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ABSTRACT

This unit of instruction includes the principles of eddy current, magnetic particle and hardness testing; standards used for analyzing test results; techniques of operating equipment; interpretation of indications; advantages and limitations of these methods of testing; care and calibration of equipment; and safety and work precautions. Motion picture films and color slides are listed for use with the program. Study periods, group discussions, and extensive use of textbooks and training manuals are required. The booklet includes goals, specific block objectives, a bibliography, and a quinmester posttest sample. (EB)

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AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

Course Outline
AVIATION QUALITY CONTROL - ADVANCED - 9227
(Eddy Current, Magnetic Particle and
Hardness Testing)
Department 48 - Quin 9227.04

DADE COUNTY PUBLIC SCHOOLS
DIVISION OF INSTRUCTION • 1973

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

1450 NORTHEAST SECOND AVENUE

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

Course Outline

AVIATION QUALITY CONTROL - ADVANCED - 9227
(Eddy Current, Magnetic Particle and Hardness Testing)

Department 48 - Quin 9227.04

county office of

VOCATIONAL AND ADULT EDUCATION

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Miami, Florida 33132

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Course Description

9227	48	9227.04	Eddy Current, Magnetic Particle and Hardness Testing
State Category Number	County Dept. Number	County Course Number	Course Title

This course includes the principles of eddy current, magnetic particle and hardness testing; standards used for analyzing test results; techniques of operating equipment; interpretation of indications; advantages and limitations of these methods of testing; care and calibration of equipment and safety and work precautions.

Clock Hours: 135

PREFACE

The following quinmester course outline will serve as a guide for the high school or adult trainee in the use and care of eddy current, magnetic particle, and hardness testing equipment. This equipment is used in nondestructive testing applications.

This outline consists of eight blocks of instruction which are subdivided into several units each. These blocks will involve the techniques of operating, testing, and calibrating eddy current, magnetic particle and hardness testing equipment. Interpreting the indications, safety and work precautions and maintenance will also be covered. This course is 135 hours in length.

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 to bring into the classroom 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 Quinmester Advisory Committee and the Vocational Curriculum Materials Service, and has been approved by the Dade County Vocational Curriculum Committee.

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with Suggested Hourly Breakdown

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BLOCK

I. THEORY OF EDDY CURRENT TESTING (5 Hours)

Definition of Eddy Current	1
Factors Affecting Eddy Current Testing	1
Direction and Distribution of Eddy Current in Part Being Tested	1

II. EDDY CURRENT TESTING EQUIPMENT (5 Hours)

Sensing System	1
Indicating Instrument (Magnatest ED-520)	1

III. EDDY CURRENT TESTING TECHNIQUES (30 Hours)

Setting Up the Equipment	1
Reading Meter Indications	1
Advantages and Limitations of Eddy Current Testing	1
Care and Maintenance of Eddy Current Equipment	2

IV. MAGNETIC PARTICLE TESTING PRINCIPLES (15 Hours)

Theory of Magnetism	2
Magnetic Materials	2
Electrically Induced Magnetic Fields	2
Magnetizing Current Characteristics	2
Demagnetization	2

V. MAGNETIC PARTICLE TESTING EQUIPMENT (10 Hours)

Wet Horizontal Equipment	2
Portable Equipment	3
Demagnetizing Equipment	3
Mediums and Their Preparation	3

VI. TECHNIQUES IN TESTING WITH MAGNETIC PARTICLE INSPECTION EQUIPMENT (50 Hours)

Materials and Specimens Capable of Being Tested	3
Setting Up Equipment Prior to Test	3
Preparation of Specimen for Test	3
Magnetizing the Specimen	3
Applying the Particles to the Specimen	3
Interpretation of Indications	3
Techniques of Proper Demagnetizing of Specimens	3
Advantages and Limitations of Magnetic Particle Testing	4
Safety and Work Precautions	4
Care and Maintenance of Equipment	4

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VII. HARDNESS TESTING OF MATERIALS AND SPECIMENS (20 Hours)
Relationship of Hardness, Heat Treatment and Tensile Strength 4
Methods of Hardness Testing 4
Principle of the Rockwell Hardness Test 4
Techniques in Operating the Rockwell Hardness Tester 4
Preparation and Supporting the Specimen for Test . . . 4
Applying the Minor Load 4
Applying the Major Load 4
Releasing the Major Load 4
Reading the Proper Scale on the Dial 4
Calibrating the Instrument 4
Care and Maintenance of Instrument 4

VIII. QUINMESTER POST-TEST

APPENDIX: QUINMESTER POST-TEST SAMPLE 7

GOALS

The student must be able to:

1. Develop skills in the use of eddy current, magnetic particle, and hardness testing equipment for nondestructive testing.

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 - THEORY OF EDDY CURRENT TESTING

The student must be able to:

1. Explain the basic principle of eddy current testing.
2. Show by diagram, eddy current patterns induced by a surface coil, by an inside coil.

BLOCK II - EDDY CURRENT TESTING EQUIPMENT

The student must be able to:

1. Illustrate, on paper, test coil arrangement for surface coil and inside coil probes.
2. Explain the purpose of each control on the ED-520 instrument panel.

BLOCK III - EDDY CURRENT TESTING TECHNIQUES

The student must be able to:

1. Set up the ED-520 instrument and adjust lift-off and balance.
2. Calibrate instrument against a known standard.
3. Run a test on at least three specimens with known defects and interpret results.
4. Discuss with the instructor the advantages and limitations of the method of nondestructive testing.
5. Demonstrate proper care and maintenance of the ED-520 instrument and accessories.

BLOCK IV - MAGNETIC PARTICLE TESTING PRINCIPLES

The student must be able to:

1. Explain and discuss with instructor the basic theory of magnetism.
2. Show by diagram, magnetic lines of force produced by longitudinal magnetization of a specimen.
3. Show by diagram, magnetic lines of force produced by circular magnetization.
4. Illustrate a leakage field in a magnetized part.
5. List a group of ferromagnetic materials.
6. Name at least three materials of a diamagnetic nature.
7. Name at least three materials of a paramagnetic nature.
8. Explain the "right hand rule."
9. Solve at least three problems involving selection of proper current using the L/D ratio and ampere turns.
10. List at least three reasons where demagnetization of a part is not necessary.
11. List at least three reasons where demagnetization of a part is necessary.

BLOCK V - MAGNETIC PARTICLE TESTING EQUIPMENT

The student must be able to:

1. Explain to the instructor the major parts and the operation of the controls of a wet horizontal machine.
2. Demonstrate the operation of the demagnetization machine.
3. Make up a bath containing the proper concentration of particles for fluorescent or visable light use.

BLOCK VI - TECHNIQUES IN TESTING WITH MAGNETIC PARTICLE INSPECTION EQUIPMENT

The student must be able to:

1. Prepare and test at least three specimens with known defects by the longitudinal method and interpret the indications.
2. Prepare and test at least three specimens with known defects by the circular method and interpret the indications.
3. Demonstrate the dry method of particle application.
4. Demonstrate the wet continuous method of particle application.
5. Demagnetize a specimen and show by indication that it is completely demagnetized.

BLOCK VII - HARDNESS TESTING OF MATERIALS AND SPECIMENTS

The student must be able to:

1. Explain the basic principles of three systems of hardness testing.
2. Set up the Rockwell Hardness Tester and determine the hardness of at least four specimens of different shape and degree of hardness. Translate the scale reading into tensile strength and the hardness numbers of other systems.
3. Calibrate the Rockwell Hardness Tester using the calibration blocks provided with the instrument.
4. Measure conductivity of at least three unknown specimens of metal and compare with known specimens to determine hardness. Use the FM-120 instrument.

Course Outline

AVIATION QUALITY CONTROL - ADVANCED - 9227
(Eddy Current, Magnetic Particle and Hardness Testing

Department 48 - Quin 9227.04

I. THEORY OF EDDY CURRENT TESTING

A. Definition of Eddy Currents

B. Factors Affecting Eddy Current Testing
1. Conductivity
2. Permeability

C. Direction and Distribution of Eddy Current in Part Being Tested
1. Eddy currents induced by encircling coil
2. Eddy currents induced by inside coil
3. Eddy currents induced by surface coil
4. Depth of eddy current penetration

II. EDDY CURRENT TESTING EQUIPMENT

A. Sensing System
1. Test coil arrangement:
a. Surface coil
b. Inside coil
2. Test coil leads

B. Indicating Instrument (Magnatest ED-520)
1. Lift-off frequency control
2. Balance control
3. Selector switch
4. Indicating meter
5. Battery charging system

III. EDDY CURRENT TESTING TECHNIQUES

A. Setting Up the Equipment
1. Adjusting lift-off
2. Checking against standard

B. Reading Meter Indications
1. Probe position
2. Balance control

C. Advantages and Limitations of Eddy Current Testing
1. Depth penetration
2. Materials that can be tested
3. Indications and read out

D. Care and Maintenance of Eddy Current Equipment
   1. Charging batteries
   2. Repairing and making probes

IV. MAGNETIC PARTICLE TESTING PRINCIPLES

A. Theory of Magnetism
   1. Magnetic poles
   2. Magnetic field
   3. Lines of force
   4. Leakage field
   5. Longitudinal magnetization
   6. Circular magnetization

B. Magnetic Materials
   1. Ferromagnetic materials
   2. Diamagnetic materials
   3. Paramagnetic materials

C. Electrically Induced Magnetic Fields
   1. Right hand rule
   2. Magnetic flux
   3. Flux density
   4. Permeability
   5. Reluctance
   6. Residual magnetism
   7. Retentivity

D. Magnetizing Current Characteristics
   1. Alternating current
   2. Half and full wave rectification
   3. Penetration characteristics
   4. Current requirements
      a. Length versus diameter ratio
      b. Correct amperage for part size

E. Demagnetization
   1. Alternating current for demagnetization
   2. Direct current for demagnetization
   3. When and when not necessary to demagnetize
   4. Field strength meter to indicate demagnetization

V. MAGNETIC PARTICLE TESTING EQUIPMENT

A. Wet Horizontal Equipment
   1. Head stock and tail stock
   2. Using the coil
   3. Meters and pilot lights
   4. Current regulating switch
   5. Pump and nozzle for bath application
   6. Ultraviolet light operation
   7. Transfer switch positions
   8. Current source

V. MAGNETIC PARTICLE TESTING EQUIPMENT (Contd.)

a. Transformer
b. Rectifier

B. Portable Equipment
1. Electromagnetic yoke
2. Powder and bath applicators
3. Ultraviolet light

C. Demagnetizing Equipment
1. A.C. current coil
2. Timer and indicating light

D. Mediums and Their Preparation
1. Fluorescent and visible light particles
2. Wet suspension
a. Selection of color
b. Type of bath
c. Concentration of particles in bath
1. Use of centrifuge tube
2. Agitation of bath
3. Dry application of particles
a. Use of applicators
b. Color selection

VI. TECHNIQUES IN TESTING WITH MAGNETIC PARTICLE INSPECTION EQUIPMENT

A. Materials and Specimens Capable of Being Tested

B. Setting Up Equipment Prior to Test

C. Preparation of Specimen for Test

D. Magnetizing the Specimen
1. Performing the longitudinal magnetization
2. Performing circular magnetization

E. Applying the Particles to the Specimen
1. Dry method of application
2. Wet method of application
a. Continuous technique
b. Residual technique

F. Interpretation of Indications
1. Visible light indications
2. Fluorescent light indications
3. Using standards

G. Techniques of Proper Demagnetizing of Specimens
1. Using A.C. or D.C. current for demagnetization
2. Methods of detecting complete demagnetization

H. Advantages and Limitations of Magnetic Particle Testing

I. Safety and Work Precautions
   1. Handling the particles and baths
   2. Operating the equipment
      a. Electrical shock hazard
      b. Physical burn hazard

J. Care and Maintenance of Equipment
   1. Cleaning of electrical terminals
   2. Periodic draining and cleaning of tank pump hose and nozzle
   3. Lubrication of air cylinder

VII. HARDNESS TESTING OF MATERIALS AND SPECIMENS

A. Relationship of Hardness, Heat Treatment and Tensile Strength

B. Methods of Hardness Testing
   1. The Rockwell system
   2. The Brinell system
   3. The Shore Scleroscope
   4. Using the conductivity tester

C. Principle of the Rockwell Hardness Test
   1. The penetrator
   2. Minor load
   3. Major load
   4. Measure of penetration into material
   5. Dial indications

D. Techniques in Operating the Rockwell Hardness Tester
   1. Selecting the proper scale
   2. Selecting the penetrator
   3. Matching the weights to scale and penetrator

E. Preparation and Supporting the Specimen for Test

F. Applying the Minor Load

G. Applying the Major Load

H. Releasing the Major Load

I. Reading the Proper Scale on the Dial

J. Calibrating the Instrument
   1. Use of calibration blocks
   2. Adjustment on the instrument

K. Care and Maintenance of Instrument
   1. Servicing the dash-pot
   2. Lubrication

VIII. QUINMESTER POST-TEST

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1. Drama of Metal Forming, The. 16 mm. 28 min. Color. Sound. Shell Oil Co. Film Library.

2. Hardness Testing: Rockwell. 16 mm. B/W. Sound. Lindsey Hopkins Material Lab. Audiovisual Center.

3. Modern Steel Making, United States Steel. 16 mm. 32 min. Color. Sound. Associate Sterling Films.

4. Quality Assistance. 16 mm. 19 min. Color. Sound. George T. Baker Aviation School.

A P P E N D I X

Quinmester Post Test Sample

Quinmester Post-Test

Name _____ Date _____ Score ____

Multiple Choice Test Items

Each statement has one right answer. Place the letter of your choice in the space provided on the left side of the statement.

___ 1. Indications caused by leakage fields due to internal splines, keyways, and drilled holes close to a test surface are:

a. Defects
b. Nonrelevant
c. Magnetic writing
d. Boundary zones

___ 2. Which is the most sensitive:

a. Continuous method
b. Residual method

___ 3. How is the inside diameter of a cylinder best magnetized:

a. Head shot
b. Prods at either end
c. Central conductor placed between contact heads
d. Cylinder placed crosswise in solenoid

___ 4. The space within and surrounding a magnetized part or conductor carrying a current is known as:

a. Saturation point
b. Magnetic field
c. Ferromagnetic
d. Paramagnetic

___ 5. Permeability is the ease with which a metal or metallic part can be magnetized.

a. True
b. False

___ 6. The magnetism which remains in a piece of magnetizable material after the magnetizing force has been removed is called residual.

a. True
b. False

___ 7. The areas on a magnetized part from which the magnetic field is leaving or returning into the part is called:

a. Salient points
b. Defects
c. Magnetic poles
d. Field

___ 8. The strength of a magnetic field is known as:

a. Flux density
b. Ferromagnetic
c. Magnetic poles
d. Coercive force

___ 9. A sharp well defined indication is most likely to be:

a. Subsurface defect
b. Surface defect

___10. The defect indication is strongest when the magnetic field is at a 90^{o} angle to the defect.

a. True
b. False

___11. What group of materials is repelled by magnets:

a. Paramagnetic
b. Ferromagnetic
c. Fluxmatic
d. Diamagnetic

___12. What group of materials is most strongly affected by magnetism and may be inspected by magnetic particle inspection:

a. Diamagnetic
b. Alloys
c. Fluxmatic
d. Nickel based metals

___13. When the flux lines or lines of force traverse the part in a direction essentially parallel to the long axis of the test piece, the lines of force tend to return through the air from one pole to the other forming a closed magnetic field. This is known as what type of magnetization:

a. Circular
b. Longitudinal
c. Transverse
d. Continuous

___14. When longitudinally magnetizing a part in a coil, how is the effective amperage determined:

a. Amps applied multiplied by number of turns in a coil
b. Number of turns in coil multiplied by width of part
c. Amperage indicated by ammeter
d. $I = \frac{E}{R}$

___15. Through what medium are discontinuities demonstrated in magnetic particle inspection:

a. Finely divided ferromagnetic particles of high permeability, low coercive force and very high retentivity
b. Finely divided ferromagnetic particles of high permeability and low retentivity
c. Red oil like substance with good capillary action
d. Metal shavings and particles

___16. When the finely divided ferromagnetic particles are in oil suspension, the test method is called:

a. Oil and whiting technique
b. Oil suspension technique
c. Wet method
d. Spray or dip method

___17. Inspecting a part by magnetizing then applying the medium is called:

a. Continuous method
b. Wet method
c. Residual method
d. Dry method

___18. Subjecting the part to a magnetic field that is constantly reversing in polarity and gradually diminishing in strength accomplishes which of the following:

a. Magnetizes the part
b. Removes residual field from the part
c. Soaks in the flux density
d. Helps find deep lying defects

___19. To detect a seam in bar stock running parallel with the longitudinal axis, you would use the circular method.

a. True
b. False

___20. The magnetic field surrounding a bar magnet is most dense:

a. Near middle of magnet
b. At ends of magnet
c. One foot from magnet

___21. To locate defects, part should be magnetized so that the long axis of possible defects:

a. Is at right angles to lines of force
b. Is parallel to lines of force

___22. When electric current is passed through a coil, the direction of the lines of flux induced in a rod positioned within the coil is:

a. Circular
b. Unknown
c. Longitudinal
d. Vector

___23. The fluorescent magnetic particle inspection method is the same as the standard magnetic particle method except for:

a. Black light
b. Higher current
c. Different machine
d. Fluorescent material in suspension

___24. After wet magnetic particle inspection, a rinse bath is necessary:

a. To remove magnetic particles
b. To aid in removing remnat magnetism
c. To provide lubrication
d. Not necessary

___25. A surface defect produces an indication which is:

a. Sharp and distinct
b. Wide and indefinite
c. Criss cross
d. High and fuzzy

___26. An eddy current is a circulating electrical current induced in a conducting article by:

a. Gamma rays
b. An alternating magnetic field
c. A piezoelectric force
d. Any of the above

___27. The conductivity of a material can be changed by changing:

a. The alloy of the specimen
b. The heat treatment of the specimen
c. The temperature of the specimen
d. All of the above

___28. When testing plate with a probe coil, it is noted that the eddy current output indication varies as the distance from the coil to the surface of the test part varies. The term used to describe this action is:

a. Fill-factor
b. Lift-off
c. Phase differentiation
d. Edge effect

___29. Eddy current test coils which are wound to form a narrow coil would normally be used to detect:

a. Slow changes in dimensions
b. Gradual changes in conductivity
c. Variations in heat treatment
d. Small surface defects

___30. Which of the following could not be tested by the eddy current testing method:

a. A 4-inch thick plate to be tested for discontinuities throughout the plate
b. Tubing to be tested for surface cracks
c. Rod to be tested for laps and seams
d. Tubing to be tested for variation in outside diameter

Essay Questions

1. Name three methods of hardness testing.

2. In relation to the Rockwell Hardness tester, what is the "brail"?

3. What is the basis of the Rockwell Hardness test?

4. How is the minor load applied?

5. What do the letters % IACS stand for on the FM-120 conductivity tester?

ANSWER KEY FOR QUINMESTER POST-TEST

Multiple Choice Test Items

1.	b	16.	c
2.	a	17.	c
3.	c	18.	b
4.	b	19.	a
5.	a	20.	b
6.	a	21.	a
7.	c	22.	c
8.	a	23.	a
9.	b	24.	a
10.	a	25.	a
11.	d	26.	b
12.	c	27.	d
13.	b	28.	b
14.	a	29.	d
15.	a	30.	a

Essay Questions

1. Rockwell, Brinell, Shore Scleroscope
2. A diamond pointed penetrator
3. Linear measurement of depth of penetration between major and minor load
4. Raising the elevator with specimen against penetrator until small indicator on dial points vertically to black dot
5. Percent of international annealed copper standard