various stages of the test taking into consideration design specifications, type of specimen, work- environment conditions, industrial safety and economic factors;
 - 3.9 Given the instructor's explanations, the student will be able to define and evaluate various penetrant techniques for leak detection.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including practical testing work on selected specimens and guided discussion of the stages of applications of the test and the results.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Laboratory, equipment and accessories for testing
Products for the various testing techniques
Specimens for testing

CONTENTS:

- 4.1 Formulation of the penetrating liquids used in various techniques
 - 4.1.1 Types of dyes and pigments; 4.1.2 penetrants for prior cleaning and for removal; 4.1.3 solvents; 4.1.4 lipophilic and hydrophilic emulsifiers; 4.1.5 characteristics and properties; 4.1.6 developers; 4.1.7 physicochemical properties and characteristics; 4.1.8 Form of presentation and use
 - 4.2 Evaluation of materials
 - 4.2.1 Characteristic properties and behaviour; 4.2.2 test methods for the evaluation; 4.2.3 standardized test pieces (ASTM, MIL, JIS, IRAM) for evaluation of processes and rating of procedures
 - 4.3 Equipment and accessories applicable to the test under way
 - 4.3.1 Pulverization systems and equipment for liquid as; 4.3.2 isothermic and adiabatic compressors; 4.3.3 electrostatic pulverizers; 4.3.4 stationary installations for manual and automatic processing.
 - 4.4 Lighting for direct observation and ultraviolet radiation sources
 - 4.4.1 Measuring instruments; 4.4.2 Devices for evaluating pigment fluorescence and efficiency of ultraviolet lamps
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations and performance of the practical work and calculations, the student will be able to analyse, evaluate and select the various economically viable processes, depending on the requirements of the examination in question and the test conditions.
- 4.2 Given the instructor's explanations and performance of the practical work and calculations, the student will be able to: a) determine the requirements of testing and analysis applicable to control of the materials used in the test; b) select the type of work piece for evaluation suited to the processes to be used; c) determine suitable methods for rating the processes to be used.
- 4.3 Given the instructor's explanations and performance of the practical work and calculations, the student will be able to: a) evaluate, select and apply correctly the equipment and accessories corresponding to the application of the specific test techniques involved; c) select, install and adjust test installations for manual of automated testing in plants.
- 4.4 Given the instructor's explanations and performance of the practical work and calculations, the student will be able to check lighting equipment and accessories to determine suitability for use to meet established procedures.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including practical work on behaviour test, practical work on the use of calibrated test pieces, discussion of results, guided visit to plants and works where the test is used.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Laboratory with equipment

Materials and suitable work pieces

CONTENTS:

- 5.1 Examination specifications
 - 5.1.1 Function of design engineering
 - 5.1.2 Design and building codes
 - 5.1.3 ASME Code
 - 5.2 Standards specific to liquid penetrant testing
 - 5.2.1 National and international standards (ASTM, DIN, MIL, IRAM)
 - 5.2.2 Interpretation of specifications, codes and standards
 - 5.3 Testing procedures
 - 5.3.1 Formulation of test procedures
 - 5.3.2 General and specific procedures
 - 5.4 Safety in penetrant testing
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to interpret, analyse and apply specifications for examination prepared by design engineers or called for in codes of practice;
 - 5.2 Given the instructor's explanations, the student will be able to analyse, evaluate and apply liquid penetrant testing according to national and international standards;
 - 5.3 Given the instructor's explanations, the student will be able to develop, evaluate and apply written procedures for liquid penetrant testing, conforming to externally imposed requirements and those imposed by the specimens, equipment available and work environment.
 - 5.4 Given the instructor's explanations, the student will be able to apply good safety practices in the application of penetrant testing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and supervised practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Sample codes, standards, specifications and procedures

CONTENTS:

- 6.1 Preparation of reports on the testing
 - 6.2 Preparation and completion of the report form
 - 6.3 Documentation of the findings
 - a) to locate the indication within the component
 - b) knowledge of documentation systems
 - c) management and control of complete documentation
-

SPECIFIC OBJECTIVES:

- 6.1 Given the results of the test he has conducted, the student will be able to develop a report showing all aspects of the inspection process and the results obtained.
 - 6.2 Given the instructor's explanation, the student will be able to design and complete an inspection report sheet in accordance with requirements and the inspection results.
 - 6.3 Given the instructor's explanation, the student will be able to:
 - a) distinguish between the different means of recording information and compare their limitations and applications;
 - b) record the results of his own inspection using each of the different recording systems.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Transparencies
Writing board
Slides
Course notes
Test pieces of various dimensions
Equipment and accessories for applying the test
Written test procedures, codes and standards relating to the tests
Photographic camera
Adhesive tape
Other recording media

CONTENTS:

- 7.1 Presentation of results
 - 7.2 Thresholds of detection:
 - a) evaluation of results according to the criteria of the procedure and specifications
 - b) additional possibilities for making the results more conclusive
 - 7.3 Interpretation of findings with reference to the manufacturing process
 - 7.4 Applications of penetrant testing and other methods of testing for surface and subsurface flaws
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanation and the results of the inspection, the student will be able to present the results obtained in an ordered and logical manner.
 - 7.2 Given a work piece of known characteristics and the corresponding procedure, the student will be able to:
 - a) choose an appropriate procedure;
 - b) determine the thresholds of the inspection;
 - c) carry out the inspection of the workpiece interpreting correctly the results obtained and determining whether the findings correspond to real discontinuities or whether they are spurious indications;
 - d) evaluate the findings in accordance with the inspection criteria.
 - 7.3 Given the instructor's explanation and the samples provided, the student will be able to relate the findings to defects inherent in the process of fabricating the test piece.
 - 7.4 Given the instructor's explanation, the student will be able to determine the application and limitation of testing by liquid penetrants and to compare penetrant testing to other methods for detecting surface flaws.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and student practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
course notes
test pieces of various dimensions
equipment and accessories for applying the test
written test procedures
codes and standards relating to the tests
codes and standards relating to NDT qualification and certification

VI. INSPECTION METHOD: EDDY CURRENT TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	4	8	1) ¹⁾
2. PHYSICAL PRINCIPLES	8	4	4
3. INSTRUMENTATION	8	12	11
4. TESTING PROCEDURES	14	16	12
5. APPLICATIONS	4	20	11
6. RECORDING AND EVALUATION OF RESULTS	2	4	8
TOTAL	40	64	46¹⁾
¹⁾ In addition to the above 46 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once.			

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION -	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology. Reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods
 - a) Visual testing, b) liquid penetrant testing, c) magnetic particle testing, d) radiographic testing, e) ultrasonic testing, f) Eddy current testing, g) leak testing
 - 1.1.4 Limitations in the application of eddy current testing

- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects

- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) Melting, b) pouring, c) cooling
 - 1.3.2 Processing and related defects
 - a) Casting, b) welding, c) forging, d) rolling, e) heat treatment, f) machining, g) plating, h) other processes
 - 1.3.3 Service related defects
 - a) Overload, b) fatigue, c) corrosion, d) brittle fracture, e) creep, f) others

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non -destructive test; b) list the characteristics of NDT technology and the reasons for using NDT; c) compare the different types of NDT methods, with particular reference to the application and uses of each method.

- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity; b) define the properties of materials, especially of metals; c) recognize how defects affect the properties of materials.

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication and bonding; b) describe the possible defects associated with each type of process; c) describe the possible defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides or computer presentations
Film (if available)
Course notes
Samples of various materials with typical defects

CONTENTS:

- 2.1 Electricity
 - 2.1.1 Direct current
 - a) Amperage and voltage, b) Ohm's law and resistance, c) conductivity and resistivity
 - 2.1.2 Alternating current
 - a) Amplitude and phase, b) impedance
- 2.2 Magnetism
 - 2.2.1 Magnetic theory
 - a) Induction and magnetic fields, b) magnetic permeability, c) iron magnetization
 - 2.2.2 Induced magnetic flux
 - a) Definition, b) lines of force and force fields, c) flux conservation, residual magnetism
- 2.3 Electromagnetism
 - 2.3.1 Magnetic field produced by a current
 - 2.3.2 Current induced by a magnetic field; eddy current, inductance
 - 2.3.3 Field created by eddy current, reactance
- 2.4 Eddy current distribution
 - 2.4.1 Plane conductors
 - a) Variation of amplitude and phase of current, b) depth of standard penetration, c) defect reaction according to position
 - 2.4.2 Cylindrical bars
 - a) Characteristic frequencies, b) variation of amplitude and phase of currents, c) depth of standard penetration, d) defect reaction according to position
 - 2.4.3 Tubes
 - a) Characteristic frequencies, b) variations of amplitude and phase, c) depth of standard penetration, d) defect reaction according to position

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanation and the student's knowledge of basic physics, the student will be able to define the terms associated with direct and alternating current.
- 2.2 Given the instructor's explanation, the student will be able to define the terms associated with magnetism and magnetic fields.
- 2.3 Given the instructor's explanation, the student will be able to define the terms associated with electromagnetism.
- 2.4 Given the instructor's explanation, the student will be able to describe the electrical and magnetic field associated with different shapes of interest in eddy current testing.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, worked examples and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides or computer presentations

Sample magnets and iron filings

Selection of typical geometric shapes used in eddy current testing

CONTENTS:

- 3.1 Principles and basic characteristics of eddy current probes
 - 3.1.1 Induction and reception functions
 - 3.1.2 Absolute and differential measure
 - 3.1.3 Types of probes
 - 3.2 Reaction of different types of probes according to coil layout
 - 3.2.1 Reaction to small defects
 - 3.2.2 Reaction to long defects
 - 3.2.3 Reaction to continuous defects
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanation, the student will be able to explain the principles and basic characteristics of eddy current probes.
 - 3.2 Given the instructor's explanation, the student will be able to describe the reaction of the different types of coil to defects of various geometries.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Examples of eddy current probes of various configurations

CONTENTS:

- 3.4 Working principles of eddy current equipment
 - 3.4.1 Transmission
 - 3.4.2 Reception
 - 3.4.3 Data presentation
 - 3.5 Adjustment of eddy current equipment
 - 3.5.1 Frequency
 - 3.5.2 Energizing device
 - 3.5.3 Balance
 - 3.5.4 Phase rotation
 - 3.5.5 Output filter
 - 3.5.6 Gain
 - 3.6 Different types of eddy current equipment
 - 3.6.1 Monoparameter and monochannel equipment
 - 3.6.3 Specialized equipment
 - 3.7 Auxiliary devices
 - 3.7.1 Auxiliary devices for signal acquisition
 - 3.7.2 Driving mechanism, saturating unit, demagnetizer
 - 3.7.3 Equipment for signal storage, stripchart recorders and digital memories
 - 3.7.4 System for automatic processing of signals
-

SPECIFIC OBJECTIVES:

- 3.4 Given the instructor's presentation, the student will be able to explain the working principles of eddy current equipment.
 - 3.5 Given the instructor's explanations, the student will be able to explain the functions of the various controls which are used to adjust the eddy current system.
 - 3.6 Given the instructor's presentation, the student will be able to describe the different types of eddy current equipment.
 - 3.7 Given the instructor's presentation, the student will be able to explain the types of auxiliary equipment commonly used and state the application of each.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides or computer presentations
Demonstration equipment

CONTENTS:

- 4.1 Influence of defect position and orientation
 - 4.1.1 Eddy current path
 - 4.1.2 Penetration depth
 - 4.1.3 Zone of probe action
 - 4.2 Influence of material temperature
 - 4.2.1 Heating
 - 4.2.2 Deviations
 - 4.2.3 Compensation
 - 4.3 Influence of structure and geometry of tested parts (noise)
 - 4.3.1 Choice of test frequency
 - 4.3.2 Phase discrimination
 - 4.3.3 Filtering
 - 4.3.4 Magnetic saturation
 - 4.4 Coupling influence
 - 5.6.3 Vibrations
 - 5.6.3 lift-off
 - 4.4.3 Centring, fill factor
 - 4.4.4 Sensitivity
 - 4.4.5 Compensation
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to describe the influence of defect position and orientation on the eddy current indication.
 - 4.2 Given the instructor's explanations, the student will be able to describe the influence of temperature on the eddy current results.
 - 4.3 Given the instructor's explanations, the student will be able to describe the effect of structure and geometry on the eddy current indications.
 - 4.4 Given the instructor's explanations, the student will be able to explain the influence of coupling on the eddy current indications.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies
Slides or computer presentations
Eddy current equipment and accessories
work pieces of various geometries and sizes

CONTENTS:

- 4.5 Reference standards used in eddy current testing
 - 4.5.1 Function of reference standards
 - 4.5.2 Choice of reference standard
 - 4.5.3 Fabrication and reproducibility of various types of reference standards
 - 4.6 Inspection method
 - 4.6.1 Range of inspection
 - 4.6.2 Recording of indications
-

SPECIFIC OBJECTIVES:

- 4.5 Given the instructor's explanation, the student will be able to explain the function and use of reference standards.
 - 4.6 Given the instructor's explanation, the student will be able to explain the inspection procedure including the recording of indications.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Eddy current equipment and accessories
Work pieces of various geometries and sizes
Reference standards

CONTENTS:

- 5.1 Measurement of product composition
 - 5.1.1 Measuring by electrical conductivity
 - 5.2 Thickness measurement
 - 5.2.1 Thickness of a product
 - 5.2.2 Thickness of coating
 - 5.3 Geometric defect characterization
 - 5.3.1 Hypothesis of interrupted currents
 - 5.4 Main types of discontinuities detected by eddy current testing
 - 5.4.1 Discontinuities arising from production
 - 5.4.2 Discontinuities arising during hot or cold processing
 - 5.4.3 Discontinuities arising during service
 - 5.5 Defect detection
 - 5.5.1 Absolute measurement
 - 5.5.2 Differential measurement
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanation, the student will be able to describe the method for measuring product composition by measuring electrical conductivity.
 - 5.2 Given the instructor's explanation, the student will be able to explain the means of thickness measurement by eddy currents.
 - 5.3 Given the instructor's explanation, the student will be able to describe how defects are detected by eddy current testing.
 - 5.4 Given the instructor's explanation, the student will be able to relate eddy current results to the origin of the discontinuity.
 - 5.5 Given the instructor's explanation, the student will be able to explain how absolute and differential measurements are applied in eddy current testing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or power-point-presentation
Equipment and test pieces of various shapes and sizes containing defects

CONTENTS:

6.1 Written instructions

6.2 Report preparation

SPECIFIC OBJECTIVES:

6.1 Given a written instruction and the instructor's explanation, the student will be able to carry out an eddy current inspection following written instructions.

6.2 Given a report chart and the instructor's explanation, the student will be able to write a clear and concise report of a test he has carried out.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and supervised practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Sample written instructions and associated test pieces
Eddy current equipment
Report forms

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods: VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects
 - b) Casting processes and associated discontinuities; ingots; blooms; billets; sand casting; centrifugal casting; investment casting
 - c) Wrought processes and associated discontinuities; forgings; rolled products; extruded products
 - d) Welding processes and associated discontinuities; submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.
- 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures; corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 Electricity
 - 2.1.1 Direct current
 - a) amperage and voltage, b) Ohm's law and resistance, c) conductivity and resistivity
 - 2.1.2 Alternating current
 - a) amplitude and phase, b) impedance

- 2.2 Magnetism
 - 2.2.1 Magnetic data
 - a) induction and magnetic fields, b) magnetic permeability, c) iron magnetization, d) B-H curve, e) Hysteresis loop
 - 2.2.2 Induced magnetic flux
 - a) definition, b) lines of force and force fields, c) flux conservation, residual magnetism
 - 2.2.3 Magnetic Ohm's law
 - a) magnetomotive force, b) reluctance, c) magnetic circuits

- 2.3 Magnetic field produced by a current
 - 2.3.1 Biot and Savart law
 - a) definition, b) practical rules, c) right hand rule
 - 2.3.2 Ampere's law
 - a) definition, b) applications (toroid, infinite coil, flat coil)

- 2.4 Electromagnetic induction law
 - 2.4.1 Lenz's law
 - a) definition, b) auto induction factor, c) mutual induction factor, d) coupling factor
 - 2.4.2 Induced currents
 - a) in a short- circuit coil, b) in a metallic mass, c) skin effect, d) field created by eddy current, e) reactance

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanation and the student's knowledge of basic physics, the student will be able to define the terms associated with direct and alternating current.

- 2.2 Given the instructor's explanation, the student will be able to define the terms associated with magnetism and magnetic fields.

- 2.3 Given the instructor's explanation and the student's knowledge of basic physics, the student will be able to explain the Biot and Savart law and Ampere's law.

- 2.4 Given the instructor's explanation, the student will be able to explain the terms associated with Lenz's law and induced currents.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, worked examples and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies
Slides or computer presentations
Sample magnets and iron filings

CONTENTS:

- 3.1 Principles and basic characteristics of eddy current probes
 - 3.1.1 Induction and reception functions
 - 3.1.2 Absolute and differential measurements
 - 3.1.3 Types of probes
 - 3.2 Eddy current distribution relative to coil position
 - 3.2.1 Field generated by non-load inductor coil
 - 3.2.2 Eddy current path in a part according to its position relative to inductor coil
 - 3.2.3 Distance influence on coupling in various shapes
 - 3.2.4 Focusing methods
 - 3.3 Reaction of different types of probes according to coil layout
 - 3.3.1 Reaction to small defects
 - 3.3.2 Reaction to long defects
 - 3.3.3 Reaction to continuous defects
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanation, the student will be able to explain the principles and operating characteristics of eddy current probes.
 - 3.2 Given the instructor's explanation, the student will be able to explain the distribution of eddy currents relative to coil position and to describe the methods of focussing eddy currents.
 - 3.3 Given the instructor's explanation, the student will be able to describe and explain the reaction of the different types of coil to defects of various geometries.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Examples of eddy current probes of various configurations

CONTENTS:

- 3.4 Technology and practical characteristics of probes
 - 3.4.1 Design technology
 - 3.4.2 Manufacturing technology
 - 3.4.3 Electrical parameters
 - 3.4.4 Maintenance

 - 3.5 Main functions and adjustments of the equipment
 - 3.5.1 Oscillator
 - 3.5.2 Energizing device
 - 3.5.3 Measuring system
 - 3.5.4 Balance
 - 3.5.5 Amplifier and filter
 - 3.5.6 Demodulator
 - 3.5.7 Display (ellipse, time- base, impedance plane, vector point)
 - 3.5.8 Phase rotation
 - 3.5.9 Output filter

 - 3.6 Different types of eddy current equipment
 - 3.6.1 Monoparameter and monochannel equipment
 - 3.6.2 Multiparameter and multichannel equipment

 - 3.7 Auxiliary devices
 - 3.7.1 Auxiliary devices for signal acquisition
 - 3.7.2 Driving mechanism, saturating unit, demagnetizer
 - 3.7.3 Equipment for signal storage: stripchart recorders and digital memories
 - 3.7.4 System for automatic processing of signals
-

SPECIFIC OBJECTIVES:

- 3.4 Given the instructor's explanation, the student will be able to explain the impact of technology and practice on the design of the probe.

- 3.5 Given the instructor's explanations, the student will be able to explain the main functions of the eddy current instrument and the controls which are associated with these functions.

- 3.6 Given the instructor's presentation, the student will be able to compare the different types of eddy current equipment and explain the most appropriate application for each.

- 3.7 Given the instructor's presentation, the student will be able to compare the types of auxiliary equipment commonly used and explain the application of each.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board

Transparencies

Slides or computer presentations

Examples of eddy current probes of various configurations

Demonstration equipment

CONTENTS:

- 4.1 Influence of defect position and orientation
 - 4.1.1 Eddy current path
 - 4.1.2 Penetration depth
 - 4.1.3 Zone of probe action
 - 4.2 Influence of material temperature
 - 4.2.1 Heating
 - 4.2.2 Deviations
 - 4.2.3 Compensation
 - 4.3 Influence of structure and geometry of tested parts (noise)
 - 4.3.1 Choice of test frequency
 - 4.3.2 Phase discrimination
 - 4.3.3 Filtering
 - 4.3.4 Magnetic saturation
 - 4.4 Coupling influence
 - 4.4.1 Vibrations
 - 4.4.3 Lift-off
 - 4.4.3 Centring-fill factor
 - 4.4.4 Sensitivity
 - 4.4.5 Compensation
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to describe and explain the influence of defect position and orientation on the eddy current indication.
 - 4.2 Given the instructor's explanations, the student will be able to explain the influence of temperature on the eddy current results.
 - 4.3 Given the instructor's explanations, the student will be able to explain the effect of structure and geometry on the eddy current indications.
 - 4.4 Given the instructor's explanations, the student will be able to explain the influence of coupling on the eddy current indications.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies
Slides or computer presentations
Eddy current equipment and accessories
Work pieces of various geometries and sizes

CONTENTS:

- 4.5 Influence of relative part/probe speed
 - 4.5.1 Testing frequencies according to speed
 - 4.5.2 Bandwidths of apparatus according to testing speed
 - 4.6 Reference standards used in eddy current testing
 - 4.6.1 Function of reference standards
 - 4.6.2 Choice of reference standard
 - 4.6.3 Fabrication and reproducibility of various types of reference standards
 - 4.7 Inspection method
 - 4.7.1 Range of inspection
 - 4.7.2 Recording of indications
 - 4.7.3 Analysis and interpretation of results
 - 4.8 Preparation of written instructions for level 1
-

SPECIFIC OBJECTIVES:

- 4.5 Given the instructor's explanation, the student will be able to explain the influence of probe speed relative to the part on the eddy current results.
 - 4.6 Given the instructor's explanation, the student will be able to explain the function and use of reference standards.
 - 4.7 Given the instructor's explanation, the student will be able to explain the inspection procedure, record the indications, and analyse and interpret the results.
 - 4.8 Given the instructor's explanation, the student will be able to prepare a written instruction based on technical standards.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Eddy current equipment and accessories
Work pieces of various geometries and sizes
Sample written instructions and associated test pieces

CONTENTS:

- 5.1 Geometric defect characterization
 - 5.1.1 Hypothesis of interrupted currents
 - 5.1.2 Case of point defects
 - 5.1.3 Case of large defects
 - 5.1.4 Case of multiple defects

 - 5.2 Coil with a long conductive product (bar or tube)
 - 5.2.1 Impedance diagram
 - 5.2.2 Influence of various parameters
 - 5.2.3 Ferromagnetic products

 - 5.3 Use of impedance diagrams
 - 5.3.1 Definition of operating point
 - 5.3.2 Choice of operating point according to sensitivity of parameter splitting

 - 5.4 Electromagnetic properties of materials
 - 5.4.1 Electrical conductivity
 - 5.4.2 Chemical analysis, temperature, grain size, texture influence, structure
 - 5.4.3 Magnetic permeability: chemical analysis, structure, grain size and texture influence
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanation, the student will be able to explain how defects of various sizes are characterized by eddy current results.

 - 5.2 Given the instructor's explanation, the student will be able to explain the importance of various parameters on the production of the eddy current signal from a long conductive product.

 - 5.3 Given the instructor's explanation, the student will be able to explain the use of impedance diagrams and the importance of the operating point.

 - 5.4 Given the instructor's explanation, the student will be able to explain how the electromagnetic properties of materials influence the eddy current result.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides or computer presentations
Equipment and test pieces of various shapes and sizes containing defects

CONTENTS:

- 5.5 Main types of discontinuities detected by eddy current testing
 - 5.5.1 Discontinuities arising from production
 - 5.5.2 Discontinuities arising during hot or cold processing
 - 5.5.3 Discontinuities arising during service

- 5.6 Thickness measurement
 - 5.6.1 Thickness of a product
 - 5.6.2 Thickness of coatings

- 5.7 Measurement of product composition
 - 5.6.3 Measuring by electrical conductivity
 - 5.6.3 Measuring by magnetic permeability

- 5.8 Inspection of welds
 - 5.8.1 Characteristic probes and frequencies
 - 5.8.2 Defect reaction according to position and weld shape

- 5.9 Multifrequency eddy current testing
 - 5.9.1 Principles
 - 5.9.2 Equipment
 - 5.9.3 Applications

SPECIFIC OBJECTIVES:

- 5.5 Given the instructor's explanation, the student will be able to relate eddy current results to the origin of the discontinuity.

- 5.6 Given the instructor's explanation, the student will be able to explain the means of thickness measurement by eddy currents.

- 5.7 Given the instructor's explanation, the student will be able to describe the method for measuring product composition by measuring electrical conductivity and magnetic comparator.

- 5.8 Given the instructor's explanation, the student will be able to describe the method for weld inspection with a representative standard.

- 5.9 Given the instructor's explanation, the student will be able to explain the principles and applications of multi frequency eddy current test equipment.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board or white board Transparencies Slides or computer presentations

Equipment and test pieces of various shapes and sizes containing defects

Equipment and test pieces of various thicknesses and with coatings

Test pieces for demonstration of conductivity testing

Test pieces for weld inspection

CONTENTS:

- 6.1 Codes and standards which apply to eddy current testing
 - 6.2 Standards for equipment characteristics and verification
 - 6.3 Specifications and procedures which apply to the method
 - 6.4 Inspection techniques and their use
 - 6.5 Inspection reports
 - 6.6 Safety
 - 6.6.1 Implementation of industrial safety standards in facilities and equipment and in their operation
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanation, the student will be able to explain the contents of some typical codes and standards which govern the application of eddy current testing.
 - 6.2 Given the instructor's explanation, the student will be able to check the equipment with a representative standard.
 - 6.3 Given the instructor's explanation, the student will be able to apply specifications and procedures which are used in eddy current testing.
 - 6.4 Given the instructor's explanation, the student will be able to develop inspection techniques for inspection problems to which the eddy current method applies.
 - 6.5 Given the instructor's explanation, the student will be able to write clear and concise reports of tests he has carried out and evaluate reports prepared by others.
 - 6.6 Given the instructor's explanation, the student will be able to apply industrial safety standards in using eddy current inspection techniques.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and supervised practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Sample written procedures and associated test pieces
Eddy current equipment
Report forms
Codes, standards and specifications

INSPECTION METHOD: EDDY CURRENT TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Phenomena of electromagnetic induction
 - 2.1.1 Field generated by a current
 - 2.1.2 Field/induction relationship
 - 2.1.3 Flux of induction vector
 - 2.1.4 Electromotive force of induction
 - 2.1.5 Self- inductance, coefficient of self- inductance
 - 2.1.6 Mutual inductance, coefficient of mutual inductance, coupling coefficient

 - 2.2 Impedance of a circuit in the presence of another circuit
 - 2.2.1 Representation of impedance plane
 - 2.2.2 Effect of variation in fill factor
 - 2.2.3 Normalized impedance plane
 - 2.2.4 Effect of variation in frequency
 - 2.2.5 Influence of a magnetic field
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanation and the student's knowledge of basic physics, the student will be able to explain the phenomena of electromagnetic induction

 - 2.2 Given the instructor's explanation, the student will be able to explain the effect of a second circuit on the impedance of one circuit.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, worked examples and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides or computer presentations

CONTENTS:

- 2.3 Electromagnetic wave propagation
 - 2.3.1 Basic laws
 - 2.3.2 Application to a plane wave incident at a plane conductor- decreasing delay of fields and currents and phase
 - 2.3.3 Definition of the standard penetration depth (d)
 - 2.3.4 Expression of (d) in the specific case of plane
 - 2.3.5 Definition of the similarity law
 - 2.4 Eddy current distribution in test pieces
 - 2.4.1 Bars, simplifying hypothesis, similarity law, limit frequency, eddy current distribution (amplitude, phase), standard penetration depth
 - 2.4.2 Tubes, simplifying hypothesis, similarity law, different expressions of limit frequency, eddy current distribution, standard penetration depth
 - 2.4.3 Field applied to short test pieces, similarity law, simplifying hypothesis, limit frequency in simple cases, case of magnetic materials
 - 2.4.4 Field applied to surfaces, complexity due to different parameters
 - 2.4.5 Characterization of geometrical discontinuities, hypothesis of interrupted currents, point defects, extensive defects, multiple defects
 - 2.5 Impedance diagrams for specific cases, feed through coils, bars, tubes, short test pieces in feed through coils, operating points, sensitivity
-

SPECIFIC OBJECTIVES:

- 2.3 Given the instructor's explanation, the student will be able to explain the principles of electromagnetic wave propagation.
 - 2.4 Given the instructor's explanation, the student will be able to explain the distribution of eddy currents in common and complex shapes.
 - 2.5 Given the instructor's explanation, the student will be able to explain the impedance diagrams for special coil geometries.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, worked examples and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies Slides or computer presentations
Selection of shapes encountered in eddy current testing

CONTENTS:

- 3.1 Principles and basic characteristics of eddy current probes
 - 3.1.1 Induction and reception functions
 - 3.1.2 Absolute and differential measurements
 - 3.1.3 Test coil arrangements, encircling coil, internal coil, surface coil, hybrid coil, coils-distance, double-differential coils, multi-differential coils
 - 3.1.4 Focusing means, magnetic circuits, coil arrangements
 - 3.2 Use of probes
 - 3.2.1 Field from an empty short coil, divergence between practice and theory
 - 3.2.2 Difference in coupling and current distribution resulting from different coil arrangements
 - 3.3 Working principle of eddy current equipment
 - 3.3.1 Transmission
 - 3.3.2 Reception
 - 3.3.3 Data presentation
-

SPECIFIC OBJECTIVES:

- 3.1 Given instructor's explanation, the student will be able to explain the principles and operating characteristics of eddy current probes.
 - 3.2 Given the instructor's explanation, the student will be able to explain the differences in coupling and current distribution that results from the various types of coil arrangements.
 - 3.3 Given the instructor's presentation, the student will be able to explain the working principles of eddy current equipment.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Examples of eddy current probes of various configurations
Eddy current equipment

CONTENTS:

- 3.4 Main functions and adjustments of the equipment
 - 3.4.1 Oscillator
 - 3.4.2 Energizing device
 - 3.4.3 Measuring system
 - 3.4.4 Balance
 - 3.4.5 Amplifier and filter
 - 3.4.6 Demodulator
 - 3.4.7 Display (ellipse, time- base, impedance plane, vector point)
 - 3.4.8 Phase rotation
 - 3.4.9 Output filter

 - 3.5 Classification of eddy current equipment
 - 3.5.1 One parameter equipment, specialized equipment, one way equipment
 - 3.5.2 Multiparameter equipment, two way equipment, multifrequency equipment
 - 3.5.3 Pulsed eddy current equipment

 - 3.6 Auxiliary devices
 - 3.6.1 Auxiliary devices for signal acquisition
 - 3.6.2 Driving mechanism, saturating unit, demagnetizer
 - 3.6.3 Equipment for signal storage, stripchart recorders and digital memories
 - 3.6.4 System for automatic processing of signals
-

SPECIFIC OBJECTIVES:

- 3.4 Given the instructor's explanations, the student will be able to explain the main functions of the eddy current instrument and the controls which are associated with these functions

 - 3.5 Given the instructor's presentation, the student will be able to compare and evaluate the different types of eddy current equipment and explain the most appropriate application for each.

 - 3.6 Given the instructor's presentation, the student will be able to compare the types of auxiliary equipment commonly used and explain the application of each.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies Slides or computer presentations
Eddy current equipment
Demonstration equipment

CONTENTS:

- 4.1 Influence of defect position and orientation
 - 4.1.1 Eddy current path
 - 4.1.2 Penetration depth
 - 4.1.3 Zone of probe action
 - 4.2 Influence of material temperature
 - 4.2.1 Heating
 - 4.2.2 Deviations
 - 4.2.3 Compensation
 - 4.3 Influence of structure and geometry of tested parts (noise)
 - 4.3.1 Choice of test frequency
 - 4.3.2 Phase discrimination
 - 4.3.3 Filtering
 - 4.3.4 Magnetic saturation
 - 4.4 Coupling influence
 - 4.4.1 Vibrations
 - 4.4.2 Lift-off
 - 4.4.3 Centring, fill factor
 - 4.4.4 Sensitivity
 - 4.4.5 Compensation
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to describe and explain the influence of defect position and orientation on the eddy current indication.
 - 4.2 Given the instructor's explanations, the student will be able to explain the influence of temperature on the eddy current results.
 - 4.3 Given the instructor's explanations, the student will be able to explain the effect of structure and geometry on the eddy current indications.
 - 4.4 Given the instructor's explanations, the student will be able to explain the influence of coupling on the eddy current indications.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies
Slides or computer presentations
Eddy current equipment and accessories
Work pieces of various geometries and sizes

CONTENTS:

- 4.5 Influence of relative part/probe speed
 - 4.5.1 Testing frequencies according to speed
 - 4.5.2 Bandwidths of apparatus according to testing speed
 - 4.6 Reference standards used in eddy current testing
 - 4.6.1 Function of reference standards
 - 4.6.2 Choice of reference standard
 - 4.6.3 Fabrication and reproducibility of various types of reference standards
 - 4.7 Inspection method
 - 4.7.1 Range of inspection
 - 4.7.2 Recording of indications
 - 4.7.3 Analysis and interpretation of results
-

SPECIFIC OBJECTIVES:

- 4.5 Given the instructor's explanation, the student will be able to explain the influence of probe speed relative to the part on the eddy current results.
 - 4.6 Given the instructor's explanation, the student will be able to explain the function and use of reference standards.
 - 4.7 Given the instructor's explanation, the student will be able to explain the inspection procedure, record the indications, and analyse and interpret the results.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Eddy current equipment and accessories
Work pieces of various geometries and sizes
Reference standards

CONTENTS:

- 5.1 Electromagnetic properties of materials
 - 5.1.1 Electrical conductivity; effects of chemical composition, temperature, grain size and structure
 - 5.1.2 Magnetic permeability: dia-, para- and ferromagnetic, hysteresis loop, Rayleigh area, saturation, Weiss area, Curie point, effects of chemical composition, grain size, structure
 - 5.2 Anomalies related to manufacture and use of products
 - 5.2.1 Related to the manufacture of cast, extruded or rolled products
 - 5.2.2 Related to service, creep, fatigue, corrosion
 - 5.3 Defect detection
 - 5.3.1 Absolute measurement
 - 5.3.2 Differential measurement
 - 5.4 Thickness measurement
 - 5.4.1 Thickness of a product
 - 5.4.2 Thickness of coating
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanation, the student will be able to explain how the electromagnetic properties of materials influence the eddy current result.
 - 5.2 Given the instructor's explanation, the student will be able to relate eddy current results to the origin of the discontinuity.
 - 5.3 Given the instructor's explanation, the student will be able to explain how differential and absolute measurements are applied in eddy current testing.
 - 5.4 Given the instructor's explanation, the student will be able to explain the means of thickness measurement by eddy currents.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Equipment and test pieces of various shapes and sizes containing defects

CONTENTS:

- 5.5 Measurement of product composition
 - 5.5.1 Measuring by electrical conductivity

 - 5.6 Recent developments in eddy current testing
 - 5.6.1 Multifrequency eddy current testing, principles, applications
 - 5.6.2 Pulsed eddy current testing, principles, applications
 - 5.6.3 Electromagnetic transducers, principles of conversion, advantages
 - 5.6.3 Arrays captors

 - 5.7 Problems encountered in eddy current inspection
 - 5.7.1 Position and orientation of defects, eddy current paths, penetration depth
 - 5.7.2 Structure and geometry for the test pieces, noise, frequency, phase discrimination
 - 5.7.3 Lift- off, vibrations, centring, sensitivity
 - 5.7.4 Coil -specimen relative speed, test frequency as a function of speed
 - 5.7.5 Temperature, overheating, drift, compensation
 - 5.7.6 Equipment, repeatability of measurement, deviation of equipment characteristics, calibration
-

SPECIFIC OBJECTIVES:

- 5.5 Given the instructor's explanation, the student will be able to describe the method for measuring product composition by measuring electrical conductivity.

 - 5.6 Given the instructor's explanation, the student will be able to explain the principles and applications of recently developed types of eddy current equipment.

 - 5.7 Given the instructor's explanation, the student will be able to analyse problems and develop solutions to produce effective inspections with eddy current equipment.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board or white board
Transparencies Slides or computer presentations
Equipment and test pieces of various thicknesses and with coatings
Test pieces for demonstration of conductivity testing
Equipment and test pieces of various geometries, sizes and characteristics

CONTENTS:

- 6.1 Codes and standards which apply to eddy current testing
 - 6.2 Standards for equipment characteristics and verification
 - 6.3 Specifications and procedures which apply to the method
 - 6.4 Inspection techniques and their use
 - 6.5 Inspection reports
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanation, the student will be able to evaluate, analyse and develop typical codes and standards to govern the application of eddy current testing.
 - 6.2 Given the instructor's explanation, the student will be able to develop a written instruction that covers all parameters for checking the system to reach a high level of repeatability in the results of tests.
 - 6.3 Given the instructor's explanation, the student will be able to analyse, evaluate and develop specifications and procedures to be used in eddy current testing.
 - 6.4 Given the instructor's explanation, the student will be able to develop and evaluate inspection techniques for inspection problems to which the eddy current method applies.
 - 6.5 Given the instructor's explanation, the student will be able to write clear and concise reports of tests he has carried out and evaluate reports prepared by others.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and supervised practical work

EQUIPMENT AND RESOURCES:

Writing board
Transparencies Slides or computer presentations
Sample written procedures and associated test pieces
Eddy current equipment
Report forms
Codes, standards and specifications

VII. INSPECTION METHOD: LEAK TESTING

SUBJECT	HOURS OF TRAINING								
	LEVEL 1			LEVEL 2			LEVEL 3		
	A ²⁾	B ²⁾	C ²⁾	A ²⁾	B ²⁾	C ²⁾	A ²⁾	B ²⁾	C ²⁾
1. GENERAL KNOWLEDGE	1	-	-	2	-	-	1 ¹⁾	1 ¹⁾	1 ¹⁾
2. PHYSICAL PRINCIPLES OF THE TEST	3	-	-	4	-	-	4	-	-
3. TEST TECHNIQUES	-	6	6	-	20	20	-	13	14
4. EQUIPMENT AND ACCESSORIES	-	8	12	-	11	16	-	8	10
5. CODES, STANDARDS, PROCEDURES AND GUIDELINES	1	-	-	4	-	-	4	-	-
6. SAFETY ASPECTS	1	-	-	1	-	-	1	-	-
7. APPLICATIONS	1	-	-	3	-	-	1	-	-
8. DOCUMENTATION OF THE TEST	1	-	-	2	-	-	2	-	-
TOTAL	8 ²⁾	14 ²⁾	18 ²⁾	16 ²⁾	31 ²⁾	36 ²⁾	12 ₂₎	21 ₂₎	24 ₂₎
<p>¹⁾ In addition to the above 40 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once..</p> <p>²⁾ A: Basic knowledge, B: Pressure method, C: Tracer gas method. The content to complete the required hours for each shall be selected by the instructor from the topics detailed for each subject</p>									

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as technology. Reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods
 - a) visual testing, b) liquid penetrant testing, c) magnetic particle testing, d) radiographic testing, e) ultrasonic testing, f) eddy current testing, g) leak testing
 - 1.1.4 Functions of leak testing
 - 1.1.5 Reasons for leak testing
 - 1.1.6 Advantages of the leak testing method
 - 1.1.7 Limitations in the application of leak testing
- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects
- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) melting, b) pouring, c) cooling
 - 1.3.2 Processing and related defects
 - a) casting, b) welding, c) forging, d) rolling, e) heat treatment, f) machining, g) plating, h) other processes
 - 1.3.3 Service and related defects
 - a) overload, b) fatigue, c) creep, d) corrosion, e) brittle fracture, f) others

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non-destructive test; b) list the characteristics of NDT technology and the reasons for using NDT; c) compare the different types of NDT, with particular reference to the application and uses of each method.
- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity; b) define the properties of materials, especially of metals; c) recognize how defects affect the properties of materials.
- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication and bonding; b) describe the possible defects associated with each type of process; c) describe the possible defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Slides

Film (if available)

Course notes

Samples of various materials with typical defects

CONTENTS:

- 2.1 Type of gases, properties and behaviour of gases, general equation of gases, pressurization of gases, temperature effects, variations in atmospheric pressure and changes in vapour pressure, definition of pressure, measuring of vapour pressure, pressure units, volume and flow rate units used in leak testing
 - 2.2 Basic knowledge of leaks and leakage, real and virtual leaks, leak conductance, sensitivity of a detector and sensitivity of test, leakage measurement, outgassing phenomena
 - 2.3 Basic knowledge of tracer fluids
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) list the general properties and behaviour of gases;
 - b) describe the units applicable to the measurement of flow-rate, volume and pressure of fluids.
 - 2.2 Given the instructor's explanations, the student will be able to recognize the difference between real and virtual leaks.
 - 2.3 Given the instructor's explanations, the student will be able to recognize the usefulness of tracer fluids.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Transparencies
Films
Course notes

CONTENTS:

- 3.1 Techniques for the application of leak testing
 - a) bubble testing
 - b) pressure change measurement
 - c) halogen detection
 - d) helium detection
 - e) radioactive tracers
 - f) liquid penetrants and chemical tracers
 - g) ultrasonic leak testing; acoustic emission leak testing
 - h) vacuum box testing
 - i) halide torch testing
 - j) high voltage discharge testing
 - k) light absorption testing; thermal conductivity leak testing
 - l) gas analysis (gas chromatography, residual gas analysis)
- 3.2 Leaks detection, location of leaks and leakage measurements, operative conditions for dynamic and static tests
- 3.3 Bubble test: operative conditions for bubble test and foam test, conditioning of liquid for bubbling, solutions for formation of foam, examination of seamed tubes and welded vessels, check of locks and gates, operative conditions for testing systems of reference, relative terminology, gas pressurization, effects of changes in temperature, vapour pressure and atmospheric pressure, application to examination of piping and vessels, advantages and limitations

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to define the different techniques used in leak detection and measurement.
- 3.2 Given the instructor's explanations, the student will be able to describe operating conditions for dynamic and static tests.
- 3.3 Given the instructor's explanations, the student will be able to:
 - a) describe the operative conditions for applying bubble tests;
 - b) prepare the solutions for bubbling and foaming tests;
 - c) apply the bubble test to different components;
 - d) operate testing in accordance with reference systems;
 - e) demonstrate knowledge of terminology; conditions for gas pressurization; effect of temperature changes and vapour pressure.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, practical student development, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Course notes

Samples

Bubble test equipment and accessories

CONTENTS:

- 3.4. Pressure change measurement, principles of pressure change method, pressurization and evacuation modes, pumping methods, observation techniques, pumping pressures, outgassing problems, pressure and vacuum analyses, advantages and limitations
- 3.5. Test by detection of halogens, operative conditions for leak test using halogen diode detector, operation principles, relative terminology, operation and maintenance of halogen detectors, application of standard leaks, halogen percentage in tracer fluid, head effects in R-12 fluid, contamination measurement, calibration, standards and sensitivity, atmosphere control, halogen vapour, advantages and limitations
- 3.6. Test with helium spectrometers, probing speed, operative conditions for leak test with helium spectrometer, operation and maintenance of helium mass spectrometers, calibration for different tests, operation of vacuum pumps, test techniques, outgassing vs. pressure, percentage of helium in tracer fluid, sniffing techniques, use of sniffers, diameter and length of sniffing hose, pressure differential, technique with accumulation in bagsdynamic method with use of probe and bag static method, pressure system, advantages and limitations

SPECIFIC OBJECTIVES:

- 3.4. Given the instructor's explanations, the student will be able to:
 - a) know operating conditions for leak tests using pressure change method;
 - b) know the corresponding technology;
 - c) know operation and maintenance of pressure and vacuum pumps and accessories.
- 3.5. Given the instructor's explanations, the student will be able to:
 - a) know operating conditions for leak tests using halogen diode detectors;
 - b) know the corresponding technology;
 - c) know operation and maintenance of halogen detectors and use of leak standards.
- 3.6. Given the instructor's explanations, the student will be able to:
 - a) know operating conditions for leak tests using helium-mass spectrometer.
 - b) know the corresponding technology;
 - c) know the operation and maintenance of helium mass spectrometer and related vacuum systems;
 - d) know the use of different test techniques;
 - e) know the use of sniffers and the calibration of standard leaks.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, practical student involvement, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Films

Course notes

Pressure change measurement test equipment and accessories

Halogen detection test equipment and accessories

Helium detection test equipment and accessories

CONTENTS:

- 3.7 Further and advanced techniques
 - 3.7.1 Radioactive tracers, applicability and principle of test, krypton-85 gas, advantages and limitations
 - 3.7.2 Liquid penetrants and chemical tracers, applicability and characteristics of techniques, penetrant materials, ammonia gas leak test, carbon dioxide tracer gas, chemical fumes leak detector, indicator solutions, advantages and limitations
-

SPECIFIC OBJECTIVES:

- 3.7.1 Given the instructor's explanations, the student will be able to:
 - a) know fundamental principle of the test;
 - b) know the corresponding technology.
 - 3.7.2 Given the instructor's explanations, the student will be able to:
 - a) know fundamental principles of the tests;
 - b) know the corresponding technology;
 - c) know the use of different test techniques.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, practical student involvement, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Films
Course notes
Liquid penetrant consumables and accessories
Other applicable test equipment and accessories

CONTENTS:

- 3.7.3 Ultrasonic leak testing, principles, characteristics and applicability, advantages and limitations
 - 3.7.4 Acoustic emission leak testing, fundamental principles of acoustic emission leak testing, applicability and characteristics of the test, methods of acoustic emission testing, advantages and limitations
 - 3.7.5 Vacuum box leak testing, applicability and principle of test, advantages and limitations
 - 3.7.6 Halide torch testing, principles and characteristics of technique, applicability of the test, advantages and limitations
-

SPECIFIC OBJECTIVES:

- 3.7.3 Given the instructor's explanations, the student will be able to:
 - a) know fundamental principle of the test;
 - b) know the corresponding technology.
 - 3.7.4 Given the instructor's explanations, the student will be able to:
 - a) know fundamental principle of the test;
 - b) know the corresponding technology.
 - 3.7.5 Given the instructor's explanations, the student will be able to:
 - a) know fundamental principle of the test;
 - b) know the corresponding technology;
 - c) know the use of test technique.
 - 3.7.6 Given the instructor's explanations, the student will be able to:
 - a) know the principle of the test;
 - b) know the corresponding technology.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, practical student involvement, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Films
Course notes
Vacuum box leak test equipment and accessories
Other applicable test equipment and accessories

CONTENTS:

- 3.7.7 High voltage discharge testing; principles of the test, white spark technique, colour differentiation technique, analysis and interpretation, applicability of the test, advantages and limitations
 - 3.7.8 Light absorption testing; applicability and characteristics, principles and methods of operation, advantages and limitations
 - 3.7.9 Thermal conductivity leak testing; applicability and characteristics, principles and methods of leak testing, advantages and limitations
 - 3.7.10 Gas analysis; (gas chromatography, residual gas analysis), fundamental principles of the test, advantages and limitations
-

SPECIFIC OBJECTIVES:

- 3.7.7 Given the instructor's explanations, the student will be able to:
 - a) know principle of the test;
 - b) know the corresponding technology.
 - 3.7.8 Given the instructor's explanations, the student will be able to:
 - a) know the principle of the test;
 - b) know the corresponding technology.
 - 3.7.9 Given the instructor's explanations, the student will be able to:
 - a) know principle of the test;
 - b) know the corresponding technology;
 - c) know the use of test technology.
 - 3.7.10 Given the instructor's explanations, the student will be able to:
 - a) know the principle of the test;
 - b) know the corresponding technology.
 - 3.8 Given the instructor's explanations, the student will be able to interpret written instructions for conducting leak tests using different techniques.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, practical student involvement, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Films
Course notes
Thermal conductivity leak test equipment and accessories
Other applicable test equipment and accessories

CONTENTS:

- 4.1 Applicators of foaming solutions; vacuum boxes, lighting devices
- 4.2 Instruments for the measurement of pressure, temperature and dew point, precision of instruments and calibration
- 4.3 Halogen diode detector, units for leak control, gun type detector, normalized leaks, electron capture
- 4.4 Helium- mass spectrometer, vacuum unit, control cabinet, spectrometer, sniffers, calibrated enclosure
- 4.5 Accessories; vacuum pumps, vacuum valves, vacuum pipes, vacuum connectors, cold traps, compound mastics for sealing to vacuum, calibrated leaks
- 4.5.1 Gauges; (assembly criteria and pressure reading techniques of all gauges), mechanical gauges (bourdon gauges and diaphragm gauges), u-tube manometers, mcLeod gauges, pirani gauges, thermocouple gauges, hot cathode ionisation gauges, cold cathode ionisation gauges
- 4.5.2 Pumps; (knowledge of maintenance and assembly criteria), rotary vane and rotary piston pump, oil diffusion pumps, liquid nitrogen traps

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations and demonstrations, the student will be able to understand the operation of foam applicators, vacuum boxes and lighting devices.
- 4.2 Given the instructor's explanations and demonstrations, the student will be able to understand the principle of operation and calibration of the instruments for measuring of pressure, temperature and dew point.
- 4.3 Given the instructor's explanations and demonstration, the student will be able to understand the characteristics of halogen diode detectors.
- 4.4 Given the instructor's explanations and demonstration, the student will be able to understand the characteristics of helium mass spectrometer and differentiate between its components.
- 4.5 Given the instructor's explanations and demonstration, the student will be able to recognize the different accessories employed in leak testing and be able to use them in accordance with given instructions.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Films
Course notes
Equipment for different leak tests and accessories

CONTENTS:

- 5.1 General knowledge
 - 5.1.1 National, regional and international codes and standards
 - 5.1.2 General knowledge of specifications
 - 5.1.3 Test performance following the established testing instructions prepared by level 2 or level 3 personnel
 - 5.2 Instruction for the test
 - 5.2.1 Interpretation
-

SPECIFIC OBJECTIVES:

- 5.1 Given the various classification of leak testing processes in accordance with standards, the student will be able to prepare a table classifying the techniques in accordance with various standards, explaining the relations between them.
 - 5.2 Given the instructor's explanations, the student will be able to:
 - a) Perform the test, properly interpreting the instructions for it;
 - b) Fill out the test forms and note the results.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Leak testing codes
Procedures
Equipment
Work pieces

CONTENTS:

- 6.1 Control of hazards from toxic and radioactive liquids, vapours and particles and of flammable liquids and vapours
 - 6.2 Safety precautions with compressed gas cylinders
 - 6.3 Safety precautions in pressure and vacuum leak testing
 - 6.4 Preparation of pressurized systems for safe leak testing, rise in temperature dangers
 - 6.5 Industrial safety standards; ASME Boiler and Pressure Vessel Code, ASTM, ASME Pressure Piping Code, others
 - 6.6 Danger in presence of hydrogen
 - 6.7 Sparking and combustion
 - 6.8 Psychological factors and safety programme
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to describe the safety conditions under which the test should be carried out.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 7.1 System reliability through leak testing
 - 7.2 Leak testing to detect material flaws
 - 7.3 Desired degree of leak tightness
 - 7.4 Application of helium leak detection
 - 7.5 Application of halogen leak detection
 - 7.6 Application of bubble leak detection
 - 7.7 Application of vacuum box leak detection
 - 7.8 Application of further and advanced techniques; radioactive tracers, liquid penetrants and chemical tracers, ultrasonic leak testing, acoustic emission leak testing, thermal conductivity and others
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of leak testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Samples

CONTENTS:

8.1 Registration of operative conditions on test forms and presentation of data sheets

8.2 Listing of anomalies observed during preparation and execution of test

SPECIFIC OBJECTIVES:

8.1 Given the instructor's explanations, the student will be able to fill out test forms and data sheets relating to the test.

8.2 Given the instructor's explanations, the student will be able to list any anomalies observed during testing.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Course notes

Samples

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods; VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects
 - a) casting processes and associated discontinuities; ingots, blooms, and billets; sand casting; centrifugal casting; investment casting
 - b) wrought processes and associated discontinuities; forgings; rolled products; extruded products
 - c) welding processes and associated discontinuities; submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.
- 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures: corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films

Slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 Type of gases, general equation of gases, perfect gases law (formula and application) pressurization of gases, effects of temperature, atmospheric pressure and vapour pressure
 - 2.2 Basic knowledge of leaks and leakages
 - 2.2.1 Basic knowledge of leaks and leakage through a confining wall, mechanism of outgassing, real leaks and virtual leaks, pressure time relationship, different types of fluid flow in the leakage
 - 2.2.2 Leak conductance, sensitivity of detector and sensitivity of test, calculation of leakages, calculation of conduction from nomograms and conductance in series and in parallel
 - 2.2.2 Definitions and units of pressure, volume and flow rate in leak testing, relationship between the main measurement units, measurement of vapour pressure
 - 2.3 Tracer fluids, liquid and gaseous tracers, physical principles for the detection of different types of tracers, ionization of gases and mass spectrometry, ionization radiations
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) know and apply the general equation of gases;
 - b) understand the effects of temperature, atmospheric and vapour pressure in the pressurization of gases.
 - 2.2 Given the instructor's explanations, the student will be able to:
 - a) describe the different types of leaks and the conditions of fluid flow through, them;
 - b) understand the principle of leakage calculations;
 - c) establish relationships between sensitivity of detectors and sensitivity of test;
 - d) use the various units related to leak testing.
 - 2.3 Given the instructor's explanations, the student will be able to describe the use different tracers in leak testing and explain the principles for their detection.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience

EQUIPMENT AND RESOURCES:

Transparencies
Writing board
Course notes
Films

CONTENTS:

- 3.1 Characteristic of test methods
 - 3.1.1 Locations of leaks; pressurized systems and evacuated systems, tracers inherent to the system and incorporated tracers, detector inherent to the system and detector applied to the system, dynamic and static tests
 - 3.1.2 Leakage measurements; multiple closed systems: in vacuum with tracer gas, closed with air, simple, closed or open units, leakage to vacuum or to atmospheric pressure, dynamic and static tests
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) Recognize the different systems in which leak testing could be applied,
 - b) Understand the techniques used in leak measurements for different systems.
-

METHODOLOGICAL STRATEGIES:

Instruction's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Films
Equipment for bubble, pressure change, helium and halogen tests

CONTENTS:

- 3.2 Different techniques for the application of leak tests
 - 3.2.1 Bubble test; establishing operative conditions for bubble and foam testing, liquids for bubbles and solutions for foam, examination of seam pipes and welded vessels, check of locks and gates, advantages and limitations
 - 3.2.2 Testing by means of pressure; establishing operative conditions for the test of absolute pressure, relative terminology, pressurization of gases, effect of changes in temperature, vapour pressure and atmospheric pressure, measurement of leakage in vessel and gates, establishing operative conditions for testing with a reference system, applications in the examination of vessels, equation for the determination of leak percentages, positioning of sensors, equations for the determination of leak percentages, positioning of sensors for temperature and dew point, filling in data sheets, advantages and limitations
 - 3.2.3 Test by detection of halogens; operating conditions of the halogen diode detector, operating principles, relative terminology, halogen vapour, operation and maintenance of halogen detectors, set- up and calibrations, application of standards leaks, cleaning and replacement of detectors of gaseous tracers, halogen percentage in r-12 fluid, influence of the halogen background, different ways of applying the technique, contamination measurement, sensitivity of the test, advantages and limitations
-

SPECIFIC OBJECTIVES:

- 3.2 Given the instructor's explanations, the student will be able to:
 - a) establish operative conditions for bubble and foam testing and specify liquids and solutions for the test;
 - b) establish the operative conditions for pressure testing with different techniques in different components and under different conditions;
 - c) to know the operational principles of halogen diode detectors and establish test conditions;
 - d) to understand the use, maintenance and calibration of the halogen diode detector;
 - e) to know the characteristics of different tracers used with the halogen diode detector and the conditions for the application.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Films
Equipment for bubble, pressure change and halogen testing

CONTENTS:

3.2.4 Helium leak testing

- a) Test with helium spectrometer, functioning principle and operating conditions for the leak test with helium spectrometer, relative terminology, pressure and vacuum technology, operation and maintenance of helium mass spectrometers, calibrations in accordance with different test techniques, sensitivity of the test
- b) Percentage of helium in tracers, operation of sniffer, speed, diameter and length of hose. techniques of accumulation in bags, dynamic method with use of probes and bags, static method, pressure system, percentage of helium in the tracer, calculation of leakage rate, advantages and limitations

3.2.5 Advanced techniques

- a) Radioactive tracers, applicability, sensitivity and principle of test, krypton-85 gas, advantages and limitations
- b) Liquid penetrants and chemical tracers, applicability, sensitivity and characteristics of techniques, penetrant materials, ammonia gas leak test, carbon dioxide tracer gas, chemical fumes leak detector, indicator solutions, advantages and limitations
- c) Ultrasonic leak testing, principles, sensitivity, characteristics and applicability of the test, advantages and limitations
- d) Acoustic emission leak testing, fundamental principles of acoustic emission leak testing. applicability, sensitivity and characteristics of test, methods of acoustic emission testing, advantages and limitations
- e) Vacuum box leak testing techniques, applicability, sensitivity and principle of test, advantages and limitations.
- f) Halide torch testing, principles, sensitivity and characteristics of technique, applicability of technique, advantages and limitations

SPECIFIC OBJECTIVES:

3.2.4 Given the instructor's explanations, the student will be able:

- a) to understand the principle of operation of helium mass spectrometer;
- b) to know the different techniques for the use of helium mass spectrometer;
- c) to know the use, maintenance and calibration of the helium mass spectrometer.
- d) to know the conditions for the use of helium in leak testing with the helium mass spectrometer.

3.2.5 Given the instructor's explanations, the student will be able to know the principle of operation and field of application of other techniques: radioactive tracers, liquid penetrants, chemical reagents, ultrasonic leak testing, acoustic emission, vacuum box and halide torch testing, and to describe the relative sensitivity and field of application of the different techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations, and discussion arising from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Films
Equipment for leak testing using helium spectrometer
Radioactive tracers
Dye penetrants and chemical agents
Ultrasonic leak, acoustic emission
Vacuum box and halide torch testing techniques

CONTENTS:

3.2.5 (continued) Advanced techniques

- g) High voltage discharge testing, principles of the test, white spark technique, colour differentiation technique, analysis and interpretation, applicability of the test, advantages and limitations
- h) Light absorption testing, applicability and characteristics, principles and methods of operation, advantages and limitations
- i) Thermal conductivity leak testing, applicability and characteristics, principles and methods of leak testing, advantages and limitations
- j) Gas analysis, (gas chromatography, residual gas analysis), fundamental principles of the test, advantages and limitations

3.3 Relative sensitivity and scope of application of the different techniques

3.4 Leak testing in accordance with written procedures for any of the techniques described

SPECIFIC OBJECTIVES:

3.2.5 Given the instructor's explanations, the student will be able to know the principle of operation and field of application of techniques such as high voltage discharge, light absorption, thermal conductivity and gas analysis testing.

3.3 Given the instructor's explanations, the student will be able to describe the relative sensitivity and field of application of the different techniques.

3.4 Given the instructor's explanations, the student will be able to apply testing in accordance with written instructions.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations, and discussion arising from student experience.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Course notes

Films

Equipment for leak testing using high voltage discharge, light absorption, thermal conductivity and gas analysis testing technique

CONTENTS:

- 4.1 Instruments for the measurement of pressure, temperature and dew point, precision of instruments and calibration
 - 4.2 Halogen diode detector, leak control units, gun detector, electron capture, standardization leaks
 - 4.3 Helium mass spectrometer, vacuum unit, control panel, spectrometer, sniffers
 - 4.4 Accessories, vacuum pumps, vacuum valves, vacuum pipes, connectors for vacuum, cold traps, sealing compound for vacuum, calibrated leaks
 - 4.4.1 Gauges, classification and selection of vacuum gauges, assembly criteria and pressure reading techniques of all gauges, mechanical gauges (bourdon gauges and diaphragm gauges), u-tube manometers, McLeod gauges, Pirani gauges, thermocouple gauges, hot cathode ionisation gauges, cold cathode ionisation gauges
 - 4.4.2 Pumps, classification and selection of vacuum pumps, knowledge of maintenance and assembly criteria of pumps, working principle and estimation of pump size, rotary vane and rotary piston pumps, roots pumps, oil diffusion pumps, liquid nitrogen traps
-

SPECIFIC OBJECTIVES:

- 4. Given the instructor's explanations, and demonstrations, the student will be able to set up and control the equipment and accessories for the different techniques.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, demonstrations, guided discussion and development of supervised practical experiments.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Films
Equipment for different leak tests and accessories

CONTENTS:

- 5.1 Standards applicable to leak testing
 - 5.1.1 Test methods
 - 5.1.2 Materials for the test (ASTM, API, DIN, MIL, IRAM)
 - 5.1.3 ASME code
 - 5.2 Test specifications and procedures
 - 5.2.1 Definition of testing and instructions, considering field of application, equipment and technique.
 - 5.2.2 Interpretation and evaluation
 - 5.2.3 Formulation of instructions for the test
 - 5.2.4 Contents of codes, standards, specification and guidelines
 - 5.3 National standards for leak testing and testing personnel
 - 5.3.1 Quality control of the test and procedure for its administration
 - 5.3.2 Quality assurance requirements
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to:
 - a) establish classification systems for the application of leak testing according to the standards in force;
 - b) explain the criteria for application of leak testing according to the standards in force.
 - 5.2 Given the instructor's explanations and the performance of the practical exercises, the student will be able to:
 - a) interpret general and specific test procedures for the leak test with liquid penetrants;
 - b) develop test instructions for level1;
 - c) formulate the information required for documenting the test and presenting reports.
 - 5.3 Given the instructor's explanations and the performance of the practical exercises. the student will be able to recognize the qualification and certification standard for NDT personnel established in the respective country.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstration, supervised practice and guided discussion.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Samples of standards and codes
Comparative tables

CONTENTS:

- 6.1 Problems of industrial safety in the use of chemical and inflammable products
 - 6.1.1 Applicable safety standards
 - 6.1.2 Drafting of safety instructions for the personnel involved
 - 6.1.3 Safety factors applicable to the test
 - 6.2 Control of hazards from toxic and radioactive liquids, vapours and particles and of flammable liquid and vapours.
 - 6.3 Safety precautions with compressed gas cylinders.
 - 6.4 Safety precautions in pressure and vacuum leak testing.
 - 6.5 Preparation of pressurized systems for safe leak testing. Rise in temperature dangers.
 - 6.6 Industrial safety standards: ASME Boiler and Pressure Vessel Code, ASTM, ASME Pressure Piping Code, others.
 - 6.7 Danger in presence of hydrogen.
 - 6.8 Sparking and combustion.
 - 6.9 Psychological factors and safety programme.
-

SPECIFIC OBJECTIVES:

- Given the instructor's explanations and discussion of the subjects, the student will be able to:
- a) describe the risks inherent in the use of chemical and inflammable products;
 - b) list the applicable safety standards;
 - c) prepare safety instructions for application of the test.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, guided discussions, demonstrations and supervised practice.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 7.1 System reliability through leak testing
 - 7.2 Leak testing to detect material flaws
 - 7.3 Desired degree of leak tightness
 - 7.4 Application of helium leak detection
 - 7.5 Application of halogen leak detection
 - 7.6 Application of bubble leak detection
 - 7.7 Application of vacuum box leak detection
 - 7.8 Application of further and advanced techniques, radioactive tracers, liquid penetrants and chemical tracers, ultrasonic leak testing, acoustic emission leak testing, thermal conductivity and others
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of leak testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Samples

CONTENTS:

-
- 8.1 Interpretation of test procedures and preparation of written instructions for level 1 operators, preparation of data sheets, preparation of reports
-

SPECIFIC OBJECTIVES:

-
- 8.1 Given the instructor's explanations, the student will be able to:
- a) interpret test procedures and prepare written instructions for level 1 operators;
 - b) prepare data sheets and reports of the test.
-

SPECIFIC OBJECTIVES:

Instructor's presentation including lectures, demonstrations, and guided discussions arising from student experience.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Films
Samples

INSPECTION METHOD: LEAK TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Type of gases, general equation of gases, perfect gases law, difference between perfect and real gases, pressurization of gases, effects of temperature, atmospheric pressure and vapour pressure, reduction of pressure and data corrections, analysis of temperature and dew point data, relationship between mean free path and pressure
 - 2.2 Basic knowledge of leaks and leakages
 - 2.2.1 Basic knowledge of leaks and leakage, real and virtual leaks, influence of virtual leaks in a pressure rise test, general theory of viscous fluids, Bernoulli's equations, behaviour of different gases and vapours from the point of view of outgassing
 - 2.2.2 Leak conductance, sensitivity of detector and sensitivity of test, calculation for producing vacuum in confined system according to pump and aspiration line capacities, influence of different flow conditions
 - 2.2.3 Definition and units of pressure, volume and flow rate, used in leak testing, expression of leakage in power units, calculation and conversions
 - 2.3 Liquid and gaseous tracers, physical principles for the detection of different types of tracers, ionization of gases and mass spectrometry, ionizing radiation
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) make calculation using the general equation of gases;
 - b) define pressure from the point of view of kinetic theory of gases;
 - c) calculate standard atmospheric pressure.
- 2.2 Given the instructor's explanations, the student will be able to:
 - a) define relationship between mean path, diameter of conduit and type of flow;
 - b) recognize influence of virtual leaks in pressure test;
 - c) define different conditions of viscous flow through a leak;
 - d) define leak conductance;
 - e) know the influence of conductance on different flow conditions;
 - f) make calculations of leakage for the different techniques;
 - g) make calculations for producing vacuum in confined systems;
 - h) make calculations of sensitivity of the test according to the detector sensitivity and applied technique
 - i) Use properly the different units employed for leak testing calculations.
- 2.3 Given the instructor's explanations, the student will be able to:
 - a) explain the physical principles for detection of the different types of tracers;
 - b) select suitable tracer fluids for each leak testing method.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes

CONTENTS:

- 3.1 Location of leak and measurement of leakage, bubble test, pressure measurement, detection of halogens, detection of helium, radioactive tracers, liquid penetrants, selection of techniques and applicable criteria, relative sensitivity between the different techniques
 - 3.2 Location of leaks, pressurized systems and evacuated systems, inherent tracers and incorporated tracers, detector included in the system and detector applied to system, dynamic and static tests, analysis and selection of different ways of operation, measurement of leakage, multiple closed systems: in vacuum, closed with tracer gas, closed with air, simple closed or open units, leakage to vacuum of atmospheric pressure, dynamic and static tests, analysis and selection of different modes of operation
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) select the best technique for the location of leaks and measurement of leakage according to type of leak to be detected and the system being tested;
 - b) establish relative sensitivity between the different methods and techniques.
 - 3.2 Given the instructor's explanations, the student will be able to:
 - a) analyse the applicability of the different techniques according to the characteristics of the system to be tested;
 - b) establish conditions for dynamic and static tests.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, solution of problems and development of supervised practical experiments.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Equipment for bubble, halogen, helium, and pressure testing

CONTENTS:

- 3.3 Different techniques for the application of leak testing:
- 3.3.1 Bubble test, determination of conditions for application of bubble test, bubble and foam formation tests, liquids for producing bubbles and solutions for foaming, design of test for seamed pipes and welded vessels, verification of locks and gates, applications in pneumatic tests, sensitivity evaluation, measurement of leakage with bubble technique
- 3.3.2 Testing by pressure measurement, conditions for absolute pressure test, relative terminology, pressurization of gases, effects of changes in temperature, pressure, steam and atmospheric pressure, equations for the determination of pressure changes, measurement of leakage rate in vessels and gates, conditions for testing with systems, vessel examination, pressure differentials, equations for the determination of leakage percentages, positioning of temperature and dew point sensing devices to ensure the reliability of test, analysis of temperature and dew point data, analysis and evaluation of results
- 3.3.3 Halogen detection tests, operating principles of halogen diode detector, establishment of test conditions, operation and maintenance of halogen detectors, set-up and calibration, application of normalized leaks, cleaning and replacement of detectors, tracer gases, halogen percentage, refrigerating gases, effect of heat on refrigerant r-12, influence of halogen background, different ways of applying technique, sensitivity of test, design operation and filling of standard leaks, analysis and evaluating of sensitivity of test, discussion of results, calculation of leaks for refrigeration systems
- 3.3.4 Helium spectrometer testing, functioning principle and establishment of operative conditions for leak testing with helium spectrometer, relative terminology, pressure and vacuum technology, vacuum pumps, operation and maintenance of helium mass spectrometers, calibrations in accordance with different test techniques, helium percentage in tracer, operation of sniffer, speed, diameter and length of hose. techniques for accumulation in bags, dynamic method with the use of probes or bags, static method, pressure system, helium percentage in tracer, leakage calculations

SPECIFIC OBJECTIVES:

- 3.3 Given the instructor's explanations, the student will be able to:
- a) determine conditions for the applicability of each method and technique;
 - b) select most suitable method and technique to be applied;
 - c) establish the reference system for evaluation of test sensitivity;
 - d) given the instructor's explanations, the student will be able to make comparative analysis of applicability of the various methods and techniques in accordance with the specifications.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, solution of problems and development of supervised practical experiments.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Course notes

Equipment for bubble and pressure testing, halogen detection and helium spectrometry

CONTENTS:

3.3.5 Further and advanced techniques

- a) Radioactive tracers, applicability and principle of test, krypton-85 gas, advantages and limitations
- b) Liquid penetrants and chemical tracers, applicability and characteristics of techniques, penetrant materials, ammonia gas leak test, carbon dioxide tracer gas
- c) Chemical fumes leak detector, indicator solutions, advantages and limitations
- d) Ultrasonic leak testing, principles, characteristics and applicability of the test, advantages and limitations
- e) Acoustic emission leak testing, fundamental principles of acoustic emission leak testing, applicability and characteristics, methods of acoustic emission testing, advantages and limitations
- f) Vacuum box leak testing techniques, applicability and principle of test, advantages and limitations
- g) Halide torch testing, principles and characteristics of technique, applicability of the test, advantages and limitations
- h) High voltage discharge testing, principles of the test, white sparks technique, colour differentiation technique, analysis and interpretation, applicability of the test, advantages and limitations
- i) Light absorption testing, applicability and characteristics, principles and methods of operation, advantages and limitations
- j) Thermal conductivity leak testing, applicability and characteristics, principles and methods of leak testing, advantages and limitations
- k) Gas analysis, (gas chromatography, residual gas analysis), fundamental principles of the test

3.4 Comparative analysis of applicability of different test techniques for compliance with examination specifications

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to make comparative analysis of applicability of the various methods and techniques in accordance with the specifications

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, solution of problems and development of supervised experiments

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Equipment for testing by further and advanced techniques

CONTENTS:

- 4.1 Instruments for the measurement of pressure, temperature and dew point, precision of instruments and calibration
 - 4.2 Halogen diode detector, leak control units, gun detector, standard leaks
 - 4.3 Helium mass spectrometer, vacuum an it, control panel, spectrometer, sniffer
 - 4.4 Accessories, vacuum pumps, vacuum valves, vacuum pipelines, vacuum connectors, cold traps, sealing compound, calibrated leaks
 - 4.4.1 Gauges, (assembly criteria and pressure reading techniques of all gauges) mechanical gauges (bourdon gauges and diaphragm gauges). u-tube manometers, Mcleod gauges, pirani gauges, thermocouple gauges, hot cathode ionisation gauges, cold cathode ionisation gauges
 - 4.4.2 Pumps, vane and rotary piston pump, roots pumps, oil diffusion pumps, liquid nitrogen traps
 - 4.5 Selection of equipment and accessories
 - 4.5.1 Set-up and verification of equipment and accessories
 - 4.5.2 Design of reception tests, control and verification tests for equipment and accessories, calibration and comparison of instruments for the measurement of pressure
-

SPECIFIC OBJECTIVES:

- 4. Given the instructor's explanations, the student will be able to:
 - a) demonstrate knowledge of the constructive characteristics and operational parameters of the various equipment and accessories applicable to the different testing methods and techniques;
 - b) demonstrate knowledge of the setting- up and verification requirements of the various tests equipment and accessories;
 - c) demonstrate capability for the design of reception, control and verification tests for equipment and accessories;
 - d) demonstrate capability to establish calibration procedures for the instruments and equipment used.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, solution of problems and practical student involvement.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Diverse equipment for leak detection

CONTENTS:

- 5.1 Examination specifications
 - 5.1.1 Function of design engineering
 - 5.1.2 Design and building codes
 - 5.1.3 ASME Boiler and Pressure Vessel Code
 - 5.2 Standards specific to leak testing
 - 5.2.1 National and international standards (IRAM, API, ASTM, DIN, MIL)
 - 5.2.2 Criteria for selection and interpretation of specifications, codes, standards and guidelines
 - 5.3 Testing procedures
 - 5.3.1 Establishment of test methods for new testing problems
 - 5.3.2 Selection of possible additional testing methods
 - 5.3.3 Formulation of test procedures
 - 5.3.4 General and specific procedures
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to interpret, analyse and apply specifications for examination prepared by design engineering or called for in codes of practice;
 - 5.2 Given the instructor's explanations, the student will be able to analyse, evaluate and apply leak testing according to national and international standards;
 - 5.3 Given the instructor's explanations, the student will be able to develop, evaluate and apply written procedures for leak testing, conforming to externally imposed requirements and those imposed by the specimen, equipment available and work environment.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and supervised practical work.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Samples codes, standards, specifications and procedures

CONTENTS:

- 6.1 Problems of industrial safety in the use of chemical and inflammable products
 - 6.1.1 Applicable safety standards
 - 6.1.2 Drafting of safety instructions for the personnel involved
 - 6.1.3 Safety factors applicable to the test
 - 6.2 Control of hazards from toxic and radioactive liquids, vapours and particles and of flammable liquid and vapours
 - 6.3 Safety precautions with compressed gas cylinders
 - 6.4 Safety precautions in pressure and vacuum leak testing
 - 6.5 Preparation of pressurized systems for safe leak testing, rise in temperature dangers
 - 6.6 Industrial safety standards, ASME Boiler and Pressure Vessel Code, ASTM, ASME Pressure Piping Code, others
 - 6.7 Danger in presence of hydrogen
 - 6.8 Sparking and combustion
 - 6.9 Psychological factors and safety programme
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to describe the safety conditions under which the test should be carried out and apply good safety practices in the application of leak testing.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 7.1 System reliability through leak testing
 - 7.2 Leak testing to detect material flaws
 - 7.3 Desired degree of leak tightness
 - 7.4 Application of helium leak detection
 - 7.5 Application of halogen leak detection
 - 7.6 Application of bubble leak detection
 - 7.7 Application of vacuum box leak detection
 - 7.8 Application of further and advanced techniques, radioactive tracers, liquid penetrants and chemical tracers, ultrasonic leak testing, acoustic emission leak testing, thermal conductivity and others
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of leak testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Samples

CONTENTS:

- 8.1 Test procedures in accordance with specifications and standards
 - 8.2 Test and data sheets, inspection protocols.
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations, the student will be able to prepare test procedures in accordance with specifications and standards.
 - 8.2 Given the instructor's explanations, the student will be able to prepare test forms, data sheets and write inspection protocols.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Standards and codes
Specifications and procedures

VIII. INSPECTION METHOD: VISUAL TESTING

SUBJECT	HOURS OF TRAINING		
	LEVEL 1	LEVEL 2	LEVEL 3
1. GENERAL KNOWLEDGE	3	5	1 ¹⁾
2. PHYSICAL PRINCIPLES OF THE TEST	2	2	1
3. VISION	1	1	2
4. EQUIPMENT AND ACCESSORIES	4	8	4
5. WORK PARAMETERS AND CONDITIONS	2	2	4
6. IMAGE RECORDING	1	2	6
7. CODES, STANDARDS, SPECIFICATIONS AND PROCEDURES	1	3	4
8. SAFETY	-	-	1
9. APPLICATIONS	2	1	2
TOTAL	16	24	24 ¹⁾
¹⁾ In addition to the above 24 hours a general knowledge common core course for level 3 (applicable to all NDT methods) is recommended, which shall be successfully completed only once.			

GENERAL KNOWLEDGE COMMON CORE COURSE FOR LEVEL 3:

SUBJECT	HOURS OF TRAINING
	LEVEL 3
1. NDT, MATERIALS AND PROCESSES	24
2. PROCEDURE WRITING	4
3. QUALITY ASSURANCE AND STANDARDIZATION	4
4. ORGANIZATION AND ADMINISTRATION OF NDT	4
5. QUALIFICATION AND CERTIFICATION OF NDT PERSONNEL	4
TOTAL	40

CONTENTS:

- 1.1 Non-destructive testing of materials
 - 1.1.1 Definitions
 - 1.1.2 NDT as a technology. Reasons for using NDT
 - 1.1.3 Description and field of application of the most common methods
 - a) visual testing, b) liquid penetrant testing, c) magnetic particle testing, d) radiographic testing, e) ultrasonic testing, f) eddy current testing, g) leak testing
 - 1.1.4 Advantages of visual testing
 - 1.1.5 Limitations in the application of visual testing
- 1.2 Materials
 - 1.2.1 Properties of materials (metallic and non-metallic)
 - 1.2.2 Properties of metals
 - 1.2.3 Discontinuities
 - 1.2.4 Defects
- 1.3 Processes and defects
 - 1.3.1 Primary processes and related defects
 - a) melting, b) pouring, c) cooling
 - 1.3.2 Processing and related defects
 - a) casting, b) welding, c) forging, d) rolling, e) heat treatment, f) machining, g) plating, h) other processes
 - 1.3.3 Service related defects
 - a) overload, b) fatigue, c) creep, d) corrosion, e) brittle fracture, f) others

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define the nature of a non -destructive test;
 - b) list the characteristics of NDT technology and the reasons for using NDT;
 - c) compare the different types of NDT, with particular reference to the application and uses of each method.
- 1.2 Given the instructor's explanations, the student will be able to:
 - a) explain the difference between defect and discontinuity;
 - b) define the properties of materials, especially of metals;
 - c) recognize how defects affect the properties of materials;
 - d) explain the terms NDE, NDT and NDI..
- 1.3 Given the instructor's explanations, the student will be able to:
 - a) list the various metallurgical processes of fabrication and bonding;
 - b) describe the possible defects associated with each type of process;
 - c) describe the possible defects associated with the performance of a component in service.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides Film (if available)
Course notes
Samples of various materials with typical defects

CONTENTS:

- 2.1 Fundamentals of visual and optical testing
 - 2.1.1 Description of visual and optical testing
 - 2.1.2 Nature of light
 - a) Wave theory
 - b) Quantum theory
 - 2.1.3 Measurement of properties of light
 - 2.2 Sources of light
 - 2.2.1 Electromagnetic radiation, light spectra
 - 2.2.2 Characteristics of light, intensity and colour
 - 2.2.3 Measurement of properties of light
 - 2.2.4 Illumination and luminance
 - 2.2.5 Experimental laws of photometry
 - 2.2.6 Units
 - 2.3 Phenomena of regular and diffuse reflection, refraction, dispersion, diffraction, absorption and transmission of light
 - 2.4 Emissivity and reflectance
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) list properties of light;
 - b) List other electromagnetic radiation;
 - c) differentiate between intensity and colour.
- 2.2 Given the instructor's explanations, the student will be able to:
 - a) describe source of light;
 - b) differentiate between illumination and luminance;
 - c) establish variation of light intensity with distance.
- 2.3 Given the instructor's explanations, the student will be able to enumerate different phenomena occurring during transmission of light through different media.
- 2.4 Given the instructor's explanations, the student will be able to differentiate between emissivity and reflectance.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, demonstration and guided discussion.

EQUIPMENT AND RESOURCES:

Slides

Transparencies

Writing board

Course notes

Various equipment for light emission

CONTENTS:

3. Physiological factors, eyes, components, visual functions

3.1 Human eye

3.1.1 Physical description and formation of image

3.1.2 Perception of intensity and colour

3.1.3 Visual acuity

3.2 Reaction of the eye to light excitation

3.2.1 Sensitivity and adaptation to variations

3.2.2 Perception of contrast and colour

3.3 Vision defects

3.3.1 Symptomatic disturbances of vision

a) Partial loss of vision

b) Complete loss of vision

SPECIFIC OBJECTIVES:

3.1 Given the instructor's explanations, the student will be able to:

- a) identify the main components of the human eye;
- b) differentiate between intensity and colour perception;
- c) define visual acuity.

3.2 Given the instructor's explanations, the student will be able to:

- a) recognize threshold limits for intensity and colour perception;
 - b) enumerate vision defects.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures and guided discussions.

EQUIPMENT AND RESOURCES:

Slides

Transparencies

Writing board

Course notes

CONTENTS:

- 4.1 Instruments for illumination
 - 4.1.1 Different types of light sources; efficiency and useful life
 - 4.1.2 Auxiliary equipment for light sources: tripod supports, transformers, filters, collimators, etc
 - 4.1.3 Sources of non-visible radiation; ultraviolet, infrared lamps, filters
 - 4.2 Visual aids
 - 4.2.1 Lenses, prisms and mirrors, characteristics of construction
 - 4.2.2 Optical systems; microscopes, telescopes, projectors, characteristics of construction, optical holographic methods, automated visual inspection and magnifier
 - 4.2.3 Microalignment telescope and accessories
 - 4.2.4 Gauges and measuring devices
 - 4.3 Image transmitting instruments
 - 4.3.1 Instruments for optical transmission of images; rigid and flexible endoscopes, characteristics of construction
 - 4.3.2 Combination equipment for the transmission of images; optical equipment coupled to TV systems [CCTV]
 - 4.3.3 Digital camera
 - 4.4 Equipment for monitoring
 - 4.4.1 Optical vibration monitoring equipment
 - 4.5 In-situ metallography
-

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to:
 - a) list different types of light sources and give reference to efficiency and useful life;
 - b) list ancillary equipment normally used with light sources;
 - c) describe ultraviolet lamps.
- 4.2 Given the instructor's explanations, the student will be able to:
 - a) describe lenses, prisms and mirrors;
 - b) describe different optical systems employed in T.V.
- 4.3 Given the instructor's explanations, the student will be able to:
 - a) describe construction and operation of rigid endoscopes;
 - b) describe construction and operation of flexible endoscopes;
 - c) describe the use of different vision angles in endoscopes;
 - d) describe TV systems.
- 4.4 Given the instructor's explanations, the student will be able to explain different types of monitoring equipment.

4.5 Given the instructor's explanations, the student will be able to explain the process of in-situ metallography.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including demonstration and student practical work.

EQUIPMENT AND RESOURCES:

Writing board

Transparencies

Course notes

Light sources

Visual aids

Instruments mentioned above

CONTENTS:

- 5.1 Surface preparation for the examination
- 5.2 Observation techniques
 - 5.2.1 Direct visual examination
 - 5.2.2 Remote visual examination
 - 5.2.3 Translucent visual examination
- 5.3 Illumination conditions dependent on type of surface to be examined and expected defects
- 5.4 Evaluation of visual acuity, use of Jaeger chart, qualification of the examination using reference samples
- 5.5 Inspection characteristics and scope of tests
 - 5.5.1 General VT; checking general condition, first impression of test piece e.g. identification, set up.
 - 5.5.2 Specific VT; testing for specific characteristics requiring higher level of illumination and equipment, e.g. deviation in shape, surface texture, defects
- 5.6 Data recording

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to describe the surface preparation for visual examination.
- 5.2 Given the instructor's explanations, the student will be able to list the different techniques applied in visual examination.
- 5.3 Given the instructor's explanations, the student will be able to describe different illumination conditions depending on the surface to be examined.
- 5.4 Given the instructor's explanations, the student will be able to describe the use of the Jaeger chart and reference samples.
- 5.5 Given the instructor's explanations, the student will be able to produce a record of data concerning a special visual test.
- 5.6 Given the instructor's explanations, the student will be able to operate test equipment using techniques following test instructions.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, demonstrations and student practice.

EQUIPMENT AND RESOURCES:

Slides
Transparencies
Writing board
Course notes
Jaeger charts
Sample pieces

CONTENTS:

- 6.1 Photographic recording
 - 6.1.1 Main characteristics and fundamentals of photographic cameras
 - 6.1.2 Different types of films
 - 6.2 Replication; conditioning techniques for observation and special requirements for surface preparation
 - 6.3 Film digitization and image processing
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanations, the student will be able to:
 - a) describe the main characteristics of photographic cameras;
 - b) describe the common films used in visual inspection.
 - 6.2 Given the instructor's explanations, the student will be able to describe the different techniques used to produce a replica and the special requirements for surface preparation.
 - 6.3 Given the instructor's explanations, the student will be able to describe film digitization and image processing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including demonstrations and student practice with different photographic cameras and films.

EQUIPMENT AND RESOURCES:

Slides
Transparencies
Course notes
Replica samples
Writing board
Photographic cameras
Photographic films

CONTENTS:

- 7.1 General knowledge
 - 7.1.1 National, regional and international codes and standards
 - 7.1.2 General knowledge of specifications
 - 7.2 Instructions for the test
 - 7.2.1 Interpretation
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations and various classifications of visual examination processes in accordance with standards, the student will be able to prepare a table classifying the techniques in accordance with various standards, explaining the relationship between them.
 - 7.2 Given the instructor's explanations and written instructions, the student will be able to:
 - a) interpret the instructions and perform the test correctly;
 - b) fill out the test forms and note the results.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, demonstrations and guided discussions.

EQUIPMENT AND RESOURCES:

Writing board
Codes, standards and specifications
Test samples
Course notes

CONTENTS:

- 8.1 Safety and environmental consideration
 - 8.1.1 Safety for visual and optical tests
 - a) Need for safety
 - b) Laser hazards
 - c) Infrared hazards
 - d) Ultraviolet hazards
 - e) Photosensitizers
 - f) Damage to the retina
 - g) Thermal factor
 - h) Blue hazards
 - i) Eye protection filters
 - 8.2 Industrial safety standards
 - 8.3 Visual and optical testing environment
 - a) Cleanliness
 - b) Texture and reflectance
 - c) Lighting for V.T.
 - d) Light intensities
 - e) Vision in the testing environment
 - 8.4 Visual safety environment
-

SPECIFIC OBJECTIVES:

- 8.1 Given the instructor's explanations, the student will be able to describe the safety conditions under which the test should be carried out.
 - 8.2 Given the instructor's explanations, the student will be able to apply good safety practices in the application of visual testing.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies, Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 9.1 Applications: VT during manufacturing process
 - 9.1.1 Applications of visual and optical tests in the electric power industries
Joining processes, acceptance standards, recording and reporting visual test results
 - 9.1.2 Specific visual inspection applications
Pumps, valves, bolting, forging, rolled stock and casting.
 - 9.1.3 Applications of visual and optical tests in the transportation industries
Optical tests in the automobile industries, optically aided visual testing of aircraft structure.
- 9.2 Interface of visual testing with other NDT methods
Visual testing of liquid penetrant, leak testing, radiographic testing, magnetic particle testing, ultrasonic testing, etc.
- 9.3 Applications of photography in visual testing
Photographs as a permanent record for VT, photogrammetry for documenting the condition of petrochemical furnaces conclusions.
- 9.4 Visual testing of ceramics
- 9.5 Visual testing of threads in oil country tubular goods
- 9.6 Visual testing of composite materials
- 9.7 Visual testing of micro electronic components
- 9.8 In-service Inspection
 - 9.8.1 ISI of plants in the light of call up maintenance card
 - 9.8.2 Displacement measurement of moving parts of equipments i.e. pumps compressor, motor, etc.
 - 9.8.3 Optical techniques for vibration monitoring
 - i) Static measurement
 - ii) Dynamic measurement

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of different visual testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes

CONTENTS:

- 1.1 Basic principles of NDT
 - 1.1.1 Definitions and methodology of applications of basic methods; VT, PT, MT, RT, UT, ET, LT
 - 1.1.2 Fields of application of common methods
 - 1.1.3 Range and limitations of common methods, including the subject method
 - 1.1.4 New developments in NDT
 - 1.1.5 Responsibilities of levels of certification
 - 1.2 Materials
 - 1.2.1 Physical and mechanical properties of materials (metallic and non-metallic)
 - 1.2.2 Structures of metals and alloys
 - 1.2.3 Indications, discontinuities and defects
 - 1.2.4 In-service and manufacturing discontinuities
-

SPECIFIC OBJECTIVES:

- 1.1 Given the instructor's explanations, the student will be able to:
 - a) define non-destructive testing;
 - b) describe the basic principles and the method of application of the common NDT methods;
 - c) discuss the best applications, limitations and problems relating to the use of each method.
 - 1.2 Given the instructor's explanations, the student will be able to:
 - a) describe the structure, physical and mechanical properties of metallic materials
 - b) describe the various types of discontinuities and defects, their sources and their classification.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion and development from student experience.

EQUIPMENT AND RESOURCES:

Transparencies
Slides
Films
Writing board
Course notes

CONTENTS:

- 1.3 Processing and defects
 - 1.3.1 Primary processes and related defects
 - 1.3.2 Manufacturing processes and related defects:
 - a) casting processes and associated discontinuities: Ingots, blooms, and billets; Sand casting; Centrifugal casting; Investment casting
 - b) wrought processes and associated discontinuities: forgings; rolled products; extruded products
 - c) welding processes and associated discontinuities: submerged arc welding (SAW); shielded metal arc welding (SMAW); gas metal arc welding (GMAW); flux cored arc welding (FCAW); gas tungsten arc welding (GTAW); resistance welding; special welding processes — electron beam, electrogas, etc.
- 1.4 Materials in service
 - 1.4.1 Behaviour of materials in service
 - 1.4.2 Service conditions leading to defects and failures: corrosion; creep; fatigue; wear; overload; brittle fracture, erosion, others
 - 1.4.3 Concepts of rupture development in metals
- 1.5 Quality and standardization
 - 1.5.1 Definition of quality, quality control and standardization
 - 1.5.2 Development of a quality system
 - 1.5.3 Examination, testing and inspection
 - 1.5.4 Standards, codes, specifications and procedures
 - 1.5.5 Protocols, records and reports

SPECIFIC OBJECTIVES:

- 1.3 Given the instructor's explanations, the student will be able to:
 - a) describe the common primary metallurgical processes and the related defects;
 - b) describe the common manufacturing processes and the related defects.
- 1.4 Given the instructor's explanations, the student will be able to:
 - a) describe basic mechanisms giving rise to defects when the component is in service;
 - b) describe defects that could arise during service and the general significance of each.
- 1.5 Given the instructor's explanations, the student will be able to:
 - a) describe the basic concepts of quality and standardization;
 - b) list the basic elements of a quality system;
 - c) explain the basic premise of administration of information in a quality system.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Films slides

Writing board

Course notes

Samples of materials and defects

Typical documents, i.e. codes

CONTENTS:

- 2.1 Fundamentals of visual and optical testing
 - 2.1.1 Description of visual and optical test
 - 2.1.2 Luminous energy test, geometrical optics, image formation, light sources, stroboscopic sources, light detection and recording, fluorescence detection
 - 2.2 Nature of light
 - a) Wave theory
 - b) Quantum theory
 - 2.2.1 Electromagnetic radiations; light spectra, infrared and ultraviolet radiation
 - 2.2.2 Characteristics of light; intensity and colour
 - 2.2.3 Magnitudes and units
 - 2.2.4 Measurement
 - 2.3 Basic laws of the phenomena of regular and diffuse reflection, refraction, dispersion, diffraction, absorption, and transmission of light
 - 2.4 Emissivity and reflectance
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) list the properties of light;
 - b) establish the characteristics of the electromagnetic spectrum;
 - c) establish the limits of the visible spectrum.
 - 2.2 Given the instructor's explanations, the student will be able to:
 - a) define the sources of equal intensity;
 - b) define luminous flux;
 - c) establish the variations of the light with the distance;
 - d) define different units of illumination.
 - 2.3 Given the instructor's explanations, the student will be able to:
 - a) define laws of reflection and refraction;
 - b) understand the concept of dispersion, diffraction, absorption and transmission of light
 - 2.4 Given the instructor's explanations, the student will be able to establish the relation between emissivity and reflectance.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, guided discussions and review of examples including simple calculations.

EQUIPMENT AND RESOURCES:

Transparencies

Course notes

Writing board

CONTENTS:

- 3 Vision
- 3.1 Human eye, the anatomical and physical aspects of the eye
 - 3.1.1 Formation of the image
 - 3.1.2 Perception of intensity and colour
 - 3.1.3 Separation ability
 - 3.1.4 Visual acuity
- 3.2 Reaction of the eye to excitation
 - 3.2.1 Adaptation, reaction to glare
 - 3.2.2 Distance and relief perception (stereoscopic perception)
 - 3.2.3 Perception of contrast and colour
 - 3.2.4 Threshold levels of intensity
- 3.3 Vision defects
 - 3.3.1 Types of blindness; night blindness; day blindness; colour blindness
 - 3.3.2 Symptomatic disturbance
 - a) Partial loss of vision
 - b) Complete loss of vision
 - 3.3.3 Injuries
 - a) Thermal injuries
 - b) Electrical injuries
 - c) Radiation injuries

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) identify the main components of the human eye;
 - b) explain image formation;
 - c) separation ability;
 - d) define visual acuity;
 - e) explain how the eye perceives the difference between intensity and colour;
- 3.2 Given the instructor's explanations, the student will be able to:
 - a) develop the concepts of illumination and luminance;
 - b) explain the concept of stereoscopic vision;
 - c) list and explain visual defects;
 - d) understand the levels of intensity and colour.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lectures, development from student experience and guided discussion of examples with practical student involvement.

EQUIPMENT AND RESOURCES:

Transparencies

Course notes

Writing board

CONTENTS:

- 4.1 Instruments for illumination
 - 4.1.1 Source of visible radiation, spectral quality, efficiency and useful life
 - 4.1.2 Classification of the sources
 - a) Continuous
 - b) Flash
 - c) Incandescent
 - d) Discharge
 - e) Fluorescent
 - f) Electronic flash
 - 4.1.3 Ancillary equipment for light sources
 - a) Tripod supports
 - b) Transformers
 - c) Filters
 - d) Collimators, etc.
 - 4.1.4 Types of illumination; directional; diffused; secondary
 - 4.1.5 Sources of non-visible radiation, ultraviolet, infrared, filters
- 4.2 Machine vision technology
 - 4.2.1 Lighting techniques, optical filtration, image processing
 - 4.2.2 Image segmentation
 - 4.2.3 Temperature indicating material
 - 4.2.4 Chemical aids

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to:
 - a) know the sources in terms of the spectral quality of the radiation;
 - b) know the efficiency and useful life of the sources;
 - c) classify different types of sources;
 - d) identify sources based on the construction characteristics;
 - e) recognize the use of various accessories for illumination systems;
 - f) ensure control requirements for result repeatability.
- 4.2 Given the instructor's explanations, the student will be able to describe the use of machine vision technology and associated aids

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical use of equipment, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies

Sample pieces

Auxiliary equipment

Course notes

Writing board

Light sources

Light transmitting equipment

Visual aids

CONTENTS:

- 4.3 Visual aids
 - 4.3.1 Lenses, prisms, mirrors, characteristics of construction
 - 4.3.3 Microalignment telescope, principle and accessories
 - 4.3.2 Optical systems, microscopes, telescopes, projectors, characteristics of construction
Image transmitting instruments, optical holographic methods, automated visual inspection
 - 4.3.4 Gauges and measuring devices
- 4.4 Image transmitting instruments
 - 4.4.1 Instruments for optical transmission of images. Rigid and flexible endoscope, Periscope. Basic principles and operations of image transmitting instruments and their construction characteristics.
 - 4.4.2 Combination equipment for the transmission of images: optical equipment coupled to T.V. systems. Basic principles and operation of combination equipment, their construction characteristics, scope and limitations; Digital cameras
- 4.5 Optical equipment for monitoring vibration
- 4.6 In-situ metallography

SPECIFIC OBJECTIVES:

- 4.3 Given the instructor's explanations, the student will be able to:
 - a) list the main optic laws;
 - b) apply those laws with simple calculations;
 - c) define lenses, prisms, mirrors, characteristics;
 - d) recognize different optical systems and describe their method of operation;
 - e) recognize the range of application and limitations of the equipment.
- 4.4 Given the instructor's explanations, the student will be able to:
 - a) recognize and describe image transmitting equipment;
 - b) operate and understand the operation characteristics;
 - c) select equipment suitable to requirements;
 - d) use schemes to explain combination systems of image transmission;
 - e) know the applications of T.V. systems.
- 4.5 Given the instructor's explanations, the student will be able to operate basic optical vibration monitoring equipment
- 4.6 Given the instructor's explanations, the student will be able to take surface replicas for in-situ metallography

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical use of equipment, development from student experience and guided discussions.

EQUIPMENT AND RESOURCES:

Transparencies]
Light transmitting equipment
Course notes
Light sources
Ancillary equipment
Visual aids
Sample pieces
Writing board

CONTENTS:

- 5.1 Surface preparation for examination
 - 5.2 Observation techniques
 - 5.2.1 Direct visual examination
 - 5.2.2 Remote visual examination
 - 5.3 Illumination conditions dependent on type of surface to be examined and expected defects
 - 5.4 Evaluation of visual acuity, use of Jaeger chart and reference samples
 - 5.5 Presentation of results to be used in analysis, documentation and filing
 - 5.6 Visual and optical testing procedures
-

SPECIFIC OBJECTIVES:

- 5.1 Given the instructor's explanations, the student will be able to describe the surface preparation for visual examination.
 - 5.2 Given the instructor's explanations, the student will be able to list the different techniques applied in visual examination.
 - 5.3 Given the instructor's explanations, the student will be able to:
 - a) describe different illumination conditions dependent on the surface to be examined;
 - b) select appropriate equipment dependent on different conditions and choose a technique suitable for the actual test problem, define its scope, field of application and limitations.
 - 5.4 Given the instructor's explanations, the student will be able to describe the use of the Jaeger chart and reference samples.
 - 5.5 Given the instructor's explanations, the student will be able to:
 - a) produce a record of data concerning a specific visual test;
 - b) translate the data in a report to analyse, document and file;
 - c) write instructions sheet.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical student involvement, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies
Course notes
Writing board
Sample pieces
Jaeger charts

CONTENTS:

- 6.1 Photographic recording
 - 6.1.1 Main characteristics and fundamentals of photographic cameras
 - 6.1.2 Different types of film
 - 6.2 Replicas, different techniques, conditioning for observations
 - 6.3 Film digitization and image processing
-

SPECIFIC OBJECTIVES:

- 6.1 Given the instructor's explanations, the student will be able to:
 - a) describe the main characteristics of photographic cameras;
 - b) describe the common films used in visual inspection and explain selection criteria.
 - 6.2 Given the instructor's explanations, the student will be able to:
 - a) describe the different techniques to produce a replica and special requirements for surface preparation;
 - b) list some of the materials used in different types of replicas.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, development from student experience and guided discussion of examples.

EQUIPMENT AND RESOURCES:

Transparencies
Course notes
Writing board
Photographic cameras
Replicas
Replica materials
Sample pieces
Photographic films

CONTENTS:

- 7.1 General knowledge and overview of codes and standards
 - 7.1.1 General knowledge of specifications and procedures
 - 7.1.2 Interpretation of procedures and compilation of test instructions
 - 7.2 Performance of test in accordance with written instructions
 - 7.2.1 Records of operating conditions on test forms
 - 7.2.2 Evaluation of tasks carried out by level 1 operators
 - 7.3 Instructions for testing in special situations
 - 7.3.1 Range of application of the test, equipment and technique
 - 7.3.2 Visual testing acceptance criteria for welds
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations and testing procedures, the student will be able to:
 - a) demonstrate understanding of the significance and application of codes, standards, specifications and procedures;
 - b) recognize various standards existing for the application of visual inspection;
 - c) prepare instructions for testing, describing all steps to be followed to perform the test.
 - 7.2 Given the instructor's explanations, the student will be able to establish and evaluate tasks for level 1 personnel.
 - 7.3 Given the instructor's explanations, the student will be able to formulate instructions for testing under special conditions and according to requirement of standards adopted for the actual working conditions.
-

METHODOLOGICAL STRATEGIES:

Instructor's explanations including lecture, guided discussion, practical exercise on interpretation of procedures and compilation of written instructions.

EQUIPMENT AND RESOURCES:

Writing board
Codes
Standards (ASME, ASTM, DIN, API, BSI, COVENIN, JIS)
Forms for data registration
Test procedures and examples of written instructions
Work pieces
Equipment and accessories

CONTENTS:

8.1 Safety and environmental consideration

8.1.1 Safety for visual and optical tests

- a) Need for safety
- b) Laser hazards
- c) Infrared hazards
- d) Ultraviolet hazards
- e) Photosensitizers
- f) Damage to the retina
- g) Thermal factor
- h) Blue hazards
- i) Eye protection filters

8.2 Industrial safety standards

8.3 Visual and optical testing environment

- a) Cleanliness
- b) Texture and reflectance
- c) Lighting for V.T.
- d) Light intensities
- e) Vision in the testing environment

8.4 Visual safety recommendations

SPECIFIC OBJECTIVES:

8.1 Given the instructor's explanations, the student will be able to describe the safety conditions under which the test should be carried out.

8.2 Given the instructor's explanations, the student will be able to apply good safety practices in the application of visual testing.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 9.1 Applications: VT during manufacturing process
 - 9.1.1 Applications of visual and optical tests in the electric power industries
 - 9.1.2 Joining processes, acceptance standards, recording and reporting visual test results
 - 9.1.3 Specific visual inspection applications, pumps, valves, bolting, forging, rolled stock and casting
 - 9.1.4 Applications of visual and optical tests in the transportation industries, optical tests in the automobile industries, optically aided visual testing of aircraft structure
- 9.2 Interface of visual testing with other NDT methods.; visual testing of liquid penetrant, leak testing, radiographic testing, magnetic particle testing, ultrasonic testing, etc.
- 9.3 Applications of photography in visual testing; photographs as a permanent record, photogrammetry for documenting the condition of petrochemical furnaces
- 9.4 Visual testing of ceramics
- 9.5 Visual testing of threads in oil industry tubular goods
- 9.6 Visual testing of composite materials
- 9.7 Visual testing of micro electronic components
- 9.8 Visual and optical testing in metal industry
- 9.9 In-service inspection
 - 9.9.1 ISI of plants in the light of call up maintenance card
 - 9.9.2 Displacement measurement of moving parts of the components i.e. pumps, compressors, motors, etc.
 - 9.9.3 Optical vibration monitoring
 - a) Static measurement
 - b) Dynamic measurement

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of different visual testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes

INSPECTION METHOD: VISUAL TESTING
SUBJECT: 1. GENERAL KNOWLEDGE

LEVEL: 3

CONTENTS: SEE SEPARATE COMMON CORE FOR LEVEL 3

CONTENTS:

- 2.1 Electromagnetic radiations
 - 2.1.1 Characteristics of luminous spectra; intensity, colour, tone and frequency
 - 2.1.2 Luminous sources; intensity of the luminous sources, photometric and radiometric measurements, illumination, luminous flux and luminance; experimental law of photometry
 - 2.1.3 Fundamental laws for emission, transmission and absorption of light, interface phenomena, emissivity and reflectance
 - 2.1.4 Role, importance and scheduling of visual testing
 - 2.1.5 Geometrical optics, distortion, measurement
 - 2.1.6 Errors of refraction and means of correction
 - a) Myopia or short-sightedness, concave spherical glasses
 - b) Hypermetropia or long sightedness, convex spherical glasses
 - c) Astigmatism cylindrical lenses or contact lenses
-

SPECIFIC OBJECTIVES:

- 2.1 Given the instructor's explanations, the student will be able to:
 - a) describe the properties of light;
 - b) establish the characteristics of the electromagnetic spectra;
 - c) establish the range of the spectra corresponding to light;
 - d) define luminous sources of equal intensity;
 - e) define luminous flux;
 - f) explain the experimental law of photometry;
 - g) define the different units of illumination;
 - h) define the phenomena occurring when light passes through an interface;
 - i) explain concepts related to dispersion, diffraction, absorption and transmission of light;
 - j) explain emissivity and reflectance.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including an analysis of the graphic expression of application rules and principles, guided discussion and laboratory experiments.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Slides
Tables and drawings
Laboratory material to demonstrate physico-chemical principles
Course notes

CONTENTS:

- 3.1 Vision
 - 3.1.1 Human eye; principal physiological and anatomical aspects, focus and resolution
 - 3.1.2 Response of eye to luminous excitation, spectral sensitivity, perception of intensity, colour and contrast, stereoscopic vision
 - 3.1.3 Sensitivity thresholds, visual acuity, contrast and colour sensitivity, influence of intensity and luminance
 - 3.1.4 Defects of vision
 - 3.2 Fundamentals of optical physics applied to lenses, mirrors, prisms and optical systems
 - 3.3 Types of blindness
 - a) Night blindness
 - b) Day blindness
 - c) Colour blindness
 - 3.4 Symptomatic disturbance
 - a) Partial loss of vision
 - b) Complete loss of vision
 - 3.5 Injuries
 - a) Thermal injuries
 - b) Electrical injuries
 - c) Radiation-induced injuries
-

SPECIFIC OBJECTIVES:

- 3.1 Given the instructor's explanations, the student will be able to:
 - a) identify the different parts of the human eye explaining their functions;
 - b) explain separation power and visual acuity;
 - c) explain perception of intensity, colour and contrast;
 - d) explain concepts of intensity and luminance;
 - e) explain the stereoscopic viewing of the eye and near and far vision;
 - f) explain the different possible defects of vision.
- 3.2 Given the instructor's explanations, the student will be able to:
 - a) explain the fundamental laws of optics;
 - b) explain the main characteristics of types of lenses, prisms, mirrors and optical systems.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Optical devices and aids

CONTENTS:

- 4.1 Illumination sources
 - 4.1.1 Various types of illumination sources, various fixing apparatus and various accessories. Sources for polarized light
 - 4.1.2 Lamps for ultraviolet radiation, lasers
 - 4.1.3 Accessories for filtering and collimating light beam, measuring instruments for measuring light intensity (luximeters)
- 4.2 Visual aids; lenses, prisms, mirrors, compound lenses, stereoscopic loops, optical microscope, telescope and projectors
- 4.3 Image transmission
 - 4.3.1 Fiber optics, acrylic and glass-fibers, transmission of image and transmission of light
 - 4.3.2 Rigid and flexible endoscopes, endoscopes with micro T.V. systems block diagram
- 4.4 Micro alignment telescope
- 4.5 Digital camera
- 4.6 Equipment for monitoring
 - a) Real time monitoring equipment; b) mobile monitoring equipment; c) vibration properties of materials; d) vibration characteristics of structure; e) methods for measuring the frequency

SPECIFIC OBJECTIVES:

- 4.1 Given the instructor's explanations, the student will be able to:
 - a) explain values of light source emitters according to spectral quality of the radiation;
 - b) explain the efficient and useful life of different sources of light;
 - c) explain principles of operation and construction of various light sources;
 - d) recognize the usefulness of various accessories for controlling light sources.
- 4.2 Given the instructor's explanations, the student will be able to:
 - a) explain the characteristics of lenses, prisms and other optical systems;
 - b) explain characteristics of compound lenses, stereoscopic loops, microscopes, telescopes and projectors;
 - c) select the suitable equipment for the test.
- 4.3 Given the instructor's explanations, the student will be able to:
 - a) explain construction characteristics of various types of endoscopes; explain the combined system for image transmission; explain the applications of T.V. systems.
- 4.4 Given the instructor's explanations, the student will be able to explain the construction and use of a micro alignment telescope.

- 4.5 Given the instructor's explanations, the student will be able to explain the working of a digital camera.
- 4.6 Given the instructor's explanations, the student will be able to explain various types of monitoring equipment.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical student work and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Light sources
Visual aids
Image transmitting equipment
Sample pieces

CONTENTS:

- 5.1 Surface preparation
 - 5.2 Illuminating conditions, intensity, angle, distance, type of illumination
 - 5.3 Viewing techniques; direct, indirect and image transmission
 - 5.3.1 Parameters for the selection and operation of the various techniques
 - 5.4 Programming the sequences of viewing, systems for identification of the areas to be examined, assessing relevance of features to be detected, evaluation of features against fitness-for-purpose aspects
 - 5.5 Control and calibration of the test
 - 5.5.1 Jaeger charts for the control of near and far vision, JIS charts for colour blindness
 - 5.5.2 Reference blocks with calibrations, reference block with cracks, control of perceptibility in accordance with procedures
 - 5.5.3 Maintenance and control of equipment and accessories, calibration of luximeter or photometer, specific objectives
 - 5.6 Rules for the use, maintenance and control for equipment and accessories, work in the laboratory and in the field
 - 5.7 Visual and optical test procedures
 - 5.8 Selection and specification of equipment for the test
-

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to:

- a) establish all necessary preparations of surface for test;
- b) establish at selected necessary parameters related to illumination, angle, distance, etc., needed to perform the test;
- c) establish the technique to be applied;
- d) establish the sequence of operation and system of identification for the test;
- e) explain the use of Jaeger and JIS charts; procedure writing;
- f) explain the use of reference blocks for the control of perceptibility;
- g) establish rules for the use, maintenance and control of equipment and accessories;
- h) calibrate luximeter and photometers;
- i) select all equipment necessary to perform a specific test;
- j) assist and advise in drafting acceptance criteria.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, practical student work and solution of problems.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies, Course notes
Sample pieces
Light sources
Jaeger and JIS charts
Reference blocks

CONTENTS:

- 6.1 Photographic recording
 - 6.1.1 Fundamentals of photography and photographic cameras
 - 6.1.2 Various types of photographic cameras. Macro and telephotography.
 - 6.1.3 Various types of film. Spectral sensitivity. Contrast, latitude and grain
 - 6.2 Replicas
 - 6.2.1 Various types of replica: positive and negative, macro and micro resolutions
 - 6.2.2 Materials employed on the different techniques
 - 6.2.3 Conditioning of replicas and requirements for their observation and conservation
 - 6.3 Film digitization and image processing.
-

SPECIFIC OBJECTIVES:

- 6. Given the instructor's explanations, the student will be able to:
 - a) explain the characteristics of the various types of photographic cameras;
 - b) list the different types of photographic film with reference to sensitivity, contrast and grain;
 - c) describe the various types of replica and explain their applications;
 - d) detail the materials used in the different techniques
-

METHODOLOGICAL STRATEGIES:

Instructor's demonstration including student's practical work with different photographic cameras and film types.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Various types of cameras
Replicas
Replica materials
Sample pieces

CONTENTS:

- 7.1 Examination specifications
 - 7.1.1 Function of design engineering
 - 7.1.2 Design and building codes
 - 7.1.3 ASME code
 - 7.2 Standards specific to visual inspection
 - 7.2.1 National and international standards (ASTM, DIN, MIL, IRAM)
 - 7.2.2 Interpretation of specifications, codes and standards
 - 7.3 Testing procedures
 - 7.3.1 Formulation of test procedures
 - 7.3.2 General and specific procedures
 - 7.4 General rules for safety in industrial establishments
-

SPECIFIC OBJECTIVES:

- 7.1 Given the instructor's explanations, the student will be able to interpret, analyse and apply specifications for examination prepared by design engineers or called for in codes of practice.
 - 7.2 Given the instructor's explanations, the student will be able to analyse, evaluate and apply visual inspection according to national and international standards.
 - 7.3 Given the instructor's explanations, the student will be able to develop, evaluate and apply written procedures for visual inspection, conforming to externally imposed requirements and those imposed by the specimens, equipment available and work environments.
 - 7.4 Given the instructor's explanations, the student will be able to apply good safety practices in the application of visual inspection.
-

METHODOLOGICAL STRATEGIES:

Instructor's presentation including lecture, guided discussion, practical exercises on the preparation and interpretation of procedures.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Codes (ASME, ASTM, DIN, API, BSI, JIS, etc.)
Formulae for data registration
Work pieces
Test procedures and examples of written instructions

CONTENTS:

- 8.1 Safety and environmental consideration
- 8.1.1 Safety for visual and optical tests
 - a) Need for safety
 - b) Laser hazards
 - c) Infrared hazards
 - d) Ultraviolet hazards
 - e) Photosensitizers
 - f) Damage to the retina
 - g) Thermal factor
 - h) Blue hazards
 - i) Eye protection filters
- 8.2 Industrial safety standards
- 8.3 Visual and optical testing environment
 - a) Cleanliness
 - b) Texture and reflectance
 - c) Lighting for V. T.
 - d) Light intensities
 - e) Vision in the testing environment
- 8.4 Visual safety recommendations
- 8.5 Implementation of industrial safety standards in facilities and equipment and in their operation
- 8.6 Hazards of using toxic and inflammable materials
- 8.7 Materials, accessories and equipment for the protection of persons and facilities

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to describe the safety conditions under which the test should be carried out and be able to apply good safety practices.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes
Safety standards
Safety equipment and accessories

CONTENTS:

- 9.1 Applications; VT during manufacturing process
 - 9.1.1 Applications of visual and optical tests in the electric power industries
 - 9.1.2 Joining processes, acceptance standards, recording and reporting visual test results
 - 9.1.3 Specific visual inspection applications, pumps, valves, bolting, forging, rolled stock and casting
 - 9.1.4 Applications of visual and optical tests in the transportation industries, optical tests in the automobile industries, optically aided visual testing of aircraft structure
- 9.2 Interface of visual testing with other NDT methods, visual testing of liquid penetrant, leak testing, radiographic testing, magnetic particle testing, ultrasonic testing, etc.
- 9.3 Applications of photography in visual testing, photographs as a permanent record, photogrammetry for documenting the condition of petrochemical furnaces conclusions
- 9.4 Visual testing of ceramics
- 9.5 Visual testing of threads in oil industry tubular goods
- 9.6 Visual testing of composite materials
- 9.7 Visual testing of micro electronic components
- 9.8 Visual and optical testing in metal industry
- 9.9 In-service inspection
 - 9.9.1 ISI of plants in the light of call up maintenance card
 - 9.9.2 Displacement measurement of moving parts of the components i.e. pumps compressors, motors, etc.
 - 9.9.3 Optical vibration monitoring
 - a) Static measurement
 - b) Dynamic measurement

SPECIFIC OBJECTIVES:

Given the instructor's explanations, the student will be able to understand different applications of different visual testing techniques.

METHODOLOGICAL STRATEGIES:

Instructor's presentation including guided discussion and practical workshop.

EQUIPMENT AND RESOURCES:

Writing board
Transparencies
Course notes

Appendix A

PRACTICAL WORKSHOPS

1.1. Background

The aim of the Practical Training Workshop is to provide the NDT trainees and inspectors with an opportunity to acquire a sound basis in detection and evaluation of various defects and discontinuities over a wide range of specimens. Also, the aim is to provide specimens from various processes and of different material types. It is designed to assist the student in acquiring practical experience and skills in interpreting results over a short period of time which would normally take weeks, months or years to accomplish.

This appendix includes a suggested workshop structure for the ultrasonic test method. Users of this publication are encouraged to develop equivalent structures for other test methods as required.

1.2. Objective

The objective of the practical training workshop is to provide students with the opportunity to inspect, record and evaluate numerous test specimens with known discontinuities and defects.

1.3. Scope

The focus of the practical workshop course is on interpretation of test results on specimens from industry and not artificial defects where possible.

1.4. Structure

The following section provides an overview of the standard syllabus and its structure, prerequisites and learning objective, and suggests duration for each part.

The standard syllabus of the Practical Training Workshop is divided into various parts and each part is divided into modules. For each part, the prerequisite is indicated as well as the general learning objective. Each module is described by the content and the link to the training material and the reference publication. For each part, a list of practical training sessions is suggested, i.e. practical lab exercise.

Table A-1 provides the prerequisites, general learning objectives and suggested sector applications. The duration and number of inspections will vary depending on the students prior experience. The prerequisite for the course is that the participants should have successfully completed the classroom requirements of the IAEA-TECDOC-628 or equivalent training criteria.

TABLE A-1. EXAMPLE OF WORKSHOP FOR ULTRASONIC TESTING

Project No.	Project	Prerequisite	Objective	Duration
1	Establish sweep and sweep delay	Level 1 theory	Calibrate the sweep and sweep delay using multiple back echoes	
2	Create a distance amplitude curve	Level 1 theory	Construct a DAC for a normal beam contact method	
3	Determine near zone length	Level 1 theory	Determine mathematical and practical the near zone	
4	Calibre for angle beam inspection	Level 1 theory	Calibrate the flaw detector and measure the angle beam characteristics using an IIW block	
5	Determine sound path and skip distance	Level 1 theory	Calibrate and measure sound path and skip distance for a given plate thickness	
6	Create an angle beam distance amplitude curve	Level 1 theory	Create an angle beam distance calibration curve	
7	Check vertical linearity of an A-scan	Level 1 theory	Determine if the vertical linearity of the flaw detector is acceptable.	
8	Check horizontal linearity of an A-scan	Level 1 theory	Determine if the horizontal linearity of the flaw detector is acceptable.	
9	Check near surface and far surface resolution	Level 1 theory	Determine the near and far surface resolution limits	
10	Determine signal to noise ratio	Level 1 theory	Determine signal to noise ratio of the system.	
11	Determine angle beam profile	Level 1 theory	Determine the angle beam profile in the vertical and horizontal planes.	
	Practical Assignment — Thickness	Level 1* and/or 2 theory	Calibrate longitudinal transducer to display 250 mm using IIW block, measure the thickness of numerous plates Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Plate scan	Level 1* and/or 2 theory	Calibrate longitudinal transducer to display 100 mm using IIW block, inspect a plate sample for lamination Level 1 — record results Level 2 — record and intrepret	
	Practical Assignment — Immersion	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Casting	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	

	Practical Assignment — Forging	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — T weld	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Butt Weld	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Transition Weld	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Extrusion	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Plate Weld	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Pipe	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	
	Practical Assignment — Manufacturing and In-service	Level 1* and/or 2 theory	Inspect a specimen sample for defect type, location and orientation: Level 1 — record results Level 2 — record and interpret	

* Note. A Level 1 student need only to record test results.

Appendix B

ADVANCED METHODS

The following sections detail suggested course content for a number of advanced NDT methods. There may not be sufficient training experience in these methods to assign hours or methodology, but the curricula provide a body of knowledge for the development of training courses.

ISO Standard 9712 and ISO TR 25107 may contain detailed information on the current requirements for training hours.

B.1. ACOUSTIC EMISSION TESTING

Level 1:

- 1. Principles of acoustic emission testing**
 - 1.1 Characteristics of acoustic emission
 - 1.2 Sources of acoustic emission
 - 1.3 Wave propagation; introduction
 - 1.4 Repeated loadings: Kaiser and Felicity effects and Felicity ratio
 - 1.5 Terminology (refer to AE Glossary, ASTM E1316)
- 2. Sensing the AE wave**
 - 2.1 Sensors
 - 2.2 Sensor attachment
- 3. Instrumentation and signal processing**
 - 1.1 Cables
 - 1.2 Signal conditioning
 - 1.3 Signal detection
 - 1.4 Signal processing
 - 1.5 Source location techniques
 - 1.6 Acoustic emission test system
 - 1.7 Accessory techniques
- 4. Acoustic emission test techniques**
 - 4.1 Equipment calibration and setup for test
 - 4.2 Loading procedures
 - 4.3 Data display
 - 4.4 Noise sources and pre-test identification techniques
 - 4.5 Precautions against noise
 - 4.6 Data interpretation and evaluation; introduction
 - 4.7 Reports
- 5. Codes, standards and procedures**
 - 5.1 Guide-type standards (glossaries, calibration, etc.)
 - 5.2 Standardized/codified AE test procedures
 - 5.3 User-developed test procedures
- 6. Applications of acoustic emission testing**
 - 6.1 Laboratory studies (material characterization)
 - 6.2 Structural applications.

Level 2:

- 1. Principles of acoustic emission testing**
 - 1.1 Characteristics of acoustic emission testing
 - 1.2 Materials and deformation
 - 1.3 Sources of acoustic emission
 - 1.4 Wave propagation
 - 1.5 Attenuation
 - 1.6 Kaiser and Felicity effects, and Felicity Ratio
 - 1.7 Terminology (refer to AE Glossary, ASTM E1316)

- 2. Sensing the AE wave**
 - 2.1 Transducing processes (piezoelectricity, etc.)
 - 2.2 Sensors
 - 2.3 Sensor attachment
 - 2.4 Sensor utilization
- 3. Instrumentation and signal processing**
 - 3.1 Cables
 - 3.2 Signal conditioning
 - 3.3 Signal detection
 - 3.4 Signal processing
 - 3.5 Source location techniques
 - 3.6 Acoustic emission test systems
 - 3.7 Accessory techniques
 - 3.8 Advanced signal processing techniques
- 4. Acoustic emission test techniques**
 - 4.1 Factors affecting test equipment selection
 - 4.2 Equipment calibration and setup for test
 - 4.3 Loading procedures
 - 4.4 Special test procedures
 - 4.5 Data display
 - 4.6 Noise sources and pre-test identification techniques
 - 4.7 Precautions against noise
 - 4.8 Data interpretation
 - 4.9 Data evaluation
 - 4.10 Reports
- 5. Codes, standards, procedures and societies**
 - 5.1 Guide-type standards (glossaries, calibration, etc.)
 - 5.2 Standardized/codified AE test procedures
 - 5.3 User-developed test procedures
 - 5.4 Societies active in AE
- 6. Applications of acoustic emission testing**
 - 6.1 Laboratory studies (material characterization)
 - 6.2 Structural applications

Level 3:

- 1. Principles and theory**
 - 1.1 Characteristics of acoustic emission testing
 - 1.2 Materials and deformation
 - 1.3 Sources of acoustic emission
 - 1.4 Wave propagation
- 2. Equipment and materials**
 - 2.1 Transducing processes (piezoelectricity), etc.
 - 2.2 Sensors
 - 2.3 Sensor attachment
 - 2.4 Sensor utilization
 - 2.5 Simulated AE sources
 - 2.6 Cables

- 2.7 Signal conditioning
- 2.8 Signal detection
- 2.9 Signal processing
- 2.10 Source location
- 2.11 Advanced signal processing
- 2.12 Acoustic emission test systems
- 2.13 Accessory materials
- 2.14 Factors affecting test equipment selection
- 3. Techniques**
 - 3.1 Equipment calibration and setup for test
 - 3.2 Establishing loading procedures
 - 3.3 Precautions against noise
 - 3.4 Special test procedures
 - 3.5 Data display
- 4. Interpretation and evaluation**
 - 4.1 Data interpretation
 - 4.2 Data evaluation
 - 4.3 Reports
- 5. Procedures**
 - 5.1 Guide-type standards (glossaries, calibration, etc.)
 - 5.2 Standardized/codified AE test procedures
 - 5.3 User-developed test procedures
 - 5.4 Societies active in AE
 - 5.5 Interpretation of codes, standards, and procedures
 - 5.6 Developing and writing AE test procedures
 - 5.7 Training and examining level 1 and 2 NDT personnel
- 6. Safety and health**
 - 6.1 Hazards associated with structural failure
 - 6.2 Other hazards associated with AE testing
 - 6.3 Importance of local regulations
- 7. Applications**
 - 7.1 Laboratory studies (material characterization)
 - 7.2 Structural applications

B.2. NEUTRON RADIOGRAPHIC TESTING

Level 1:

- 1. Personnel monitoring**
 - 1.1 Personnel monitoring dosimeters
 - 1.2 Permissible personnel exposure limits
- 2. Radiation survey instruments**
 - 2.1 Types of instruments
 - 2.2 Reading and interpreting meter indication
 - 2.3 Calibration frequency
 - 2.4 Calibration expiry; actions to be taken
 - 2.5 Battery check; importance
- 3. Radiation area surveys**
 - 3.1 Type and quantity of radiation
 - 3.2 Posting
 - 3.3 Establishment of time limits
- 4. Radioactivity**
 - 4.1 Radioactive components (fuel, sources, etc)
 - 4.2 Induced radioactivity due to neutron radiography
- 5. Radiation-area work practices: safety**
 - 5.1 Use of time, shielding and distance to reduce personnel radiation exposure
 - 5.2 Restricted areas
 - 5.3 Radioactive contamination
 - 5.4 Specific procedures
- 6. Explosive-device safety**
 - 6.1 Static electricity
 - 6.2 Grounding devices
 - 6.3 Clothing requirements
 - 6.4 Handling and storage requirements and procedures
 - 6.5 Shipping and receiving procedures
- 7. State and Federal regulations**
 - 7.1 Nuclear Regulatory Commission (NRC) and agreement states authority
 - 7.2 Occupational Safety and Health Administration (OSHA)
 - 7.3 Department of Transportation (DOT)
 - 7.5 State and Federal explosive-licensing requirements
- 8. Introduction**
 - 8.1 History of industrial neutron radiography
 - 8.2 General principles of examination of materials by penetrating radiation
 - 8.3 Relationship of penetrating neutron radiation, radiography, and radiometry
 - 8.4 Comparison with other NDT methods, particularly with X rays and gamma ray radiography
 - 8.5 General areas of application

- 9. Physical principles**
 - 9.1 Sources for neutron radiography (general description)
 - 9.2 Interaction between neutrons and matter
 - 9.3 Neutron radiography techniques
 - 9.4 Glossary of terms and units of measure
- 10. Radiation sources for neutrons (specific description)**
 - 10.1 Reactors
 - 10.2 Accelerators
 - 10.3 Isotopic sources
- 11. Personnel safety and radiation protection**
 - 11.1 Hazards of excessive exposure
 - 11.2 Methods of controlling radiation dose
 - 11.3 Specific equipment requirements
 - 11.4 Radiation work procedures
 - 11.5 Federal, state and local regulations
- 12. Radiation detection and imaging**
 - 12.1 Converter screens
 - 12.2 Film; principles of operation
 - 12.3 Track-etch detectors
- 13. Neutron radiographic process: basic imaging considerations**
 - 13.1 Definition of sensitivity (including penetrameters)
 - 13.2 Contrast and definition
 - 13.3 Geometric principles
 - 13.4 Generation and control of scatter
 - 13.5 Choice of neutron source
 - 13.6 Choice of film
 - 13.7 Use of exposure curves
 - 13.8 Cause and correction of unsatisfactory radiographs
 - 13.9 Arithmetic of exposure
- 14. Test result interpretation**
 - 14.1 Relationship between X ray and neutrons
 - 14.2 Effects on measurement and interpretation of test
 - 14.3 Administrative control of test quality by interpreter
 - 14.4 Familiarization with image

Level 2:

- 1. Introduction**
 - 1.1 General principles of examination of materials by penetrating radiation
 - 1.2 Relationship of penetrating neutron radiation, radiography, and radiometry
 - 1.3 Comparison with other methods, particularly with X-Rays and gamma rays
 - 1.4 Specific areas of application in industry
- 2. Review of physical principles**
 - 2.1 Nature of penetrating radiation (all types)
 - 2.2 Interaction between penetrating radiation and matter (neutron and gamma ray)
 - 2.3 Glossary of terms and units of measure

- 3. Radiation sources for neutrons**
 - 3.1 Neutron sources — general
- 4. Radiation detection**
 - 4.1 Imaging
 - 4.2 Non-imaging devices
- 5. Personnel safety and radiation protection**
 - 5.1 Hazards of excessive exposure
 - 5.2 Methods of controlling accumulated radiation dose
 - 5.3 Specific equipment requirements
 - 5.4 Operation and emergency procedures
 - 5.5 Federal, state, and local regulations
- 6. Neutron radiographic process**
 - 6.1 Basic neutron-imaging considerations
 - 6.2 Miscellaneous applications
- 7. Test result interpretation**
 - 7.1 Basic factors
 - 7.2 Material considerations
 - 7.3 Codes, standards, specifications, and procedures

Level 3:

- 1. Principles; theory**
 - 1.1 Nature of penetrating radiation
 - 1.2 Interaction between penetrating radiation and matter
 - 1.3 Neutron radiography
 - 1.4 Radiometry
- 2. Equipment; materials**
 - 2.1 Sources of neutrons
 - 2.2 Radiation detectors
 - 2.3 Non-imaging devices
- 3. Techniques; calibrations**
 - 3.1 Blocking and filtering
 - 3.2 Multi-film technique
 - 3.3 Enlargement and projecting
 - 3.4 Stereoradiography
 - 3.5 Triangulation methods
 - 3.6 Autoradiography
 - 3.7 Flash radiography
 - 3.8 In-motion radiography
 - 3.9 Fluoroscopy
 - 3.10 Electron emission radiography
 - 3.11 Microradiography
 - 3.12 Laminography (tomography)
 - 3.13 Control of diffraction effects
 - 3.14 Panoramic exposures
 - 3.15 Gauging
 - 3.16 Real time imaging
 - 3.17 Image analysis techniques

- 4. Interpretation/evaluation**
 - 4.1 Radiographic interpretation
- 5. Procedures**
 - 5.1 The radiographic process
 - 5.2 Film processing
 - 5.3 Viewing of radiographs
 - 5.4 Judging radiographic quality
- 6. Safety and health**
 - 6.1 Personnel safety and radiation hazards

B.3. THERMAL/INFRARED TESTING

Level 1:

- 1. The nature and measurement of heat**
 - 1.1 Instrumentation
 - 1.2 Scales and conversions
- 2. Temperature and its measurement**
 - 2.1 Instrumentation
 - 2.2 Scales and conversions
- 3. Heat transfer modes**
 - 3.1 Heat conduction
 - 3.2 Heat convection
 - 3.3 Heat radiation
- 4. Radiosity concepts**
 - 4.1 Reflectivity
 - 4.2 Transmissivity
 - 4.3 Absorptivity
 - 4.4 Emissivity
 - 4.5 Infrared radiometry and imaging
 - 4.6 Spatial resolution concepts
 - 4.7 Error potential in radiant measurements (an overview)
- 5. Introduction**
 - 5.1 Thermography
 - 5.2 Working of infrared imagers
 - 5.3 Differences among imagers and alternative equipment
 - 5.4 Operation of infrared thermal imager
 - 5.5 Operation of support equipment for infrared surveys
- 6. Checking equipment calibration with blackbody references**
- 7. Infrared image and documentation quality**
 - 7.1 Elements of a good infrared image
 - 7.2 Recording
- 8. Support data collection**
 - 8.1 Environmental data
 - 8.2 Emissivity
 - 8.3 Surface reference temperatures
 - 8.4 Identification and others
- 9. Detection of thermal anomalies resulting from difference in thermal resistance (quasi steady-state heat flow)**
 - 9.1 Large surface-to-ambient temperature difference
 - 9.2 Small surface-to-ambient temperature difference
- 10. Detection of thermal anomalies resulting from differences in thermal capacitance, using system or environmental heat cycles**
- 11. Detection of thermal anomalies resulting from differences in physical state**
- 12. Detection of thermal anomalies resulting from fluid flow problems**

13. **Detection of thermal anomalies resulting from friction**
14. **Detection of thermal anomalies resulting from non-homogeneous exothermic or endothermic conditions**
15. **Field quantification of point temperatures**
 - 15.1 Simple techniques for emissivity
 - 15.2 Typical (high emissivity) applications
 - 15.3 Special problem of low emissivity applications.

Level 2:

1. **Basic calculations in the three modes of heat transfer**
 - 1.1 Conduction; principles and elementary calculations
 - 1.2 Convection; principles and elementary calculations
 - 1.3 Radiation; principles and elementary calculations
2. **The infrared spectrum**
 - 2.1 Planck's law/curves
 - 2.2 Effects due to semi-transparent windows and/or gasses
 - 2.3 Filters
3. **Radiosity problems**
 - 3.1 Black bodies; theory and concepts
 - 3.2 Emissivity problems
 - 3.3 Calculation of emissivity, reflectivity and transmissivity (practical use of Kirchoff's law)
 - 3.4 Reflectivity problem
 - 3.5 Transmissivity problem
4. **Resolution tests and calculations**
 - 4.1 IFOV and FOV measurement and calculations
 - 4.2 MRTD measurements and calculations
 - 4.3 Slit response function; measurement, calculations, interpretations and comparisons
 - 4.4 Resolution vs. lens and distance
 - 4.5 Dynamic range
 - 4.6 Data acquisition rate/data density
 - 4.7 Frame rate and field rate
 - 4.8 Image data density
5. **Infrared measurements (quantification)**
 - 5.1 Simple infrared energy measurement
 - 5.2 Quantifying the emissivity of the target surface
 - 5.3 Quantifying temperature profiles
 - 5.4 Computer processing to enhance imager data
6. **High speed data collection**
 - 6.1 Producing accurate images of transient processes
 - 6.2 Recording accurate images of transient processes
 - 6.3 Equipment selection and operation for imaging from moving vehicles

- 7. Special equipment for ‘active’ techniques**
 - 7.1 Hot or cold fluid energy sources
 - 7.2 Heat lamp energy sources
 - 7.3 Flash lamp energy sources
 - 7.4 Electromagnetic induction
 - 7.5 Laser energy sources
- 8. Reports and documentation**
 - 8.1 Calibration requirements and records
 - 8.2 Report data requirements
 - 8.3 Preparation of reports
- 9. Temperature measurement applications**
 - 9.1 Isotherms/alarm levels; personnel safety audits, etc.
 - 9.2 Profiles
- 10. Energy loss analysis applications**
 - 10.1 Conduction losses through envelopes
 - 10.2 Mass-transfer heat exchange (air or other flows into or out of the system)
- 11. “Active” applications**
 - 11.1 Insulation flaws
 - 11.2 De-lamination of composites
 - 11.3 Bond quality of coatings
 - 11.4 Location of high heat-capacity components
- 12. Filtered applications**
 - 12.1 Sunlight
 - 12.2 Furnace interiors
 - 12.3 Semi-transparent targets
- 13. Transient applications**
 - 13.1 Imaging a rapidly moving process
 - 13.2 Imaging from a vehicle

Level 3:

- 1. Principles/theory**
 - 1.1 Conduction
 - 1.2 Convection
 - 1.3 Radiation
 - 1.4 Nature of heat and heat flow
 - 1.5 Temperature measurements principles
 - 1.6 Proper selection of Thermal/Infrared testing (TIR) as technique of choice
- 2. Equipment and materials**
 - 2.1 Temperature measurement equipment
 - 2.2 Heat flux indicators
 - 2.3 Performance parameters of non-contact devices
- 3. Techniques**
 - 3.1 Contact temperature indicators
 - 3.2 Non-contact pyrometers
 - 3.3 Infrared line scanners

- 3.4 Thermal/Infrared imaging
- 3.5 Heat flux indicators
- 3.6 Exothermic or endothermic investigations
- 3.7 Friction investigations
- 3.8 Fluid flow investigations
- 3.9 Thermal resistance (steady state heat flow) investigations
- 3.10 Thermal capacitance investigations
- 4. Interpretation/evaluation**
 - 4.1 Exothermic or endothermic processes
 - 4.2 Friction
 - 4.3 Fluid flow
 - 4.4 Differences in thermal resistance (steady state heat flow)
 - 4.5 Thermal capacitance
- 5. Procedures**
 - 5.1 Existing codes and standards
 - 5.2 Elements of thermal/infrared testing job procedure development
- 6. Safety and health**
 - 6.1 Safety responsibility and authority
 - 6.2 Safety for personnel
 - 6.3 Safety for client and facilities
 - 6.4 Safety for testing equipment

B.4. VIBRATION ANALYSIS

Level 1:

1. Introduction

- 1.1 Brief history of NDT and vibration analysis
- 1.2 The purpose of vibration analysis
- 1.3 Basic principles of vibration analysis
- 1.4 Basic terminology of vibration analysis

2. Transducers

- 2.1 Types
- 2.2 Applications
- 2.3 Mounting
- 2.4 Limitations

3. Instrumentation

- 3.1 Types
- 3.2 Applications
- 3.3 Limitations

4. Machinery basics

- 4.1. Machine types
- 4.2. Machine components
- 4.3. Machine orientations

5. Data collection procedures

- 5.1 Upload/download route
- 5.2 Following a route
- 5.3 Data acquisition

6. Safety and health

- 6.1 Mechanical
- 6.2 Electrical
- 6.3 Environmental
- 6.4 Regulations
- 6.5 Equipment

Level 2:

1. Review

- 1.1 Basic principles
- 1.2 Basic terminology
- 1.3 Transducers
- 1.4 Instrumentation

2. Additional terminology

- 2.1 Data acquisition
- 2.2 Signal processing
- 2.3 Data presentation

- 3. Diagnostic tools**
 - 3.1 Phase
 - 3.2 FFT
 - 3.3 Time waveform
 - 3.4 Orbit analysis
 - 3.5 Bode/Nyquist
 - 3.6 Trend analysis

- 4. Data acquisition**
 - 4.1 Units
 - 4.2 Analysis parameters
 - 4.3 Alarm levels
 - 4.4 Time constant (min/max)
 - 4.5 Speed consideration
 - 4.6 Lines of resolution
 - 4.7 Overlap
 - 4.8 Averages
 - 4.9 Averaging and data collection methods
 - 4.10 Windows
 - 4.11 Sensitivity
 - 4.12 Special transducers
 - 4.13 Routes and online systems
 - 4.14 Transducer selection
 - 4.15 Transducer location
 - 4.16 Types of data collection
 - 4.17 Resonance testing
 - 4.18 Instrument calibration check
 - 4.19 Codes, standards and specifications

- 5. Signal processing**
 - 5.1 Windows/weighing
 - 5.2 Overlap
 - 5.3 Filters
 - 5.4 Sampling rate and size
 - 5.5 Digital vs. analog

- 6. Data presentation**
 - 6.1 Scope and limitations of different testing methods
 - 6.2 Waterfall/cascades
 - 6.3 Linear vs. logarithmic
 - 6.4 Trends
 - 6.5 Changing units
 - 6.6 True zoom and expansion
 - 6.7 Order and/or frequency

- 7. Problem identification**
 - 7.1 Imbalance
 - 7.2 Misalignment
 - 7.3 Resonance
 - 7.4 Bearing defects
 - 7.5 Looseness

- 7.6 Bent shafts
- 7.7 Gear defects
- 7.8 Electrical defects
- 7.9 Hydraulic/flow dynamics
- 7.10 Ribs
- 7.11 Belts and couplings
- 7.12 Eccentricity

8. Reporting methodology

- 8.1 Technical reports
- 8.2 Management oriented reports
- 8.3 Oral reports

9. Safety and health

Level 3:

1. Principles/theory

- 1.1 Physical concepts
- 1.2 Data presentation
- 1.3 Sources of vibration
- 1.4 Correction methods

2. Equipment

- 2.1 Sensors
- 2.2 Signal condition
- 2.3 Instruments
- 2.4 On-line monitoring
- 2.5 Equipment response to environments

3. Techniques/calibration

- 3.1. Calibration
- 3.2. Measurement and techniques
- 3.3. Correction techniques

4. Analysis/evaluation

- 4.1 Data analysis
- 4.2 Data evaluation

5. Procedures

- 5.1 “To be able to develop procedures for performing the various types of testing techniques needed to determine equipment condition”

6. Safety and health

- 6.1 “Working in close proximity to operating equipment containing a great deal of energy, special care must be taken to avoid injury in addition to using specific personal protective equipment”

Appendix C

TRAINING EQUIPMENT

The following appendix includes suggested equipment requirements for training courses in the key NDT methods.

SR. NO	EQUIPMENT UT	QUANTITY
1	Digital ultrasonic flaw detector with A-screen image and Lemo 0 socket for probes (including DGS- and DAC-correction)	3
2	Calibration Block V1	3
3	Calibration Block V2	3
4	Straight beam probe (frequency = 2 MHz and diameter = 24 mm)	3
5	Straight beam probe (frequency = 4 MHz and diameter = 10–13 mm)	3
6	Twin crystal straight beam probe (frequency = 4 MHz and diameter = 10–13 mm)	3
7	Angle beam probe (frequency = 4 MHz, diameter = 10–13 mm and angle = 30°)	3
8	Angle beam probe (frequency = 4 MHz, diameter = 10–13 mm and angle = 60°)	3
9	Angle beam probe (frequency = 4 MHz, diameter = 10–13 mm and angle = 45°)	3
10	Angle beam probe (frequency = 2 MHz, diameter = 10–13 mm and angle = 30°)	3
11	Angle beam probe (frequency = 2 MHz, diameter = 10–13 mm and angle = 60°)	3
12	Angle beam probe (frequency = 2 MHz, diameter = 10–13 mm and angle = 45°)	3
13	Straight beam probe (frequency = 1 MHz and diameter = 24 mm)	3
14	High resolution straight beam probe (frequency = 0.5–4 MHz and diameter = 24 mm)	4
15	Cable for miniature probes (Lemo 00/Lemo 0) with length of 1.5–2 m	10
16	Cable for normal probes (Lemo 0/Lemo 0) with length of 1.5–2 m	5
17	Twin cable for twin crystal probes (Lemo 00/Lemo 0) with length of 1.5 — 2 m	5

Position 4 to 14 must be delivered with valid DGS diagramme

SR. No	EQUIPMENT UT	QUAN-TITY
1	AC hand yoke for MT testing with rigid legs (for 220 Volts)	3
2	Portable UV-light for 220 Volts, 100 Watt	3
3	Current generator 42 volts, 1500 A eff. including cables and prods for MT	1
4	Portable Power supply 220 V, 50 Hz, 3 KVA for field work	1
5	Tangential field strength meter with digital reading (min. range: 0–200 A/cm for AC and DC measurements including reference magnet for system calibration)	3
6	Calibrated portable lux meter with digital reading and battery operation (min. Range 0- 3000 lux)	3
7	Calibrated portable UV meter with analog reading for wave length 365 nm (battery operated)	3
8	Reference blocks for magnetisation, field direction, quality of fluid	4

SR. No	EQUIPMENT PT	QUAN-TITY
1	Calibrated portable lux meter with digital reading and battery operation (min. Range 0–3000 lux)	2
2	Calibrated portable UV meter with analog reading for wave length 365 nm (battery operated)	2
3	Reference block No. 2 in accordance with EN/ISO 3452-3	2
4	Ultrasonic cleaning bath for test specimens with dimensions of 300 x 300 mm	1
5	Set of penetrant testing systems for daylight and black-light	5

SR. No	EQUIPMENT RT	QUANTITY
1	Portable X ray tube and gamma source	1
2	Manual developing unit for radiographs	1
3	Film drying unit	1
4	Set of double wire image quality indicator in Fe and Al	1
5	Set of step-hole type image quality indicator (material: Fe)	1
6	Vacuum packaged films	50 of each class
7	Chemicals for manual film development	1
8	Film density meter	1
9	Film viewing apparatus	2

SR. No	EQUIPMENT VT	QUANTITY
1	Rigid videoscope with mirror tube technique for direction of view (0° and 90°) max. diameter = 20 mm, length = 500–600 mm including light source, light-conductor and 30 cm colour monitor	1
2	Rigid fiber optic light stick with direction of light = 0° and length ≈ 200 mm	2
3	Surface quality comparators for castings (shorter set)	1
4	Surface quality comparators for castings big set	1
5	Education kit with min. 10 samples of welds (butt- and tee-joints) with typical surface defects (different types of cracks, porosity, lack of penetration and imperfect shape and dimensions)	2 (1 for training and 1 for examination)
6	Different types of welding gauges according to EN 970 for butt welds and tee welds	12 for each weld joint

7	Set of magnifying lenses (magnification: 2x, 5x, 8x, 10x)	2
8	Set of inspection mirrors with diameter \approx 5, 10 and 20 mm and length = 200–300 mm	2
9	Rigid endoscope with direction of view = 0°, length = 500–600 mm, diameter = 8–10 mm including light source and light-conductor	1
10	Same as Sr. No. 9 with direction of view = 90°	1
11	Rigid endoscope with exchangeable objectives for direction of view (0° and 90°) and diameter = 8–10 mm, length = 500–600 mm including light source and light-conductor	1
12	Rigid endoscope with zoom (10x–20x) and direction of view 90°, diameter = 8–10 mm, length = 500–600 mm including light source and light-conductor	1

SR. NO	EQUIPMENT ET FOR TESTING OF NON-FERROUS MATERIALS	QUAN-TITY
1	Eddy current instruments with an impedance plane display which has a continuous frequency selection ranging from approximately 100Hz–2 MHz	1
2	Number of surface, ID, and ring probes	1
3	Reflection ring probes for fastener holes inspection frequency range 100 Hz–10KHz	1
4	Reflection ring probes for fastener holes inspection frequency range 250 Hz–40KHz	1
5	Reflection ring probes for fastener holes inspection frequency range 400 Hz–5 KHz	1
6	Set of eight conductivity standards	1
7	Test samples with fasteners, coatings, conductivity differences, cracks	10

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