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ABSTRACT

The course consists of the basic and simpler methods of inspecting and nondestructive testing of parts and materials to insure the quality and reliability of the finished product. The outline consists of six blocks totaling 135 hours: (1) defects in the metal ingot, (2) defects resulting from processing metals, (3) defects in metals in service, (4) visual inspection, (5) hardness testing, (6) liquid penetrant test and a posttest. Adequate laboratory time, experience on aircraft and other equipment, proficiency in the nature and application of techniques, and drill in the usage of testing equipment are necessary elements in skill development. A bibliography listing basic and supplementary references and a sample posttest conclude the document. (MW)

VT

AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

Course Outline
METALLURGY, VISUAL INSPECTION, HARDNESS AND LIQUID PENETRANT TESTING
(Aviation Quality Control 2 - 9227)

Department 48 - Course 9227.01

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION • 1971

D A D E C O U N T Y P U B L I C S C H O O L S

1 4 1 0 N O R T H E A S T S E C O N D A V E N U E

M I A M I, F L O R I D A 33132

Course Outline

AVIATION QUALITY CONTROL 2 - 9227

(Metallurgy, Visual Inspection, Hardness and Liquid Penetrant Testing)

Department 43 - Course 9227.01

the division of

VOCATIONAL, TECHNICAL AND ADULT EDUCATION

Published by the Dade County School Board

Course Description

9227	48	9227.01	Metallurgy, Visual Inspection, Hardness and Liquid Penetrant Testing
State Category Number	County Dept. Number	County Course Number	Course Title

This quinmester course consists of the basic and simpler methods of inspecting and nondestructive testing. The fundamentals of metallurgy are necessary for all testing of metals. Visual inspection with various optical instruments is included. Techniques of hardness testing and liquid penetrant testing are covered in detail.

Clock hours: 135

PREFACE

The following quinmester course outline will serve as a guide for the high school and adult trainee in testing, inspecting and checking parts and materials to insure the quality and reliability of the finished product.

This outline consists of six blocks or 135 hours of instruction which are subdivided into several units each. These blocks will involve the techniques of visible inspection, hardness testing and liquid penetrant testing of metals. Fundamentals of metallurgy necessary for intelligent inspecting and testing are also included.

Adequate laboratory time and actual experience on aircraft and other equipment will be provided to develop skills in the student. The student is expected to be proficient, not just familiar, with the nature and the application of these techniques. The student will work with and receive substantial drill in the use of actual equipment used in the NDT field. Motion picture films and color slides will be used in the classroom to demonstrate and aid in the application of these techniques. Study periods, group discussions, and extensive use of textbooks and training manuals will be used. These are listed along with references and periodicals.

This outline was developed through the cooperative efforts of the instructional and supervisory personnel, the Quirmester Advisory Committee, and the Vocational Teacher Education Service, and has been approved by the Dade County Vocational Curriculum Committee.

TABLE OF CONTENTS
with Suggested Hourly Breakdown

GOALS

The aviation quality control student must be able to:

1. Develop skills in the use of nondestructive testing equipment.

2. Develop the attitudes of patience and persistence to gain maximum accuracy.

3. Develop the habits of cleanliness of person and work area.

4. Be aware of the responsibility involved in his chosen work.

5. Maintain the standards required for the field.

6. Control quality of the finished product.

SPECIFIC BLOCK OBJECTIVES

BLOCK I - DEFECTS IN THE METAL INGOT

The student must be able to:

1. Identify and describe at least 4 discontinuities found in the poured metal ingot.
2. Explain how these discontinuities are formed in the metal.

BLOCK II - DEFECTS RESULTING FROM PROCESSING METALS

The student must be able to:

1. Define a crack.
2. Name and identify three forging discontinuities (or defects) from samples, photographs or radiographs.
3. Describe how these forging defects are formed.
4. Name and identify three rolling defects from samples, photographs or radiographs.
5. Describe how these rolling defects are formed.
6. Name and identify three cold drawing defects from samples or photographs.
7. Describe how these cold drawing defects are formed.
8. Name and identify two common extrusion defects.
9. Name and identify at least four casting defects from photographs, samples or radiographs.
10. Describe how these defects are formed in the cast metal.
11. Name the applicable NDT methods of detecting these defects.

BLOCK III - DEFECTS IN METALS IN SERVICE

The student must be able to:

1. Name and identify two service defects from samples or photographs.
2. Name the applicable NDT methods of detecting these defects.

BLOCK IV - VISUAL INSPECTION

The student must be able to:

1. Demonstrate his ability to set up and use a microscope.
2. Demonstrate his ability to assemble, set up and use a borescope.
3. Show by doing, how to properly clean and care for optical equipment.

BLOCK V - HARDNESS TESTING

The student must be able to:

1. Check the calibration of the Rockwell hardness tester to within test block tolerances on at least two scales.
2. Demonstrate his ability to test Rockwell hardness of a specimen against blueprints or specifications.
3. Explain the principle of the Brinell hardness tester.
4. Calibrate the conductivity tester on both the high and low scales.
5. Explain the principle of the conductivity tester.
6. Demonstrate his ability to test the conductivity of a specimen and to apply this knowledge.
7. Identify a specimen from a group of metal samples against a known standard.

BLOCK VI - LIQUID PENETRANT TESTING

The student must be able to:

1. Explain the theory of liquid penetrant testing.
2. Identify the three processes used in liquid penetrant testing.
3. Explain at least three pre and post parts cleaning methods.
4. Demonstrate at least two methods of applying penetrant.
5. Demonstrate penetrant removal by two of the above processes.
6. Apply developer to a prepared specimen.
7. Demonstrate ability to interpret indications from live specimens or photographs.

Course Outline

AVIATION QUALITY CONTROL 2 - 9227
(Metallurgy, Visual Inspection, Hardness
and Liquid Penetrant Testing)

Department 48 - Course 9227.01

I. DEFECTS IN THE METAL INGOT

A. Inclusions
   1. The cause of inclusions
   2. The effect of inclusions in forming the ingot

B. Gas Holes or Porosity
   1. The cause of gas holes
   2. The effect of gas holes on working the metal

C. Pipe
   1. Where pipe occurs
   2. How the amount of pipe is reduced in the ingot

D. Shrinkage
   1. How shrinkage occurs in the ingot
   2. Effects of shrinkage on the metal
   3. Detection of shrinkage

II. DEFECTS RESULTING FROM PROCESSING METALS

A. Cracks
   1. Heat treat cracks
   2. Forming cracks

B. Forging Defects
   1. Laps
      a. Cause of laps
      b. Effect of laps in the finished forging
   2. Surface tears
      a. How surface tears occur
      b. How surface tears effect the finished forging
   3. Bursts
      a. The cause of bursts
      b. Effect of bursts in the finished forging
      c. Inspection methods for bursts

II. DEFECTS RESULTING FROM PROCESSING METALS (Contd.)

C. Rolling Defects
  1. Seams
    a. How seams occur in rolling
      1. Rolling of sheet stock
      2. Rolling of bar stock
    b. Effects of seams on the finished product
  2. Laminations
    a. The cause of laminations in rolling sheet stock
    b. Effects of laminations in the finished sheet stock
    c. Detections of laminations
  3. Laps and fins
    a. How laps and fins are formed in rolling
    b. Where laps and fins are found and their effect on the stock
    c. Inspection for laps and fins

D. Cold Drawing Defects
  1. Laps
    a. How laps are formed in cold drawing
    b. The detection and effect of laps in the finished material
  2. Pits
    a. Causes of pits in the drawing of metals
    b. Visual inspection for pits and their effects on the finished product
  3. Tears
    a. How tears occur in drawing
    b. Inspection for tears in the drawn metal
  4. Scratches
    a. Causes of scratches in the drawing process
    b. Inspection for scratches in the drawn metal

E. Extruding Defects
  1. Die marks
  2. Cracks
    a. Causes of cracks in extruding
    b. Detection of cracks
  3. Cut outs

II. DEFECTS RESULTING FROM PROCESSING METALS (Contd.)

F. Casting Defects
   1. Porosity
      a. Causes of porosity
      b. Detection of porosity
   2. Blow holes
      a. How blow holes occur
      b. Detection of blow holes
   3. Inclusions
      a. Metallic inclusions
      b. Non metallic inclusions
      c. Causes and the effects of inclusions in casting
      d. Detection of inclusions
   4. Shrinkage
      a. What causes shrinkage
      b. Where shrinkage occurs in casting
      c. How shrinking is reduced
      d. Detection of shrinkage
   5. Cold shuts
      a. What cold shuts are
      b. Causes of cold shuts
      c. How to detect cold shuts

III. DEFECTS IN METALS IN SERVICE

A. Fatigue Cracks
   1. How fatigue cracks occur
   2. Methods of detecting fatigue cracks

B. Stress Cracks
   1. Causes of stress cracks
   2. Stress crack detection methods

C. Temperature Cracks

D. Brittleness
   1. The cause of brittleness
   2. Testing for brittleness

IV. VISUAL INSPECTION

A. Use of the Magnifying Glass

IV. VISUAL INSPECTION (Contd.)

1. Types and construction
   a. Single and compound lens
   b. Methods of supporting and holding glasses
2. Magnification
   a. How magnification is expressed
   b. Proper selection of "power" or magnification
3. Proper lighting
4. Techniques in cleaning and handling magnifying glasses
5. Safety and work precautions in inspecting with magnifying glasses

B. Mirrors
   1. Types and construction of inspection mirrors available
   2. Techniques in inspection with mirrors
   3. Care and cleaning mirrors

C. Microscopes
   1. Types of microscopes
      a. Monocular
      b. Binocular
   2. Magnification
      a. Turret
      b. Zoom
      c. Proper selection of power
   3. Types of stages available
   4. Methods of lighting
      a. Substage lighting
      b. Direct lighting
   5. Preparation of specimen
   6. Techniques of operating the microscope
      a. Adjusting the eye piece
      b. Focusing
   7. Care and maintenance of the microscope
   8. Safety and work precautions in using the microscopes

D. Borescopes
   1. Types of borescopes
   2. Magnification
   3. Lighting and sighting the borescope
   4. Borescope adjustments and focusing techniques
   5. Care and handling the borescope

IV. VISUAL INSPECTION (Contd.)

6. Safety and work precautions

V. HARDNESS TESTING

A. Reasons for Testing Hardness of Metals
   1. Tensile strength
   2. Degree of heat treatment

B. How Hardness is Expressed

C. Electrical Testing
   1. Theory of conductance
   2. How conductance is expressed
   3. Operation of the conductivity tester
      a. Theory of operation of the tester
      b. Calibrating the tester
      c. Care and maintenance of the tester
      d. Safety and work precautions in using the tester

D. Mechanical Hardness Testing
   1. Operation of the Rockwell hardness tester
      a. Theory of the Rockwell hardness test
      b. Setting up the tester
      c. Techniques in servicing and calibrating the tester
         (1) Checking the dashpot
         (2) Use of test blocks
         (3) Tolerances allowed
      d. Techniques of operating the tester
         (1) Proper weight and scale selection
         (2) Penetrator selection
         (3) Anvil selection
         (4) Importance of the "dry run"
         (5) Location of penetrator on specimen
         (6) Applying the minor load
         (7) Applying the major load
         (8) Reading the dial indications
      e. Safety and work precautions in using the Rockwell hardness tester
         (1) Avoid damage to the penetrator
         (2) Handling the weights

V. HARDNESS TESTING (Contd.)

2. Testers other than the Rockwell
   a. Brinell hardness tester
      (1) Theory of the Brinell method
      (2) How the Brinell hardness tester operates
   b. Shore schleroscope
      (1) Theory of the Shore schleroscope
      (2) How the Shore schleroscope operates

VI. LIQUID PENETRANT TESTING

A. Theory of Testing with Liquid Penetrants
   1. Surface discontinuities
   2. Penetration through capillary action
   3. Developing
   4. Viewing
      a. Visible dye
      b. Fluorescent dye

B. Material Grouping
   1. Group I, Solvent--removable visible dye penetrants
   2. Group II, Post emulsifiable visible dye penetrant
   3. Group III, Water washable visible dye penetrant
   4. Group IV, Water washable fluorescent dye penetrant
   5. Group V, Post emulsifiable fluorescent penetrant
   6. Group VI, High-sensitivity fluorescent penetrant

C. Fluorescent and Visible Dye Processes Grouping
   1. Process A, Water washable
   2. Process B, Post emulsifiable
   3. Process C, Solvent Removable

D. Pre and Post Test Cleaning Processes
   1. Detergent cleaning
   2. Vapor degreasing
   3. Steam cleaning
   4. Solvent cleaning

E. Application of Penetrant
   1. Dipping process
   2. Spraying techniques
   3. Applying with brush
   4. Dwell time

VI. LIQUID PENETRANT TESTING (Contd.)

F. Techniques of Removing Penetrant
   1. Water washable penetrants
   2. Post emulsifiable penetrants
   3. Solvent removable penetrants

G. Application of Developer
   1. Dipping of specimen
   2. Spraying techniques

H. Interpretation of Indications
   1. False indications
   2. Non-relevant indications
   3. True indications
      a. Continuous line
      b. Intermittent line
      c. Round
      d. Small dots
      e. Diffused or weak indications
      f. Depth indications

I. Advantages and Limitations of Liquid Penetrant Testing

J. Safety and Work Precautions in Using Liquid Penetrants
   1. Fire hazard
   2. Ultra-violet light used for fluorescent penetrant
      a. Hazards involved
      b. Warm-up time

VII. QUINMESTER POST TEST

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1. Hardness Testing: Rockwell. 16mm. B/W. Sound. Lindsey Hopkins Material Lab. Audio Visual Center, Miami, Florida.

2. Quality Assistance. 16mm. 19 min. Color. Sound. G.T. Baker Aviation School.

A P P E N D I X

Quinmester Post Test Sample

QUINMESTER POST TEST
(Metallurgy, Visual Inspection, Hardness
and Liquid Penetrant Testing)

Name_____Date_____Score____

Multiple Choice Test Items

Each question below is followed by four possible answers, select the best answer and mark your answer sheet accordingly.

1. Which one of the following conditions will affect the rate and extent a liquid penetrant will enter cracks, fissures and other small openings?
   a. The hardness of the specimen being tested
   b. The surface condition of the specimen being tested
   c. The color of the penetrant
   d. The conductivity of the specimen being tested

2. Which of the following is a commonly used classification for penetrants?
   a. Post-emulsification penetrant
   b. Nonferrous penetrant
   c. Chemical etch penetrant
   d. Nonaqueous penetrant

3. Which of the following discontinuities can be found by the penetrant test method?
   a. A surface crack
   b. A subsurface crack
   c. An internal inclusion
   d. None of the above

4. Which of the following is generally the most acceptable method for cleaning parts prior to penetrant testing?
   a. Sand blasting
   b. Wire brushing
   c. Grinding
   d. Vapor degreasing

5. Which of the following is not a generally accepted method for cleaning parts prior to penetrant testing?
   a. Vapor degreasing
   b. Liquid solvent
   c. Wire brushing
   d. Alkaline cleaner

6. The most common type of contaminate found in fluorescent penetrant fuid is
   a. Metal filings
   b. Oil
   c. Detergents (from cleaning)
   d. Water

7. Black light used for fluorescent penetrant inspection can cause permanent damage to
   a. Human tissue
   b. Human eyes
   c. Human blood cells
   d. None of the above

8. Which of the following is not a basic inspection principle which applies to all penetrant methods?
   a. The penetrant must enter the discontinuity in order to form an indication
   b. Indications glow when subjected to a black light
   c. A longer penetrant time is required for smaller discontinuities
   d. If the penetrant is washed out of the discontinuity, an indication will not be formed by that discontinuity.

9. Which of the materials listed below is not normally tested by the liquid penetrant test method?
   a. Rubber
   b. Aluminum
   c. Glass
   d. Copper

10. The first step in conducting a liquid penetrant test on a surface that has been painted is to
   a. Carefully apply the penetrant over the surface
   b. Completely remove the paint
   c. Thoroughly wash the surface with a detergent
   d. Wire brush the surface to roughen the smooth surface coating of paint

11. Which of the following discontinuities would be impossible to detect using a liquid penetrant test?
    a. Forging lap
    b. Crater crack
    c. Grinding cracks
    d. Non-metallic internal inclusions

12. The term used to describe the action of the developer in soaking up the penetrant in a discontinuity, so as to cause the maximum bleed out of the liquid penetrant for increased contrast and sensitivity is known as
    a. Blotting
    b. Capillary action
    c. Concentration
    d. Attraction

13. A black light lamp should not be used with a cracked filter or without a filter in place because of the harmful effects to the human eyes caused by _____ emitted from such a lamp.
    a. Black light
    b. Ultraviolet light
    c. Infrared light
    d. None of the above

14. The term used to define the period of time in which the test part is covered with penetrant is
    a. Waiting time
    b. Soak time (drain time)
    c. Penetration time (dwell time)
    d. Bleed-in time

15. Which of the following is <u>not</u> a characteristic that applies to liquid penetrant testing?
    a. This method can accurately measure the depth of a crack or discontinuity
    b. This method can be used for on-site testing of large parts
    c. This method can be used to find shallow surface discontinuities
    d. This method can be made more or less sensitive by using different penetrant materials.

16. When conducting a fluorescent penetrant test, a commonly used technique for assuring that the excess penetrant has been removed prior to the application of a developer is
    a. To blow compressed air over the surface
    b. To chemically etch the surface
    c. To blot the surface with absorbant paper
    d. To scan the surface with a black light

17. Which of the following surface conditions could have a detrimental effect on a liquid penetrant test?
    a. A wet surface
    b. A rough weld
    c. An oily surface
    d. All of the above could have a detrimental effect

18. Liquid penetrant testing is capable of detecting
    a. Intergranular discontinuities
    b. Surface discontinuities
    c. Subsurface discontinuities
    d. All of the above

19. The term used to define the tendency of certain liquids to penetrate into small openings such as cracks or fissures is
    a. Saturation
    b. Capillary action
    c. Blotting
    d. Wetting agent

20. Which of the following materials cannot be tested by the liquid penetrant test method?
    a. Unglazed ceramic
    b. Plastic sheet
    c. High alloy steel
    d. Cast iron

21. A continuous linear indication can be caused by which of the following discontinuities?
    a. Porosity
    b. Slag inclusions
    c. Pitting
    d. Cracks

22. Which of the following production techniques or conditions is not likely to cause nonrelevant indications?
    a. Poor surface preparation
    b. Press fit parts
    c. Improper washing or rinsing of penetrant
    d. Improper heat treatment of a test specimen

23. A magnesium sand casting with a 1/4 inch thick wall is being penetrant tested. Several rounded indications ranging from pinpoint to pinhead size are noted in an approximately 3 sq. inch area of the casting. Some sections of this area are more densely covered with these indications than are other areas. The opposite side of the wall shows somewhat the same pattern except there are fewer indications. Most likely these indications are caused by
    a. Slag inclusions
    b. A seam
    c. Porosity
    d. Weld overlay

24. Which of the following discontinuities might be found in a welded fabrication?
    a. Shrinkage
    b. Lack of fusion
    c. Seams
    d. Laps

25. Which of the following discontinuities might be found in rolled bar stock?
    a. Shrinkage
    b. Bleedout
    c. Laps
    d. Undercut

26. Which of the following discontinuities might be found in rolled plate?
    a. Laminations
    b. Shrinkage
    c. Lack of fusion
    d. Undercut

27. A penetrant indication in the form of a fine line could be caused by
    a. A deep open crack
    b. A shallow tight crack
    c. Weld cracks
    d. Surface porosity on a casting

28. A penetrant indication in the form of multiple scattered dots could be caused by
    a. A deep open crack
    b. A shallow tight crack
    c. Weld cracks
    d. Surface porosity on a casting

29. A penetrant indication in the form of a wide line could be caused by
    a. A deep open crack
    b. A shallow tight crack
    c. Weld cracks
    d. Surface porosity on a casting

30. Wet, non-aqueous developers usually consists of
    a. Pumice and kerosene
    b. Chalk and alcohol
    c. Powdered white lead and linseed oil
    d. Clay and gasoline

31. A complicated cast magnesium oil pump housing which contains several threaded holes and sharp cornered keyways after machining is penetrant tested. Fluorescent indications are noted at the root of the threads in one of the threaded holes and in the sharp corners of two keyways. The indications are not sharp or well defined. Also, the indications are milky in color and do not reappear when wiped off the surface. Which of the following discontinuities or conditions could cause such an indication?
    a. Pipe
    b. Seam
    c. Lap
    d. False indication

32. Which of the following is a discontinuity that might be found in a forging?
    a. Shrinkage cracks
    b. Laps
    c. Cold shuts
    d. Insufficient penetration

33. Which of the following is a discontinuity that might be found in rolled bar stock?
    a. Blow holes
    b. Shrinkage laps
    c. Cracks or seams
    d. Insufficient penetration

34. Which of the following is a discontinuity that might be found in rolled plate stock?
    a. Shrinkage cracks
    b. Inclusions
    c. Forging laps
    d. Blow holes

35. A discontinuity which may be found either at the surface or internally in forged, wrought and extruded metals, is normally flat and extremely thin, and may contain oxide between the discontinuity surfaces. Which of the following discontinuities fits this description?
    a. Crack
    b. Lamination
    c. Porosity
    d. Slag

36. The proper technique to be used in focusing a microscope would be to
    a. Use the lowest power first
    b. Use the highest power first
    c. Place objective lens close to specimen then rack away until focus is reached
    d. Start high then slowly rack toward specimen until focus is reached

37. Which of the following would be a good operating technique for the Rockwell hardness tester?
    a. Go through a "dry run" whenever an anvil or a penetrator is changed.
    b. Always place penetrator adjacent to existing penetration marks for a closer reading
    c. Zero needle on scale by adjusting minor load
    d. Remove all paints and scale before testing specimen

38. The proper sequence of steps for operating the Rockwell hardness tester is as follows:
    a. Apply major load, zero scale, remove major load, read hardness
    b. Apply minor load, apply major load, read hardness
    c. Apply minor load, zero scale, apply major load, release major load, read hardness
    d. Apply major load, zero scale, apply minor load, release minor load, read hardness

39. Two copper standards are used to calibrate the conductivity tester:
    a. True
    b. False

40. Probe of conductivity tester must seat against a flat surface of the specimen with at least a diameter of
    a. .030 inch
    b. 1/4 inch
    c. 1/2 inch
    d. .750 inch

ANSWER KEY TO QUINMESTER POST TEST
(Metallurgy, Visual Inspection, Hardness and Liquid Penetrant Testing)

1.	b	14.	c	27.	b
2.	a	15.	a	28.	d
3.	a	16.	d	29.	a
4.	d	17.	d	30.	b
5.	c	18.	b	31.	d
6.	d	19.	b	32.	b
7.	d	20.	a	33.	c
8.	b	21.	d	34.	b
9.	a	22.	d	35.	b
10.	b	23.	c	36.	c
11.	d	24.	b	37.	a
12.	a	25.	c	38.	c
13.	b	26.	a	39.	b
				40.	c