B1

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

MATERIALS AND HARDWARE

6

COMPLIANT WITH EASA
European Aviation Safety Agency
EASA PART 66/147

EASA 2023-989 COMPLIANT

REVISION LOG

Update notices for this book will be available online at www.actechbooks.com/revisions.html
If you would like to be notified when changes occur, please join our mailing list at www.actechbooks.com

VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2013.01	Module creation and release.
002	2014.07	Format Updates
003	2018.07	Modified Submodule sequence in accordance to Appendix A. Added content in the following areas: 6.3 – Thixotropic agents; Wood preservation methods; Types of fabric defects. 6.4 – Stress corrosion; Exfoliated corrosion detection; Galvanic corrosion growth; Fretting corrosion. 6.5 – Screw threads; Dowels. 6.6 – Rigid fluid line sizes; Swaged fittings. 6.7 – Laws obeyed by springs. 6.8 – Bearing material and construction. 6.11 – Connector types, Identification codes, and ratings.
003.1	2023.04	Inclusion of Measurement Standards for clarification, page iv. Minor appearance and format updates.
004	2024.04	Regulatory update for EASA 2023-989 compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 004 are:

6.1 *Aircraft Materials — Ferrous* - added Inspection of Ferrous material structures.
6.2 *Aircraft Materials — Non*-ferrous - added Inspection of Non-ferrous material structures.
6.3.1 *Aircraft Materials — Composite and Non*-metallic - added Sealant and Bonding Agents.
6.3.2 *Aircraft Materials — Composite and Non*-metallic - Wooden structures reduced to level 1.
6.3.3 *Aircraft Materials — Composite and Non*-metallic - Fabric covering reduced to level 1.
6.5.4 *Fasteners* - added Pin Fasteners, Lockbolts, Blind Bolts, and Rivnuts.

TABLE OF CONTENTS

MATERIALS AND HARDWARE

- Revision Log ... iii
- Measurement Standards ... iv
- Basic Knowledge Requirements ... v
- Part 66 Basic Knowledge Requirements ... vi
- Table of Contents ... ix

6.1 AIRCRAFT MATERIALS — FERROUS ... 1.1

- Properties of Metals ... 1.1
- Hardness ... 1.1
- Strength ... 1.1
- Density ... 1.1
- Malleability ... 1.1
- Ductility ... 1.1
- Elasticity ... 1.1
- Toughness ... 1.2
- Brittleness ... 1.2
- Fusibility ... 1.2
- Conductivity ... 1.2
- Thermal Expansion ... 1.2
- Iron ... 1.2
- Steel and Steel Alloys ... 1.2
  - Spark Testing ... 1.2
- Types of Alloyed Steel Carbon Steel ... 1.3
  - Nickel Steel ... 1.4
  - Chromium Steel ... 1.4
  - Stainless Steel ... 1.4
  - Chrome-Vanadium Steel ... 1.4
  - Chromoly Steel ... 1.4
  - Inconel ... 1.4
- Substitution of Aircraft Metals ... 1.4
- Metal Working Processes ... 1.4
  - Hot Working ... 1.4
  - Heat Treating ... 1.6
    - Internal Structure of Metals ... 1.6
    - Heat Treating Equipment ... 1.6
  - Furnaces and Salt Baths ... 1.7
    - Temperature Measurement and Control ... 1.7
  - Heating ... 1.7
  - Soaking ... 1.8
  - Cooling ... 1.8
  - Quenching Equipment ... 1.10
- Heat Treatment and Application of Alloy Steels ... 1.10
  - Behavior of Steel During Heating and Cooling ... 1.10
  - Hardening ... 1.10
    - Hardening Precautions ... 1.11
  - Tempering ... 1.11
  - Annealing ... 1.11
  - Normalizing ... 1.11
  - Case Hardening ... 1.12
    - Carburizing ... 1.12
    - Nitriding ... 1.12
  - Forging ... 1.12
  - Casting ... 1.12
  - Extruding ... 1.13
  - Cold Working/Hardening ... 1.13
- Section B ... 1.13
  - Hardness Testing ... 1.13
    - Brinell Tester ... 1.13
    - Rockwell Tester ... 1.14
    - Other Testing ... 1.15
    - Fatigue Strength Testing ... 1.15
    - Impact Testing ... 1.16
    - Electrochemical Testing of Stainless Versus Inconel ... 1.16
- Section C ... 1.17
  - Defects ... 1.17
  - Inspection Procedures ... 1.17
    - Visual Inspection ... 1.17
      - Surface Cracks ... 1.17
      - Borescopes ... 1.17
    - Non-Destructive Inspection (NDI) ... 1.17
  - Corrosion Control ... 1.18
  - General Repair Methods ... 1.18
- Submodule 1 Practice Questions ... 1.19
- Submodule 1 Practice Answers ... 1.20

6.2 AIRCRAFT MATERIALS — NON-FERROUS ... 2.1

- Section A ... 2.1
  - Characteristics, Properties and Identification of NonFerrous Materials ... 2.1
    - Aluminum ... 2.1
      - Wrought Aluminum ... 2.2
      - Effect of Alloying Element ... 2.3
      - Hardness Identification ... 2.3
    - Magnesium ... 2.3
    - Titanium ... 2.4
      - Titanium Designations ... 2.5
      - Corrosion Characteristics of Titanium ... 2.5
    - Copper ... 2.5
    - Nickel ... 2.6
      - Monel ... 2.6
      - K-Monel ... 2.6
      - Inconel ... 2.6
    - Substitution of Aircraft Metals ... 2.6
  - Heat Treatment of Non-Ferrous Alloys ... 2.7
    - Aluminum Alloys ... 2.7
      - Alclad Aluminum ... 2.7
      - Solution Heat Treatment ... 2.7
        - Temperature ... 2.7
        - Time at Temperature ... 2.7
      - Quenching ... 2.8
        - Cold Water Quenching ... 2.8
        - Hot Water Quenching ... 2.8
        - Spray Quenching ... 2.8
        - Lag Between Soaking and Quenching ... 2.8
      - Reheat Treatment ... 2.8
      - Straightening After Solution Heat Treatment ... 2.8
      - Precipitation Heat Treating ... 2.8
        - Precipitation Practices ... 2.9
      - Annealing of Aluminum Alloys ... 2.9
      - Heat Treatment of Aluminum Rivets ... 2.9
    - Magnesium Alloys ... 2.10

TABLE OF CONTENTS

Solution Heat Treatment 2.10
Precipitation Heat Treatment 2.10
Titanium 2.10
Stress Relieving 2.10
Annealing of Titanium 2.10
Thermal Hardening 2.11
Case Hardening 2.11
Casting 2.11
Extruding 2.11
Cold Working/Hardening 2.11
Section B 2.12
Hardness Testing 2.12
Brinell Tester 2.12
Rockwell Tester 2.12
Barcol Tester 2.13
Tensile, Fatigue and Impact Testing 2.13
Section C 2.13
Defects 2.13
Inspection Procedures 2.13
Visual Inspection 2.13
Surface Cracks 2.14
Borescopes 2.14
Non-Destructive Inspection (NDI) 2.14
Corrosion Control 2.14
General Repair Methods 2.14
Submodule 2 Practice Questions 2.15
Submodule 2 Practice Answers 2.16

6.3 AIRCRAFT MATERIALS — COMPOSITE AND NON-METALLIC 3.1
6.3.1 SECTION A 3.1
Characteristics, Properties and Identification 3.1
Composite Materials 3.1
Advantages/Disadvantages of Composites 3.1
Composite Safety 3.2
Fiber Reinforced Materials 3.2
Laminated Structures 3.2
Advanced Laminated Composite Materials 3.2
Major Components of a Laminate 3.3
Strength Characteristics 3.3
Fiber 3.3
Fiber Orientation 3.3
Warp Clock 3.3
Fiber Forms 3.4
Roving 3.4
Unidirectional (Tape) 3.4
Bidirectional Fabric 3.4
Non-woven (Knitted or Stitched) 3.5
Types of Fiber 3.5
Fiberglass 3.5
Kevlar® 3.6
Carbon/Graphite 3.6
Boron 3.6
Ceramic Fibers 3.6
Lightning Protection Fibers 3.6
Dry Fiber Material 3.7
Thermosetting Resins 3.7
Polyester Resins 3.7
Vinyl Ester Resin 3.7
Phenolic Resin 3.7
Epoxy 3.7
Polyimides 3.7
Polybenzimidazoles 3.8
Bismaleimides 3.8
Thermoplastic Resins 3.8
Semicrystalline Thermoplastics 3.8
Amorphous Thermoplastics 3.8
Polyether Ether Ketone 3.8
Curing Stages of Resins 3.8
Thixotropic Agents 3.8
Pre-Impregnated Products (Prepregs) 3.8
Adhesives 3.9
Film Adhesives 3.9
Paste Adhesives 3.9
Foaming Adhesives 3.10
Sandwich Structures 3.10
Properties 3.10
Facing Materials 3.10
Core Materials 3.11
Honeycomb 3.11
Foam 3.11
Balsa Wood 3.12
Plastics 3.12
Reinforced Plastic 3.12
Transparent Plastics 3.12
Optical Considerations 3.13
Storage and Handling 3.13
Forming Procedures and Techniques 3.13
Heating Wear 3.13
Forms 3.13
Forming Methods 3.14
Simple Curve Forming 3.14
Compound Curve Forming 3.14
Stretch Forming 3.14
Male and Female Die Forming 3.14
Vacuum Forming Without Forms 3.14
Vacuum Forming With a Female Form 3.14
Sawing 3.14
Drilling 3.14
Cementing 3.14
Application of Cement 3.14
Repairs 3.15
Cleaning 3.15
Polishing 3.15
Windshield Installation 3.15
Installation Procedures 3.16
Sealant and Bonding Agents 3.16
One Part Sealants 3.16
Two Part Sealants 3.16
6.3.1 Section b 3.17
Detection of Defects/Deterioration in Composite Materials 3.17
Fiber Breakage 3.17

Matrix Imperfections . . . 3.17
Delamination and Debonds . . . 3.18
Combinations of Damages . . . 3.18
Flawed Fastener Holes . . . 3.18
In-Service Defects . . . 3.18
Corrosion . . . 3.19
Non-Destructive Inspection of Composites . . . 3.19
Visual Inspection . . . 3.19
Audible Sonic Testing (Coin Tapping) . . . 3.19
Automated Tap Test . . . 3.20
Ultrasonic Inspection . . . 3.20
Through Transmission Ultrasonic Inspection . . . 3.21
Pulse Echo Ultrasonic Inspection . . . 3.21
Ultrasonic Bond Tester Inspection . . . 3.21
Phased Array Inspection . . . 3.21
Radiography . . . 3.21
Thermography . . . 3.22
Neutron Radiography . . . 3.22
Moisture Detector . . . 3.22
6.3.1 Section C . . . 3.22
Repair Procedures for Composite Materials and Structures . . . 3.22
Layup Materials and Tools . . . 3.22
Air Tools . . . 3.22
Caul Plate . . . 3.22
Support Tooling and Molds . . . 3.23
Vacuum Bag Materials . . . 3.23
Release Agents . . . 3.23
Bleeder Ply . . . 3.24
Peel Ply . . . 3.24
Layup Tapes . . . 3.24
Solid Release Film . . . 3.24
Breather Material . . . 3.24
Vacuum Bag . . . 3.24
Vacuum Equipment . . . 3.24
Vacuum Compaction Table . . . 3.25
Heat Sources . . . 3.25
Ovens . . . 3.25
Autoclave . . . 3.25
On Aircraft Heating . . . 3.25
Heat Bonder . . . 3.26
Heat Blanket . . . 3.26
Hot Air System . . . 3.26
Heat Press Forming . . . 3.26
Thermocouples . . . 3.27
Thermocouple Placement . . . 3.27
Thermal Survey of Repair Area . . . 3.27
Temperature Variations in Repair Zone . . . 3.27
Thermal Survey . . . 3.28
Solutions to Heat Sink Problems . . . 3.28
Types of Layups . . . 3.28
Wet Layups . . . 3.28
Prepregs . . . 3.28
Secondary Bonding . . . 3.29
Co-Bonding . . . 3.30
Wet Laminated Layup Techniques . . . 3.30
Bleedout Technique . . . 3.30
No Bleedout . . . 3.30
Ply Orientation Warp Clock . . . 3.31
Mixing Resins . . . 3.31
Saturation Techniques . . . 3.31
Impregnation With a Brush or Squeegee . . . 3.31
Vacuum Bagging Techniques . . . 3.31
Single Side Vacuum Bagging . . . 3.32
Envelope Bagging . . . 3.32
Impregnation Using a Vacuum Bag . . . 3.32
Alternate Pressure Application . . . 3.33
Shrink Tape . . . 3.33
C Clamps . . . 3.33
Shotbags and Weights . . . 3.33
Curing of Composite Materials . . . 3.33
Room Temperature Curing . . . 3.33
Elevated Temperature Curing . . . 3.33
Composite Honeycomb Sandwich Repairs . . . 3.34
Damage Classification . . . 3.35
Minor Core Damage (Filler and Potting Repairs) . . . 3.35
Damage Requiring Core Replacement and Repair to One or Both Face Plates . . . 3.35
Step 1: Inspect the Damage . . . 3.35
Step 2: Remove Water From Damaged Area . . . 3.35
Step 3: Remove the Damage . . . 3.35
Step 4: Prepare the Damaged Area . . . 3.35
Step 5: Installation of Honeycomb Core (Wet Layup) . . . 3.36
Step 6: Prepare and Install the Repair Plies . . . 3.37
Step 7: Vacuum Bag the Repair . . . 3.37
Step 8: Curing the Repair . . . 3.37
Step 9: Post Repair Inspection . . . 3.37
Bonded Flush Patch Repairs . . . 3.37
Step 1: Inspection and Mapping of Damage . . . 3.39
Step 2: Removal of Damaged Material . . . 3.39
Step 3: Surface Preparation . . . 3.39
Step 4: Molding . . . 3.39
Step 5: Laminating . . . 3.39
Step 6: Finishing . . . 3.39
Trailing Edge and Transition Area Patch Repairs . . . 3.39
Composite Patch Bonded to Aluminum Structure . . . 3.40
Fiberglass Molded Mat Repairs . . . 3.40
Radome Repairs . . . 3.40
External Bonded Patch Repairs . . . 3.41
External Bonded Repair With Prepreg Plies . . . 3.41
Step 1: Investigating and Mapping the Damage . . . 3.41
Step 2: Damage Removal . . . 3.41
Step 3: Layup of the Repair Plies . . . 3.41
Step 4: Vacuum Bagging . . . 3.41
Step 5: Curing the Repair . . . 3.41
Step 6: Applying Top Coat . . . 3.41
External Repair Using Wet Layup and Double Vacuum Debulk Method (DVD) . . . 3.41
Double Vacuum Debulk Principle . . . 3.41
Patch Installation on the Aircraft . . . 3.42
External Repair Using Precured Laminate Patches . . . 3.42
Step 3: A Precured Patch . . . 3.43
Step 4: For a Precured Patch . . . 3.43

TABLE OF CONTENTS

Bonded Versus Bolted Repairs. 3.43
Bolted Repairs 3.43
Bolted Repair Procedures 3.44
Step 1: Inspection of the Damage 3.44
Step 2: Removal of the Damage 3.44
Step 3: Patch Preparation. 3.44
Step 4: Hole Pattern Lay Out 3.44
Step 5: Drilling and Reaming Holes in Patch and Parent Structure 3.44
Step 6: Fastener Installation 3.44
Step 7: Sealing of Fasteners and Patch 3.44
Step 8: Finish Coat and Lightening Protection Mesh . . . 3.44
Fasteners Used With Composite Laminates 3.44
Corrosion Precautions 3.45
Fastener Materials 3.45
Fastener Systems 3.45
Adjustable Sustain Preload Fastening System (ASP) 3.45
Hi-Lok® and Huck-Spin® Lockbolt Fasteners 3.45
Eddie Bolt Fasteners 3.46
Cherry's E-Z Buck (CSR90433) Hollow Rivet. 3.46
Blind Fasteners. 3.46
Blind Bolts 3.47
Fiberlite 3.47
Screws and Nutplates in Composite Structures 3.47
Machining Processes and Equipment 3.47
Drilling 3.47
Equipment 3.48
Processes and Precautions 3.49
Countersinking 3.49
Cutting Processes. 3.50
Cutting Equipment 3.50
Repair Safety 3.50
Eye Protection 3.51
Respiratory Protection 3.51
Downdraft Tables 3.51
Skin Protection 3.51
Fire Protection 3.51
Section 6.3.2 . . . . 3.51
Construction Methods of Wooden Airframe Structures 3.51
Wood Aircraft Construction and Repairs. 3.52
Characteristics, Properties and Types of Wood and Glue Used in Aeroplanes 3.52
Wood 3.52
Glues (Adhesives) 3.52
Casein Glue 3.52
Plastic Resin Glue 3.52
Resorcinol 3.52
Epoxy. 3.53
Preservation and Maintenance of Wooden Structures 3.53
Wood Preservation 3.53
Care and Maintenance of Wood Frame Structures 3.53
Types of Defects in Wood Materials and Structures 3.54
Defects Permitted 3.54
Defects Not Permitted. 3.54
Detection of Defects in Wooden Structures 3.54
External and Internal Inspection. 3.54
Glued Joint Inspection. 3.55
Wood Condition 3.56
Repair of Wooden Structures 3.57
Gluing Procedures 3.57
Preparation of Wood for Gluing 3.57
Preparing Glues for Use. 3.58
Applying the Glue/Adhesive 3.58
Pressure on the Joint 3.58
Testing Glued Joints 3.58
Structural Repairs 3.59
Wing Rib Repairs 3.59
Bolt and Bushing Holes. 3.60
Finishing Wood Structures 3.60
Precautions. 3.61
Finishing Exterior Surfaces. 3.62
Finishing of End Grain Surfaces. 3.62
Sealing of Bolt Holes 3.62
Section 6.3.3 . . . . 3.62
Fabric Covering 3.62
General History 3.62
Characteristics, Properties and Types of Fabrics. 3.63
Fabric Terms 3.63
Approved Materials 3.63
Fabric 3.63
Anti-Chafe Tape 3.63
Reinforcing Tape 3.63
Rib Bracing 3.63
Surface Tape. 3.64
Rib Lacing Cord 3.64
Sewing Thread 3.64
Special Fabric Fasteners. 3.64
Inspection Rings 3.64
Primer 3.65
Fabric Cement 3.65
Fabric Sealer. 3.65
Fillers 3.65
Topcoats. 3.65
Types of Defects in Fabrics 3.66
Excess Tension. 3.66
Loose Fabric. 3.66
Coating Cracks 3.66
Deterioration 3.66
Inspection Methods for Fabric 3.67
Determining Fabric Condition; Repair or Recover?. 3.67
Fabric Strength 3.67
How Fabric Breaking Strength is Determined 3.67
Fabric Testing Devices. 3.67
Repair of Fabric Covering 3.68
Blanket Method Versus Envelope Method 3.68
Preparation for Fabric Covering Work 3.68
Removal of Old Fabric Coverings 3.68
Preparation of the Airframe Before Covering. 3.69
Attaching Polyester Fabric to the Airframe 3.70
Fabric Cement 3.70
Fabric Heat Shrinking. 3.71
Attaching Fabric to the Wing Ribs 3.71

Rib Lacing . . . 3.71
Rings, Grommets, and Gussets . . . 3.73
Finishing Tapes . . . 3.74
Coating the Fabric . . . 3.74
Polyester Fabric Repairs . . . 3.75
Applicable Instructions . . . 3.75
Repair Considerations . . . 3.75
Submodule 3 Practice Questions . . . 3.83

6.4 - CORROSION . . . 4.1
Section A . . . 4.1
Common Corrosive Agents . . . 4.1
Corrosion Formation . . . 4.2
Galvanic Action . . . 4.2
Microbiological Corrosion . . . 4.2
Stress Corrosion . . . 4.3
Section B . . . 4.3
General Surface Corrosion . . . 4.3
Pitting Corrosion . . . 4.3
Concentration Cell Corrosion . . . 4.4
Metal Ion Concentration Cells . . . 4.4
Oxygen Concentration Cells . . . 4.4
Active Passive Cells . . . 4.4
Filiform Corrosion . . . 4.5
Intergranular Corrosion . . . 4.6
Exfoliation Corrosion . . . 4.6
Galvanic Corrosion . . . 4.6
Stress Corrosion Cracking . . . 4.6
Fatigue Corrosion . . . 4.7
Fretting Corrosion . . . 4.8
Causes of Corrosion . . . 4.8
Material Types . . . 4.9
Aluminum and Aluminum Alloys . . . 4.9
Magnesium and Magnesium Alloys . . . 4.9
Ferrous Metals . . . 4.10
Noble Metals . . . 4.10
Chromium and Nickel Plated Parts . . . 4.10
Cadmium and Zinc Plated Parts . . . 4.10
Titanium and Titanium Alloys . . . 4.10
Susceptibility to Corrosion (Corrosion Prone Areas) . . . 4.10
Exhaust Trail Areas . . . 4.11
Battery Compartments and Battery Vent Openings . . . 4.11
Lavatories, Buffets and Galleys . . . 4.11
Bilge Areas . . . 4.11
Wheel Wells and Landing Gear . . . 4.11
External Skin Areas . . . 4.12
Water Entrapment Areas . . . 4.13
Engine Frontal Areas and Cooling Air Vents . . . 4.14
Electronic Package Compartments . . . 4.14
Miscellaneous Trouble Areas . . . 4.15
Seaplanes and Flooding . . . 4.16
Submodule 4 Practice Questions . . . 4.17
Submodule 4 Practice Answers . . . 4.18

6.5 FASTENERS . . . 5.1
6.5.1 Screw Threads . . . 5.2
Screw Principles . . . 5.2
The Inclined Plane . . . 5.2
Screw Nomenclature . . . 5.2
Bolt and Screw Terminology . . . 5.2
Screw Thread Terminology . . . 5.2
Thread Forms, Dimensions and Tolerances . . . 5.3
Coarse and Fine Pitch Threads . . . 5.3
Single and Multi Start Threads . . . 5.3
Screw Thread Profile . . . 5.3
International Thread System . . . 5.3
Unified Screw Thread . . . 5.3
Metric Screw Thread . . . 5.3
Choosing Threaded Fasteners . . . 5.3
Thread Tolerances . . . 5.4
Measuring Screw Threads . . . 5.4
Screw Thread Pitch . . . 5.4
Go-NoGo Gauges . . . 5.4
6.5.2 - Bolts, Studs And Screws . . . 5.4
Bolt Types: Specifications, Identification, and Marking of Aircraft Bolts, International Standards . . . 5.4
Aircraft Bolt Types . . . 5.4
Identification and Coding . . . 5.4
General Purpose Bolts . . . 5.4
Close Tolerance Bolts . . . 5.5
Internal Wrenching Bolts . . . 5.5
Special-Purpose Bolts . . . 5.5
Clevis Bolts . . . 5.6
Eyebolt . . . 5.6
Jo-Bolt . . . 5.6
Lockbolts . . . 5.6
Nuts: Self-locking, Anchor, Standard Types . . . 5.8
Aircraft Nuts . . . 5.8
Identification and Coding . . . 5.8
Non-Self-Locking Nuts . . . 5.8
Self-Locking Nuts . . . 5.9
Boots Self-Locking Nut . . . 5.9
Stainless Steel Self-Locking Nuts . . . 5.10
Elastic Stop Nuts . . . 5.10
Pal Nuts . . . 5.11
Sheet Spring Nuts . . . 5.11
Internal and External Wrenching Nuts . . . 5.11
Anchor Nuts . . . 5.11
Nutplates . . . 5.12
Sealing Nutplates . . . 5.12
Riveted and Rivetless Nutplates . . . 5.12
Rivnuts . . . 5.13
Machine Screws; Aircraft Specification . . . 5.14
Screws . . . 5.14
Identification/Coding for Screws . . . 5.14
Structural Screws . . . 5.14
Machine Screws . . . 5.14
Studs; Types and Uses . . . 5.14
Standard Studs . . . 5.15
Waisted Studs . . . 5.15
Stepped Studs . . . 5.15
Shouldered Studs . . . 5.15

TABLE OF CONTENTS

Self-Tapping Screws, Dowels ... 5.15
Self-Tapping Screws... 5.15
Drive Screws ... 5.16
Dowels ... 5.16
Thread Repair Hardware ... 5.16
Replacement Bushings... 5.16
Helicoils... 5.16
6.5.3 - Locking Devices ... 5.17
Aircraft Washers ... 5.17
Plain Washers ... 5.17
Lockwashers ... 5.17
Shakeproof Lockwashers... 5.18
Special Washers ... 5.18
LockPlates ... 5.18
Pins ... 5.18
Cotter Pins... 5.18
Cotter Pin Hole Line Up... 5.18
Cotter Pin Safetying ... 5.18
Roll Pins... 5.19
Quick Release (Captive) Fasteners ... 5.19
Turnlock Fasteners... 5.19
Dzus Fasteners... 5.19
Camloc Fasteners... 5.19
Airloc Fasteners ... 5.20
Keys ... 5.20
Safety Wire Locking ... 5.21
General Safety Wiring Rules... 5.21
Nuts, Bolts, and Screws ... 5.21
Oil Caps, Drain Cocks, and Valves... 5.22
Electrical Connectors ... 5.22
Turnbuckles ... 5.22
6.5.4 Aircraft Rivets ... 5.23
Standards and Specifications ... 5.23
Solid Shank Rivets... 5.24
Solid Rivet Identification... 5.24
Rivet Corrosion ... 5.25
Heat Treating Rivets ... 5.25
Blind Rivets ... 5.27
Friction Locked Blind Rivets ... 5.27
Mechanical Lock Blind Rivets ... 5.28
CherryMAX® Blind Rivets... 5.28
Removal of Mechanically Locked Blind Rivets ... 5.28
Blind Rivet Specifications ... 5.29
Rivet Material ... 5.29
Diameters... 5.29
Blind Rivet Identification ... 5.30
Nonstructural Blind Fasteners... 5.32
Pop rivets ... 5.32
Pull Through Nutplate Blind Rivets ... 5.32
Special Purpose Rivets and Fasteners ... 5.32
Pin Fastening Systems (High Shear Fasteners)... 5.32
Installation of High Shear Fasteners ... 5.32
Inspection of Pin Rivets... 5.32
Removal of Pin Rivets ... 5.32
Hi-Lok Fastening System ... 5.33
Hi-Tigue Fastening System... 5.33
Hi-Lite Fastening System ... 5.33
Lockbolt Fastening Systems ... 5.33
Installation Procedure ... 5.34
Lockbolt Inspection... 5.35
Lockbolt Removal ... 5.35
Blind Bolts... 5.35
Pull Type Blind Bolt ... 5.35
Cherry Maxibolt Blind Bolt System ... 5.35
Huck Blind Bolt System ... 5.35
Drive Nut Type of Blind Bolt ... 5.36
Installation procedure ... 5.36
Tapered Shank Bolt ... 5.36
Sleeve Bolts ... 5.37
Rivet Nuts ... 5.37
Rivnut Hole Preparation ... 5.37
Deutsch Rivets... 5.37
Hole Repair Hardware ... 5.38
Acres Fastener Sleeves ... 5.38
Identification ... 5.38
Hole Preparation ... 5.38
Installation... 5.38
Sleeve Removal ... 5.38
Submodule 5 Practice Questions... 5.41
Submodule 5 Practice Answers ... 5.42

6.6 PIPES AND UNIONS ... 6.1
Section A ... 6.1
Rigid Fluid Lines... 6.1
Tubing Material... 6.1
Copper Tubing... 6.1
Aluminum Alloy Tubing ... 6.1
Steel Tubing ... 6.1
Titanium Tubing 3AL-2.5V ... 6.1
Material Identification... 6.1
Tubing Sizes... 6.2
Flexible Hose Fluid Lines ... 6.2
Rubber Hose Materials and Construction ... 6.2
Buna-N... 6.2
Neoprene ... 6.2
Butyl... 6.2
Low, Medium, and High Pressure Hoses... 6.2
Teflon™ Hose ... 6.2
Hose Identification ... 6.2
Size Designations... 6.3
Fluid Line Identification ... 6.3
Section B ... 6.3
Fluid Line End Fittings... 6.3
Universal Bulkhead Fittings ... 6.4
AN Flared Fittings ... 6.4
Flareless Fittings ... 6.5
Swaged Fittings ... 6.7
Cryofit™ Fittings... 6.8
Flexible Hose Fittings ... 6.9
Submodule 6 Practice Questions... 6.11
Submodule 6 Practice Answers ... 6.12

6.7 SPRINGS 7.1
Types of Springs and Applications 7.1
Flat Springs 7.1
Leaf Springs 7.1
Spiral Springs 7.1
Helical Compression/Tension Springs 7.1
Helical Torsion Springs 7.1
Belleville (Cone Disc) Springs 7.2
Torsion Bar Springs 7.2
Spring Materials 7.2
Spring Dimensions 7.3
Spring Characteristics 7.3
Forces Exerted on, and Applied by Springs 7.3
Law Obeyed by Springs 7.3
Submodule 7 Practice Questions 7.5
Submodule 7 Practice Answers 7.6

6.8 BEARINGS 8.1
Bearing Loads 8.1
Bearings Material 8.1
Construction of Ball Bearings 8.1
Types of Bearings 8.2
Plain Bearings 8.2
Ball Bearings 8.2
Roller Bearings 8.2
Submodule 8 Practice Questions 8.3
Submodule 8 Practice Answers 8.4

6.9 TRANSMISSIONS 9.1
Driving and Driven Gears 9.1
Bevel Gears 9.1
Worm Gears 9.1
Helical Worm Gears 9.2
Planetary Gears 9.2
Rack and Pinion Gears 9.2
Gear Systems 9.2
Gear Terms 9.2
Backlash (or lash) 9.2
Idler Gear 9.3
Intermediate Gear 9.3
Compound Gear 9.3
Pinion Gear 9.3
Lay-shaft 9.3
Step-Up Drive 9.3
Step-Down Drive 9.3
Gear Ratio 9.3
Propeller Reduction Gearing 9.4
Gear Lash and Pattern 9.5
Non-gear Transmissions 9.6
Belts and Pulleys 9.6
Types of Belt Drives 9.6
Open Belt Drives 9.6
Crossed Belt Drives 9.6
Advantages and Disadvantages of Belt Drives 9.6
Chains and Sprocket 9.7
Advantages and Disadvantages of Chain Drives 9.7
Leaf Chains 9.8
Submodule 9 Practice Questions 9.9
Submodule 9 Practice Answers 9.10

6.10 CONTROL CABLES 10.1
Cable Control Systems 10.1
Types of Cables 10.1
Cable Construction 10.1
Cable Material 10.1
Cable Designations 10.1
Flexible Cables 10.1
Extra Flexible Cable 10.1
Non-Flexible Cables 10.2
End Fittings, Turnbuckles and Compensating Devices 10.2
Cable End Fittings 10.2
Cable Tension 10.2
Turnbuckles 10.2
Tensiometers 10.2
Compensating Devices 10.3
Pulleys and Cable System Components 10.3
Pulleys 10.3
Fairleads 10.4
Pressure Seals 10.4
Cable Connectors 10.4
Control Surface Travel Adjustment 10.4
Rigging Fixtures 10.4
Spring Back 10.4
Cable Drums 10.5
Aircraft Flexible Control Systems 10.5
Bowden Cables 10.5
Teleflex® Controls 10.5
Control Rods 10.6
Push Pull Rods 10.6
Torque Tubes 10.6
Submodule 10 Practice Questions 10.7
Submodule 10 Practice Answers 10.8

6.11 ELECTRICAL CABLES AND CONNECTORS 11.1
Conductors 11.1
Plating 11.2
Insulation 11.2
Wire Shielding 11.2
Wire Substitutions 11.2
Severe Wind and Moisture Problem (SWAMP) 11.3
Wire Size Selection 11.3
Current Carrying Capacity 11.3
Maximum Operating Temperature 11.6
Computing Current Carrying Capacity 11.6
Allowable Voltage Drop 11.9
Electric Wire Chart Instructions 11.9
Wire Identification 11.10
Placement of Identification Markings 11.10
Types of Wire Markings 11.11
High Tension and Coaxial Cables 11.11
High Tension Cables 11.11
Coaxial Cable 11.11

TABLE OF CONTENTS

Coaxial Connector Connectors 11.12
Crimping 11.12
Crimping Tools 11.12
Inspection and Testing of Crimped Joints. 11.12
Connectors. 11.12
Types of Connectors 11.15
In-Line Junctions. 11.15
Connector Identification Codes 11.16
Current and Voltage Rating. 11.16
Spare Contacts for Future Wiring. 11.16
Submodule 11 Practice Questions 11.19
Submodule 11 Practice Answers 11.20

Acronym Definitions A.1

ROCKWELL TESTER

The Rockwell hardness tester [**Figure 1-7**] measures the resistance to penetration, as does the Brinell tester. Instead of measuring the diameter of the impression, the Rockwell tester measures the depth, and the hardness is indicated directly on a dial attached to the machine.

The dial numbers in the outer circle are black, and the inner numbers are red. Rockwell hardness numbers are based on the difference between the depth of penetration at major and minor loads. The greater this difference, the lower the hardness number and the softer the material.

Two types of penetrators are used with the Rockwell tester: a diamond cone and a hardened steel ball. The load which forces the penetrator into the metal is called the major load and is measured in kilograms. The results of each penetrator and load combination are reported on separate scales, designated by letters.

The penetrator, the major load, and the scale vary with the kind of metal being tested. For hardened steels, the diamond penetrator is used; the major load is 150 kilograms; and the hardness is read on the "C" scale. When this reading is recorded, the letter "C" must precede the number indicated by the pointer.

The C-scale setup is used for testing metals ranging in hardness from C-20 to the hardest steel (usually about C-70). If the metal is softer than C-20, the B-scale setup is used. With this setup, the 1/16 inch ball is used as a penetrator; the major load is 100 kilograms; and the hardness is read on the B scale. In addition to the "C" and "B" scales, there are other setups for special testing. The scales, penetrators, major loads, and dial numbers to be read are listed in **Figure 1-8.**

The Rockwell tester is equipped with a weight pan, and two weights are supplied with the machine. One weight is marked in red. The other weight is marked in black. With no weight in the weight pan, the machine applies a major load of 60 kilograms. If the scale setup calls for a 100 kilogram load, the red weight is placed in the pan. For a 150 kilogram load, the black weight is added to the red weight. The black weight is always used with the red weight; it is never used alone.

Practically all testing is done with either the B scale setup or the C scale setup. For these scales, the colors may be used as a guide in selecting the weight (or weights) and in reading the dial. For

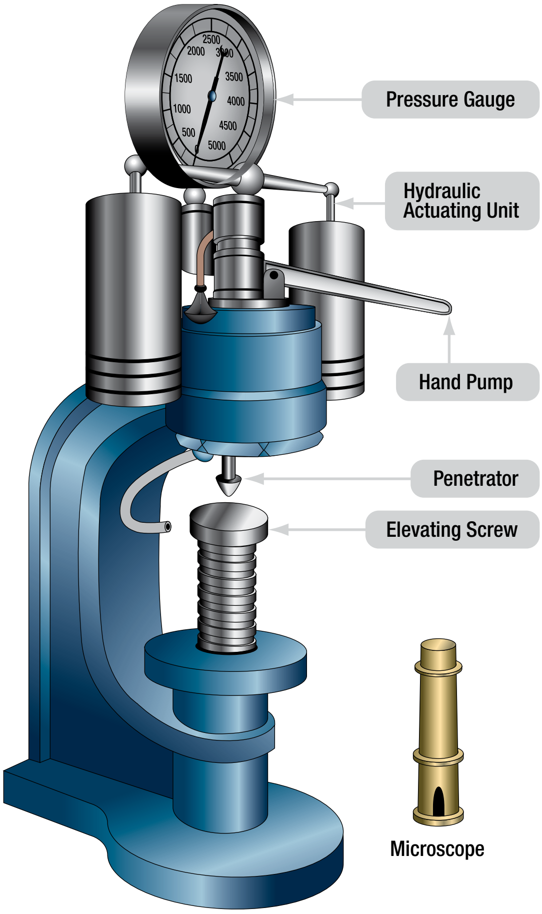

Figure 1-6. Brinell hardness tester.

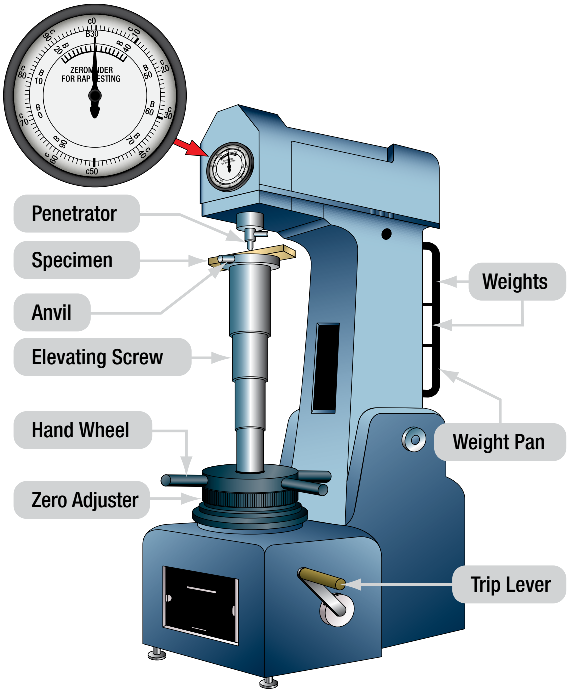

Figure 1-7. Rockwell hardness tester.

Scale Symbol	Penetrator	Major Load (kg)	Dial Color/Number
A	Diamond	60	Black
B	1/16-inch ball	100	Red
C	Diamond	150	Black
D	Diamond	100	Black
E	1/8-inch ball	100	Red
F	1/16-inch ball	60	Red
G	1/16-inch ball	150	Red
H	1/8-inch ball	60	Red
K	1/8-inch ball	150	Red

Figure 1-8 Standard Rockwell hardness scales.

the B-scale test, use the red weight and read the red numbers. For a C-scale test, add the black weight to the red weight and read the black numbers.

In setting up the Rockwell machine, use the diamond penetrator for testing materials known to be hard. If the hardness is unknown, try the diamond, since the steel ball may be deformed if used for testing hard materials. If the metal tests below C-22, then change to the steel ball. Use the steel ball for all soft materials, those testing less than B-100. Should an overlap occur at the top of the B-scale and the bottom of the C scale, use the C scale setup.

Before the major load is applied, securely lock the test specimen in place to prevent slipping and to seat the anvil and penetrator properly. To do this, apply a load of 10 kilograms before the lever is tripped. This preliminary load is called the minor load. The minor load is 10 kilograms regardless of the scale setup.

The metal to be tested in the Rockwell tester must be ground smooth on two opposite sides and be free of scratches and foreign matter. The surface should be perpendicular to the axis of penetration, and the two opposite ground surfaces should be parallel. If the specimen is tapered, the amount of error will depend on the taper. A curved surface will also cause a slight error in the hardness test. The amount of error depends on the curvature; i.e., the smaller the radius of curvature, the greater the error. To eliminate such error, a small flat should be ground on the curved surface if possible.

Clad aluminum alloy sheets cannot be tested directly with any accuracy with a Rockwell hardness tester. If the hardness value of the base metal is desired, the pure aluminum coating must be removed from the area to be checked prior to testing.

OTHER TESTING

Materials strength testing is largely done by manufacturer's and design engineers long before the field technician ever encounters the aircraft for maintenance. It is vitally important that all materials, not just metals, have the strength required for the application in which they are used. The tensile strength of a material is what is commonly thought of as the strength of a material. It is a measurement of tension, which is the stress that resists a force that tends to pull a material apart. To perform a test of tensile strength, the material is secured in a specially designed electromagnetically or hydraulically powered machine that exerts force on the material to pull it apart. While the force is applied and increased, dimensional measurements are made and recorded. Most materials will elongate before the force becomes so great that there is critical failure. Many materials also have an elastic range where a relatively small amount of force elongates the material, and, when released, the material returns to it's original dimensions.

A tensile strength test could be performed by clamping a sample of the material securely and then hanging weight from it until it fails. From this, one can understand that tensile strength is a weight related measurement. But the area of the sample is an important factor that contributes to when a sample will fail. Thus, to be able to compare tensile strengths of various materials, weight per unit area is used. In the Imperial system, this is denominated in of pounds per square inch (psi). In SI, measurement is typically in Pascals (Pa), hectoPascals (hPa) or kiloPascals (kPa) depending on the relative strength of the material being tested.

Many materials are tested along a single axis since they are isotropic. This means tensile strength is uniform in all directions. Aviation metals are in this category. Aircraft fabrics and composites are anisotropic, meaning that tensile strength varies depending upon which direction the force is applied. Standards exist for size, and shape of the sample material to be tested and the attachment methods into the testing machine are also carefully regulated. Alignment is important as well, especially in anisotropic. Test results can be graphed and numerous characteristics of the material can be examined or derived. **Figure 1-9** illustrates a tensile testing machine.

FATIGUE STRENGTH TESTING

Fatigue is a weakness in materials, especially metals, caused by repeated variations of stress. Fatigue is of great concern in aviation due to the constantly changing loads experience by nearly all parts of the structure during operation. Older aircraft are particularly suspect of weakness due to fatigue. The critical issue with fatigue is that numerous, repeated applications of over and over a relatively small load can result in failure. A single small load of the size under considerations size would have virtually no effect on the material. But application and release of the small load gradually weakens it. An example of fatigue failure is bending a piece of metal back and force until is weakened and breaks.

Aircraft and materials manufacturer's cannot rely solely on tradition strength measurements such as tensile strength or shear strength. Simple and elaborate repeated load and unload machines are constructed to observe fatigue in various structural aircraft components. There are also commercially available machines designed to test the fatigue strength of a variety of components. Stresses beyond those projected during service life are produced. The effects are measured so the component can be designed to perform without failure when installed on the aircraft.

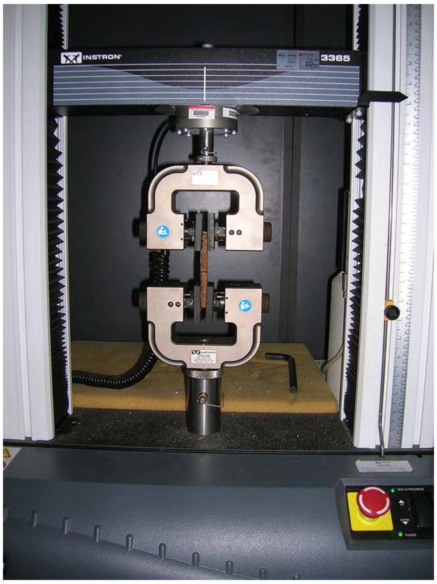

Figure 1-9. A tensile testing machine.

Metal fatigue can cause micro cracks and other fatigue damage precursors that are sought during periodic inspection. Visual, eddy current, ultra sound, fluorescent penetrant, magnetic particle, and even radiography inspection techniques are all employed in various situation to detect metal fatigue. The progression from a micro crack to cracks that join to cause a large section of metal to fail can be rapid. It is critical, especially on aircraft with a high number of operating cycles, to follow all manufacturer's specifications for investigating fatigue. New studies and method of detection are being developed such as electrochemical and light scattering inspection processes. Some country authorities have placed limits on the number of cycles an aircraft may accrue before it must be frequently inspected or retired from service.

IMPACT TESTING

Impact tests are used to indicate the toughness of a material and most importantly its ability to resist mechanical shock, to ensure that temper brittleness has not been introduced during heat treatments. Toughness is, broadly, a measure of the amount of energy required to cause an item - a test piece or a bridge or a pressure vessel - to fracture and fail. The more energy that is required then the tougher the material.

There are two types of machine used for testing aircraft materials, both of which use a pendulum weight to fracture the specimen. The energy absorbed by the specimen is measured from the angle through which the pendulum swings after causing the fracture. The IZOD test is required by most of the British material specifications, but where the test piece must be tested at high or low temperatures the CHARPY test is used. The test is carried out within the 6 seconds of removal of the test piece from the heating or cooling bath. Machines are available which carry out both the Izod and Charpy tests. [**Figure 1-10**]

ELECTROCHEMICAL TESTING OF STAINLESS VERSUS INCONEL

Prepare a wiring assembly as shown in **Figure 1-11**, and prepare the two reagents (ammonium fluoride and dimethylglyoxime solutions) placing them in separate dedicated dropper solution bottles. Before testing, you must thoroughly clean the metal in order for the electrolytic deposit to take place. You may use nonmetallic hand scrubbing pads or 320 to 600 grit "crocus cloth" to remove deposits and corrosion products (thermal oxide).

Connect the alligator clip of the wiring assembly to the bare metal being tested. Place one drop of a 0.05 percent reagent grade ammonium fluoride solution in deionized water on the center of a 1 inch × 1 inch sheet of filter paper. Lay the moistened filter paper over the bare metal alloy being tested. Firmly press the end of the aluminum rod over the center of the moist paper. Maintain connection for 10 seconds while rocking the aluminum rod on the filter paper. Ensure that the Light Emitting Diode (LED) remains lit (indicating good electrical contact and current flow) during this period.

Disconnect the wiring assembly and set it aside. Remove the filter paper and examine it to determine that a light spot appears where the connection was made.

Deposit one drop of 1.0 percent solution of reagent grade dimethylglyoxime in ethyl alcohol on the filter paper (same side that was in contact with the test metal). A bright, distinctly pink spot will appear within seconds on the filter paper if the metal being tested is Inconel. A brown spot will appear if the test metal is stainless steel. Some stainless steel alloys may leave a very light pink color. However, the shade and depth of color will be far less than would appear for Inconel. For flat surfaces, the test spot will be circular while for curved surfaces, such as the outside of a tube or pipe, the test spot may appear as a streak. (Refer to **Figure 1-12** for sample test results.) This procedure should not be used in the heat affected zone of weldments or on nickel coated surfaces.

Figure 1-10. An IZOD impact test machine.

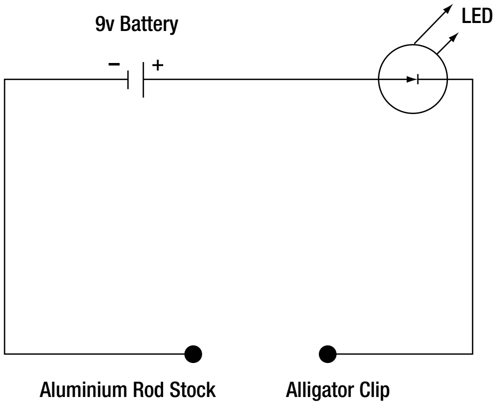

Figure 1-11. Wiring assembly schematic.

SECTION C

REPAIR AND INSPECTION PROCEDURES FOR FERROUS MATERIAL STRUCTURES AND AIRFRAMES

DEFECTS

A defect is any condition which reduces the serviceability of the part. There are nearly countless defects that could occur on an aircraft. However, manufacturers typically specify the areas needed to be inspected and the type of defect expected to be found. However, this does not relieve the technician of the responsibility to look for any sign of abnormality. The following types of defects can occur on ferrous components and structures.

- Overheating
- Distortion, dents, scores, and chafing
- Pulled or missing fasteners, rivets, bolts or screws
- Evidence of cracks or wear
- Failures of welds
- Deterioration of protective treatment
- Corrosion

INSPECTION PROCEDURES

VISUAL INSPECTION

As a first step in identifying any defect, the component or structure should be thoroughly cleaned.

Visual inspection can be enhanced by looking at the suspect area with a bright light, a magnifying glass, and a mirror (when required). Some defects might be so obvious that further inspection methods are not required.

SURFACE CRACKS

When searching for surface cracks with a flashlight, direct the light beam at a 5 to 45 degree angle to the inspection surface towards the face. [**Figure 1-13**] Do not direct the light beam at such an angle that the reflected light beam shines directly into the eyes. Determine the extent of any cracks found by directing the light beam at right angles to the crack and tracing its length. Use a 10 power magnifying glass to confirm the existence of a suspected crack. If this is not adequate, use other NDI techniques, such as penetrant, magnetic particle, ultrasonics or eddy current inspection to verify cracks.

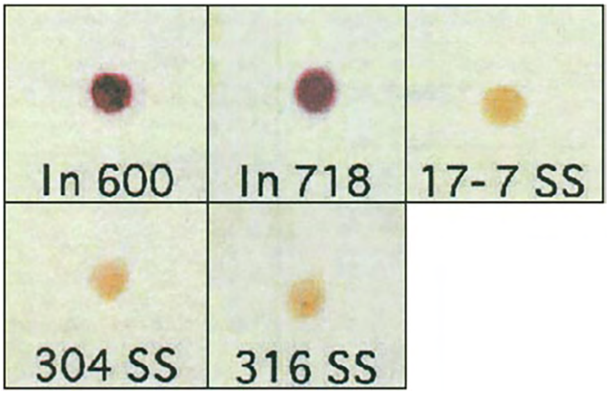

Figure 1-12. Electrochemical test results, Inconel and stainless steel alloys.

BORESCOPES

A borescope is a device that enables the inspector to see inside areas that could not otherwise be inspected without disassembly. An example of an area that can be inspected with a borescope would be the hot section of a turbine engine to which access could be gained through the hole of a removed igniter or removed access plugs specifically installed for inspection purposes.

Many borescopes provide images that can be displayed on a computer or video monitor for better interpretation of what is being viewed and to record images for future reference. Most borescopes also include a light to illuminate the area being viewed.

NON-DESTRUCTIVE INSPECTION (NDI)

The lack of visible defects does not necessarily mean further inspection is unnecessary. Some defects may lie beneath the surface or may be so small that the human eye, even with the assistance of a magnifying glass, cannot detect them.

The objective of non-destructive inspection is to determine the airworthiness of a component without damaging it. Some of these methods are simple, requiring little additional expertise, while others are highly sophisticated and require that the technician be highly trained and specially certified.

Before conducting NDI, it is necessary to follow preparatory steps in accordance with procedures specific to that type of inspection. Generally, the parts or areas must be thoroughly cleaned. Some parts must be removed from the aircraft or engine. Others might need to have any paint or protective coating stripped. A complete knowledge of the equipment and procedures is essential, and if required, calibration and inspection of the equipment must be current. The following NDI procedures are useful for ferrous materials:

Common non-destructive inspection techniques relevant to ferrous materials include:

- Visual inspection
- Penetrant inspections
- Eddy current inspections
- Ultrasonic inspections
- Magnetic particle inspection

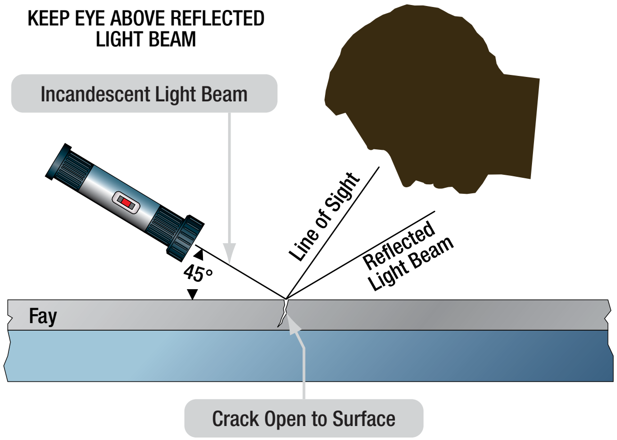

Figure 1-13. Using a flashlight to inspect for cracks.

Each of these techniques and the related equipment are covered in depth in *Module 7 Submodule 18 of the Aviation Maintenance Technician Certification series*.

CORROSION CONTROL

Corrosion is a problem that requires continuous preventive maintenance. Inspection for and removal of corrosion, including rust (ferrous oxide), the most common form of corrosion of ferrous material, is a critical step during any inspection and repair procedure. Corrosion, assessment, removal and control is covered in *Submodule 4* of this module and in *Submodule 18* of *Module 7* of the *Aviation Maintenance Technician Certification Series*.

GENERAL REPAIR METHODS

Aircraft structural members are designed to perform a specific function or to serve a definite purpose. The primary objective of aircraft repair is to restore damaged parts to their original condition. Very often, replacement is the only way this can be done effectively. When repair of a damaged part is possible, first study the part carefully to fully understand its purpose or function.

Strength may be the principal requirement in the repair of certain structures, while others may need entirely different qualities. For example, fuel tanks and floats must be protected against leakage; cowlings, fairings, and similar parts must have such properties as neat appearance, streamlined shape, and accessibility. The function of any damaged part must be carefully determined to ensure the repair meets the requirements.

Specific repair methods for all components, including ferrous structures are too numerous to be covered in this module. Aircraft Structural Repair Manuals (SRMs) can be many hundreds of pages long, encompassing nearly every conceivable repair to any aspect of the airframe the manufacturer deems appropriate. For older and non production aircraft where SRMs are not available, generalized documents exist such as the FAA Advisory Circular 43.13 1B/2B; Acceptable Methods of Aircraft Inspection and Repair which details the acceptable standards which must be followed for continuing airworthiness. When available, always consult the manufacturer's maintenance manual and the structural repair manual before beginning a repair on the aircraft and follow the instructions for the correct repair method.