CHAPTER 10

INSPECTION FUNDAMENTALS

GENERAL

Inspections are visual examinations and manual checks to determine the condition of an aircraft or component. An aircraft inspection can range from a casual walkaround to a detailed inspection involving complete disassembly and the use of complex inspection aids.

An inspection system consists of several processes, including: (1) Reports made by mechanics or by the pilot or crew flying an aircraft and (2) regularly scheduled inspections of an aircraft. An inspection system is designed to maintain an aircraft in the best possible condition. Thorough and repeated inspections must be considered the backbone of a good maintenance program. Irregular and haphazard inspection will invariably result in gradual and certain deterioration of an aircraft. The time which must eventually be spent in repairing an aircraft thus abused often totals far more than any time saved in hurrying through routine inspections and maintenance.

It has been proven that regularly scheduled inspections and preventive maintenance assure airworthiness. Operating failures and malfunctions of equipment are appreciably reduced if excessive wear or minor defects are detected and corrected early. The importance of inspections and the proper use of records concerning these inspections cannot be overemphasized.

Airframe and engine inspections may range from preflight inspections to detailed inspections. The time intervals for the inspection periods vary with the models of aircraft involved and the types of operations being conducted. The airframe and engine manufacturer's instructions should be consulted when establishing inspection intervals.

Aircraft may be inspected using flight hours as a basis for scheduling, or on a calendar inspection system. Under the calendar inspection system, the appropriate inspection is performed on the expiration of a specified number of calendar weeks. The calendar inspection system is an efficient system from a maintenance management standpoint. Scheduled replacement of components with stated hourly operating limitations is normally accomplished during the calendar inspection falling nearest the hourly limitation.

In some instances, a flight-hour limitation is established to limit the number of hours that may be flown during the calendar interval.

Aircraft operating under the flight-hour system are inspected when a specified number of flight hours are accumulated. Components with stated hourly operating limitations are normally replaced during the inspection that falls nearest the hourly limitation.

REQUIRED INSPECTIONS

Federal Aviation Regulations (FAR) provide for the inspection of all civil aircraft at specific intervals, depending generally upon the type of operations in which they are engaged, for the purpose of determining their overall condition. Some aircraft must be inspected at least once each 12 calendar months, while inspection is required for others after each 100 hours of flight. In other instances, an aircraft may be inspected in accordance with an inspection system set up to provide for total inspection of the aircraft over a calendar or flight-time period.

In order to determine the specific inspection requirements and rules for the preformance of inspections, reference should be made to the Federal Aviation Regulations which prescribe the requirements for the inspection and maintenance of aircraft in various types of operations.

INSPECTION TECHNIQUES

Before starting an inspection, be certain all plates, access doors, fairings, and cowling have been opened or removed and the structure cleaned. When opening inspection plates and cowling, and before cleaning the area take note of any oil or other evidence of fluid leakage.

CHECKLIST

Always use a checklist when performing the inspection. The checklist may be of your own design, one provided by the manufacturer of the equipment being inspected, or one obtained from some other source. The checklist should include the following:

1. Fuselage and hull group.
   a. Fabric and skin—for deterioration, distortion, other evidence of failure, and defective or insecure attachment of fittings.
   b. Systems and components—for proper installation, apparent defects, and satisfactory operation.
   c. Envelope gas bags, ballast tanks, and related parts— for condition.
2. Cabin and cockpit group.
   a. Generally—for cleanness and loose equipment that should be secured.
   b. Seats and safety belts—for condition and security.
   c. Windows and windshields—for deterioration and breakage.
   d. Instument—for condition, mounting, marking, and (where practicable) for proper operation.
   e. Flight and engine controls—for proper installation and operation.
   f. Batteries—for proper installation and charge.
   g. All systems—for proper installation, general condition, apparent defects, and security of attachment.
3. Engine and nacelle group.
   a. Engine section—for visual evidence of excessive oil, fuel, or hydraulic leaks, and sources of such leaks.
   b. Studs and nuts—for proper torquing and obvious defects.
   c. Internal engine—for cylinder compression and for metal particles or foreign matter on screens and sump drain plugs. If cylinder compression is weak, check for improper internal condition and improper internal tolerances.
   d. Engine mount—for cracks, looseness of mounting, and looseness of engine to mount.
   e. Flexible vibration dampeners—for condition and deterioration.
   f. Engine controls—for defects proper travel, and proper safetying.
   g. Lines, hoses, and clamps—for leaks, condition, and looseness.
   h. Exhaust stacks—for cracks, defects, and proper attachment.
   i. Accessories—for apparent defects in security of mounting.
   j. All systems—for proper installation, general condition defects, and secure attachment.
   k. Cowling—for cracks and defects.
   l. Ground runup and functional check—check all powerplant controls and systems for correct response, all instruments for proper operation and indication.
4. Landing gear group.
   a. All units—for condition and security of attachment.
   b. Shock absorbing devices—for proper oleo fluid level.
   c. Linkage, trusses, and members—for undue or excessive wear, fatigue, and distortion.
   d. Retracting and locking mechanism—for proper operation.
   e. Hydraulic lines—for leakage.
   f. Electrical system—for chafing and proper operation of switches.
   g. Wheels—for cracks defects, and condition of bearings.
   h. Tires—for wear and cuts.
   i. Brakes—for proper adjustment.
   j. Floats and skis—for security of attachment and obvious defects.
5. Wing and center section.
   a. All components—for condition and security.
   b. Fabric and skin—for deterioration, distortion, other evidence of failure, and security of attachment.
   c. Internal structure (spars, ribs compression members)—for cracks, bends, and security.
   d. Movable surfaces—for damage or obvious defects, unsatisfactory fabric or skin attachment and proper travel.
   e. Control mechanism—for freedom of movement, alignment, and security.
   f. Control cables—for proper tension, fraying, wear and proper routing through fairleads and pulleys,

6. Empennage group.
   a. Fixed surfaces—for damge or obvious defects, loose fasteners, and security of attachment.
   b. Movable control surfaces—for damage or obvious defects, loose fasteners, loose fabric, or skin distortion.
   c. Fabric or skin—for abrasion, tears, cuts or defects, distortion, and deterioration.
7. Propeller group.
   a. Propeller assembly—for cracks, nicks, bends, and oil leakage.
   b. Bolts—for proper torquing, and safetying.
   c. Anti-icing devices—for proper operations and obvious defects.
   d. Control mechanisms—for proper operation, secure mounting, and travel.
8. Communication and navigation group.
   a. Radio and electronic equipment—for proper installation and secure mounting.
   b. Wiring and conduits—for proper routing, secure mounting, and obvious defects.
   c. Bonding and shielding—for proper installation and condition.
   d. Antennas—for condition, secure mounting and proper operation.
9. Miscellaneous.
   a. Emergency and first-aid equipment—for general condition and proper stowage.
   b. Parachutes, life rafts, flares, etc.—inspect in accordance with the manufacturer's recommendations.
   c. Autopilot system—for general condition, security of attachment, and proper operation.

AIRCRAFT LOGS

"Aircraft logs" as used in this handbook is an inclusive term which applies to the aircraft logbook and all supplemental records concerned with the aircraft. The logs and records provide a history of maintenance and operation, control of maintanance schedules, and data for time replacements of components or accessories.

The aircraft logbook is the record in which all data concerning the aircraft is recorded. Information gathered in this log is used to determine the aircraft condition, date of inspections, time on airframe and engines. It reflects a history of all significant events occurring to the aircraft, its components, and accessories, and provides a place for indicating compliance with FAA Airworthiness Directives or manufacturers' service bulletins.

SPECIAL INSPECTIONS

During the service life of an aircraft, occasions may arise when landings are made in an overweight condition or part of a flight must be made through severe turbulence. Rough landings are also experienced for a number of reasons.

When these situations are encountered, special inspection procedures should be followed to determine if any damage to the aircraft structure has occurred. The procedures outlined on the following pages are general in nature and are intended to acquaint the aviation mechanic with the areas which should be inspected. As such, they are not all inclusive. When performing any one of these special inspections, always follow the detailed procedures in the aircraft maintenance manual.

Hard or Overweight Landing Inspection

The structural stress induced by a landing depends not only upon the gross weight at the time but also upon the severity of impact. However, because of the difficulty in estimating vertical velocity at the time of contact, it is hard to judge whether or not a landing has been sufficiently severe to cause structural damage. For this reason, a special inspection should be performed after a landing is made at a weight known to exceed the design landing weight or after a rough landing, even though the latter may have occurred when the aircraft did not exceed the design landing weight.

Wrinkled wing skin is the most easily detected sign of an excessive load having been imposed during a landing. Another indication which can be detected easily is fuel leaks along riveted seams. Other possible locations of damage are spar webs, bulkheads, nacelle skin and attachments, firewall skin, and wing and fuselage stringers.

If none of these areas show adverse effects, it is reasonable to assume that no serious damage has occurred. If damage is detected, a more extensive inspection and alignment check may be necessary.

Severe Turbulence Inspection

When an aircraft encounters a gust condition, the airload on the wings exceeds the normal wingload supporting the aircraft weight. The gust tends to accelerate the aircraft while its inertia acts to resist this change. If the combination of gust velocity and airspeed is too severe, the induced stress can cause structural damage.

A special inspection should be performed after a flight through severe turbulence. Emphasis should be placed upon inspecting the upper and lower wing surfaces for excessive buckles or wrinkles with permanent set. Where wrinkles have occurred, remove a few rivets and examine the rivet shanks to determine if the rivets have sheared or were highly loaded in shear.

Inspect all spar webs from the fuselage to the tip, through the inspection doors and other accessible openings. Check for buckling, wrinkles, and sheared attachments. Inspect for buckling in the area around the nacelles and in the nacelle skin, particularly at the wing leading edge.

Check for fuel leaks. Any sizeable fuel leak is an indication that an area may have received overloads which have broken the sealant and opened the seams.

If the landing gear was lowered during a period of severe turbulence, inspect the surrounding surfaces carefully for loose rivets, cracks, or buckling. The interior of the wheel well may give further indications of excessive gust conditions.

Inspect the top and bottom fuselage skin. An excessive bending moment may have left wrinkles of a diagonal nature in these areas.

Inspect the surface of the empennage for wrinkles, buckling, or sheared attachments, Also, inspect the area of attachment of the empennage to the fuselage.

The above inspections cover the critical areas. If excessive damage is noted in any of the areas mentioned, the inspection should be continued until all damage is detected.

PUBLICATIONS

Aeronautical publications are the sources of information for guiding aviation mechanics in the operation and maintenance of aircraft and related equipment. The proper use of these publications will greatly aid in the efficient operation and maintenance of all aircraft. These include manufacturers' service bulletins, manuals, and catalogs, as well as FAA regulations, airworthiness directives, advisory circulars, and aircraft, engine and propeller specifications.

Bulletins

Service bulletins are one of several types of publications issued by airframe, engine, and component manufacturers.

The bulletins may include: (1) The purpose for issuing the publication; (2) the name of the applicable airframe, engine, or component; (3) detailed instructions for service, adjustment, modification or inspection, and source of parts, if required; and (4) the estimated number of man-hours required to accomplish the job.

Maintenance Manual

The aircraft maintenance manual provided by the manufacturer contains complete instructions for maintenance of all systems and components installed in the aircraft. It contains information for the mechanic who normally works on units, assemblies, and systems, while they are installed in the aircraft, and not for the overhaul mechanic. A typical aircraft maintenance manual contains: (1) A description of the systems such as electrical, hydraulic, fuel, control, etc.; (2) lubrication instructions setting forth the frequency and the lubricants and fluids which are to be used in the various systems; (3) pressures and electrical loads applicable to the various systems; (4) tolerances and adjustments necessary to proper functioning of the airplane; (5) methods of leveling, raising, and towing; (6) methods of balancing control surfaces; (7) identification of primary and secondary structures; (8) frequency and extent of inspections necessary to the proper operation of the airplane; (9) special repair methods applicable to the airplane; (10) special inspection techniques requiring X-ray, ultrasonic, or magnetic particle inspection; and (11) a list of special tools.

Overhaul Manual

The manufacturer's overhaul manual contains brief descriptive information and detailed step-by-step instructions covering work normally performed on a unit away from the aircraft. Simple, inexpensive items, such as switches and relays, on which overhaul is uneconomical, are not covered in the overhaul manual.

Structural Repair Manual

This manual contains information and specific instructions from the manufacturer for repairing primary and secondary structure. Typical skin, frame, rib, and stringer repairs are covered in this manual. Also included are material and fastener substitutions and special repair techniques.

Illustrated Parts Catalog

This catalog presents component breakdowns of structure and equipment in disassembly sequence. Also included are exploded views or cutaway illustrations for all parts and equipment manufactured by the aircraft manufacturer.

Federal Aviation Regulations (FAR)

Federal Aviation Regulations were established by law to provide for the safe and orderly conduct of flight operations and to prescribe airmen privileges and limitations. A knowledge of the FARs is necessary during the performance of maintenance, since all work done on aircraft must comply with FAR provisions.

Airworthiness Directives

A primary safety function of the Federal Aviation Administration is to require correction of unsafe conditions found in an aircraft, aircraft engine, propeller, or appliance when such conditions exist and are likely to exist or develop in other products of the same design. The unsafe condition may exist because of a design defect, maintenance, or other causes. FAR Part 39, Airworthiness Directives, defines the authority and responsibility of the administrator for requiring the necessary corrective action. The Airworthiness Directives (AD) are the media used to notify aircraft owners and other interested persons of unsafe conditions and to prescribe the conditions under which the product may continue to be operated.

Airworthiness Directives are Federal Aviation Regulations and must be complied with, unless specific exemption is granted.

Airworthiness Directives may be divided into two categories: (1) Those of an emergency nature requiring immediate compliance upon receipt and (2) those of a less urgent nature requiring compliance within a relatively longer period of time.

The contents of ADs include the aircraft, engine, propeller, or appliance model and serial numbers affected. Also included are the compliance time or period, a description of the difficulty experienced, and the necessary corrective action.

Type Certificate Data Sheets

The type certificate data sheet describes the type design and sets forth the limitations prescribed by the applicable Federal Aviation Regulations. It also includes any other limitations and information found necessary for type certification of a particular model aircraft.

Type certificate data sheets are numbered in the upper right-hand corner of each page. This number is the same as the type certificate number. The name of the type certificate holder, together with all of the approved models, appears immediately below the type certificate number. The issue date completes this group, which is enclosed in a box to set it off.

The data sheet is separated into one or more sections. Each section is identified by a Roman numeral followed by the model designation of the aircraft to which the section pertains. The category or categories in which the aircraft can be certificated are shown in parentheses following the model number. Also included is the approval date shown on the type certificate.

The data sheet contains information regarding:

1. Model designation for all engines for which the aircraft manufacturer obtained approval for use with this model aircraft.
2. Minimum fuel grade to be used.
3. Maximum continuous and takeoff ratings of the approved engines, including manifold pressure (when used), r.p.m., and horsepower (hp.).
4. Name of the manufacturer and model designation for each propeller for which the aircraft manufacturer obtained approval will be shown together with the propeller limits and any operating restrictions peculiar to the propeller or propeller-engine combination.
5. Airspeed limits in both m.p.h. and knots.
6. Center of gravity range for the extreme loading conditions of the aircraft is given in inches from the datum. The range may also be stated in percent of MAC (Mean Aerodynamic Chord) for transport category aircraft.

7. Empty weight c.g. range (when established) will be given as fore and aft limits in inches from the datum. If no range exists, the word "none" will be shown following the heading on the data sheet.
8. Location of the datum.
9. Means provided for leveling the aircraft.
10. All pertinent maximum weights.
11. Number of seats and their moment arms.
12. Oil and fuel capacity.
13. Control surface movements.
14. Required equipment.
15. Additional or special equipment found necessary for certification.
16. Information concerning required placards.

It is not within the scope of this handbook to list all the items that can be shown on the type certificate data sheets. Those items listed above are merely to acquaint aviation mechanics with the type of information generally included on the data sheets.

A.T.A. Specification No. 100

The Air Transport Association of America (A.T.A.) issued the specifications for Manufacturers Technical Data June 1, 1956.

Quote: "This specification establishes a standard for the presentation of technical data, by an aircraft, aircraft accessory, or component manufacturer required for their respective products."

Quote: "In order to standardize the treatment of subject matter and to simplify the user's problem in locating instructions, a uniform method of arranging material in all publications has been developed."

The A.T.A. Specification 100 has the aircraft divided into systems such as electrical which covers the basic electrical system (ATA 2400). Numbering in each major system provides an arrangement for breaking the system down into several subsystems. Late model aircraft, both over and under the 12,500 dividing line, have their parts manuals and maintenance manuals arranged according to the A.T.A. coded system.

The following table of A.T.A. System, Subsystem, and Titles is included for familiarization purposes.

ATA SPEC. 100—Systems

Sys.	*Sub*	*Title*
21		AIR CONDITIONING
	00	General
	10	Compression
	20	Distribution
	30	Pressurization Control
	40	Heating
	50	Cooling
	60	Temperature Control
	70	Moisture/Air Contaminate Control
22		AUTO FLIGHT
	00	General
	10	Autopilot
	20	Speed-Attitude Correction
	30	Auto Throttle
	40	System Monitor
23		COMMUNICATIONS
	00	General
	10	High Frequency (HF)
	20	VHF/UHF
	30	Passenger Address and Entertainment
	40	Interphone
	50	Audio Integrating
	60	Static Discharging
	70	Audio and Video Monitoring
24		ELECTRICAL POWER
	00	General
	10	Generator Drive
	20	AC Generation
	30	DC Generation
	40	External Power
	50	Electrical Load Distribution

Sys.	*Sub*	*Title*
25		EQUIPMENT/FURNISHINGS
	00	General
	10	Flight Compartment
	20	Passenger Compartment
	30	Buffet/Galley
	40	Lavatories
	50	Cargo Compartments/AG Spray Apparatus
	60	Emergency
	70	Accessory Compartments
26		FIRE PROTECTION
	00	General
	10	Detection
	20	Extinguishing
	30	Explosion Suppression
27		FLIGHT CONTROLS
	00	General
	10	Aileron and Tab
	20	Rudder/Ruddervator and Tab
	30	Elevator and Tab
	40	Horizontal Stabilizers/Stabilator
	50	Flaps
	60	Spoiler, Drag Devices & Variable Aerodynamic Fairings
	70	Gust Lock and Dampener
	80	Lift Augmenting
28		FUEL
	00	General
	10	Storage
	20	Distribution/Drain Valves
	30	Dump
	40	Indicating

Sys.	*Sub*	*Title*
29		HYDRAULIC POWER
	00	General
	10	Main
	20	Auxiliary
	30	Indicating
30		ICE AND RAIN PROTECTION
	00	General
	10	Airfoil
	20	Air Intakes
	30	Pilot and Static
	40	Windows and Windshields
	50	Antennas and Radomes
	60	Propellers/Rotors
	70	Water Lines
	80	Detection
31		INDICATING/RECORDING SYSTEMS
	00	General
	10	Unassigned
	20	Unassigned
	30	Recorders
	40	Central Computers
	50	Central Warning System
32		LANDING GEAR
	00	General
	10	Main Gear
	20	Nose Gear/Tail Gear
	30	Extension & Retraction, Level Switch
	40	Wheels and Brakes
	50	Steering
	60	Position, Warning & Ground Safety Switch
	70	Supplementary Gear/Skis/Floats
33		LIGHTS
	00	General
	10	Flight Compartment & Annunciator Panels
	20	Passenger Compartments
	30	Cargo and Service Compartments
	40	Exterior Lighting
	50	Emergency Lighting
34		NAVIGATION
	00	General
	10	Flight Environment Data
	20	Attitude and Direction
	30	Landing and Taxiing Aids
	40	Independent Position Determining
	50	Dependent Position Determining
	60	Position Computing
35		OXYGEN
	00	General
	10	Crew
	20	Passenger
	30	Portable
36		PNEUMATIC
	00	General
	10	Distribution
	20	Indicating

Sys.	*Sub*	*Title*
37		VACUUM/PRESSURE
	00	General
	10	Distribution
	20	Indicating
38		WATER/WASTE
	00	General
	10	Potable
	20	Wash
	30	Waste Disposal
	40	Air Supply
39		ELECTRICAL/ELECTRONIC PANELS AND MULTIPURPOSE COMPONENTS
	00	General
	10	Instrument & Control Panels
	20	Electrical & Electronic Equipment Racks
	30	Electrical & Electronic Junction Boxes
	40	Multipurpose Electronic Components
	50	Integrated Circuits
	60	Printed Circuit Card Assemblies
49		AIRBORNE AUXILIARY POWER
	00	General
	10	Power Plant
	20	Engine
	30	Engine Fuel and Control
	40	Ignition/Starting
	50	Air
	60	Engine Controls
	70	Indicating
	80	Exhaust
	90	Oil
51		STRUCTURES
	00	General
52		DOORS
	00	General
	10	Passenger/Crew
	20	Emergency Exit
	30	Cargo
	40	Service
	50	Fixed Interior
	60	Entrance Stairs
	70	Door Warning
	80	Landing Gear
53		FUSELAGE
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Aerodynamic Fairings
54		NACELLES/PYLONS
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Fillets/Fairings

Sys.	*Sub*	*Title*
55		**STABILIZERS**
	00	General
	10	Horizontal Stabilizers/Stabilator
	20	Elevator/Elevon
	30	Vertical Stabilizer
	40	Rudder/Ruddervator
	50	Attach Fittings
56		**WINDOWS**
	00	General
	10	Flight Compartment
	20	Cabin
	30	Door
	40	Inspection and Observation
57		**WINGS**
	00	General
	10	Main Frame
	20	Auxiliary Structure
	30	Plates/Skin
	40	Attach Fittings
	50	Flight Surfaces
61		**PROPELLERS**
	00	General
	10	Propeller Assembly
	20	Controlling
	30	Braking
	40	Indicating
65		**ROTORS**
	00	General
	10	Main Rotor
	20	Anti-torque Rotor Assembly
	30	Accessory Driving
	40	Controlling
	50	Braking
	60	Indicating
71		**POWERPLANT**
	00	General
	10	Cowling
	20	Mounts
	30	Fireseals & Shrouds
	40	Attach Fittings
	50	Electrical Harness
	60	Engine Air Intakes
	70	Engine Drains
72		**(T) TURBINE/TURBOPROP**
	00	General
	10	Reduction Gear & Shaft Section
	20	Air Inlet Section
	30	Compressor Section
	40	Combustion Section
	50	Turbine Section
	60	Accessory Drives
	70	By-pass Section
72		**(R) ENGINE RECIPROCATING**
	00	General
	10	Front Section
	20	Power Section
	30	Cylinder Section
	40	Supercharger Section
	50	Lubrication

Sys.	*Sub*	*Title*
73		**ENGINE FUEL & CONTROL**
	00	General
	10	Distribution
	20	Controlling/Governing
	30	Indicating
74		**IGNITION**
	00	General
	10	Electrical Power Supply
	20	Distribution
	30	Switching
75		**BLEED AIR**
	00	General
	10	Engine Anti-Icing
	20	Accessory Cooling
	30	Compressor Control
	40	Indicating
76		**ENGINE CONTROLS**
	00	General
	10	Power Control
	20	Emergency Shutdown
77		**ENGINE INDICATING**
	00	General
	10	Power
	20	Temperature
	30	Analyzers
78		**ENGINE EXHAUST**
	00	General
	10	Collector/Nozzle
	20	Noise Suppressor
	30	Thrust Reverser
	40	Supplementary Air
79		**ENGINE OIL**
	00	General
	10	Storage (Dry Sump)
	20	Distribution
	30	Indicating
80		**STARTING**
	00	General
	10	Cranking
81		**TURBINES (RECIPROCATING ENG)**
	00	General
	10	Power Recovery
	20	Turbo-Supercharger
82		**WATER INJECTION**
	00	General
	10	Storage
	20	Distribution
	30	Dumping & Purging
	40	Indicating
83		**REMOTE GEAR BOXES (ENG DR)**
	00	General
	10	Drive Shaft Section
	20	Gearbox Section

MAGNETIC PARTICLE INSPECTION

Magnetic particle inspection is a method of detecting invisible cracks and other defects in ferromagnetic materials, such as iron and steel. This method of inspection is a nondestructive test, which means it is performed on the actual part without damage to the part. It is not applicable to nonmagnetic materials.

In rapidly rotating, reciprocating, vibrating, and other highly stressed aircraft parts, small defects often develop to the point that they cause complete failure of the part. Magnetic particle inspection has proved extremely reliable for the rapid detection of such defects located on or near the surface. In using this method of inspection, the location of the defect is indicated and the approximate size and shape are outlined.

The inspection process consists of magnetizing the part and then applying ferromagnetic particles to the surface area to be inspected. The ferromagnetic particles (indicating medium) may be held in suspension in a liquid that is flushed over the part; the part may be immersed in the suspension liquid; or the particles, in dry powder form, may be dusted over the surface of the part. The wet process is more commonly used in the inspection of aircraft parts.

If a discontinuity is present, the magnetic lines of force will be disturbed and opposite poles will exist on either side of the discontinuity. The magnetized particles thus form a pattern in the magnetic field between the opposite poles. This pattern, known as an "indication," assumes the approximate shape of the surface projection of the discontinuity. A discontinuity may be defined as an interruption in the normal physical structure or configuration of a part such as a crack, forging lap, seam, inclusion, porosity, and the like. A discontinuity may or may not affect the usefulness of a part.

Development of Indications

When a discontinuity in a magnetized material is open to the surface and a magnetic substance in the form of an indicating medium is available on the surface, the flux leakage at the discontinuity tends to form the indicating medium into a path of higher permeability. (Permeability is a term used to refer to the ease with which a magnetic flux can be established in a given magnetic circuit.) Because of the magnetism in the part and the adherence of the magnetic particles to each other, the indication remains on the surface of the part in the form of an approximate outline of the discontinuity that is immediately below it.

The same action takes place when the discontinuity is not open to the surface, but since the amount of flux leakage is less, fewer particles are held in place and a fainter and less sharply defined indication is obtained.

If the discontinuity is very far below the surface, there may be no flux leakage and, therefore, no indication on the surface. The flux leakage at a transverse discontinuity is shown in figure 10–1. The flux leakage at a longitudinal discontinuity is shown in figure 10–2.

Types of Discontinuities Disclosed

The following types of discontinuities are normally detected by the magnetic particle test: cracks, laps, seams, cold shuts, inclusions, splits, tears, pipes, and voids. All these may affect the reliability of parts in service.

Cracks, splits, bursts, tears, seams, voids, and pipes are formed by an actual parting or rupture of the solid metal. Cold shuts and laps are folds that have been formed in the metal, interrupting its continuity.

Inclusions are foreign material formed by impurities in the metal during the metal processing stages. They may consist, for example, of bits of furnace lining picked up during the melting of the basic metal or of other foreign constituents. Inclusions interrupt the continuity of the metal because they prevent the joining or welding of adjacent faces of the metal.

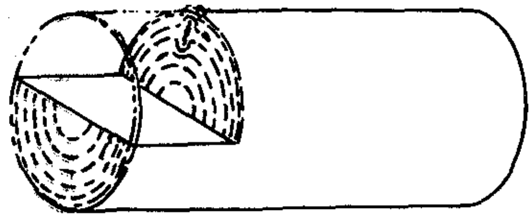


FIGURE 10–1. Flux leakage at transverse discontinuity.

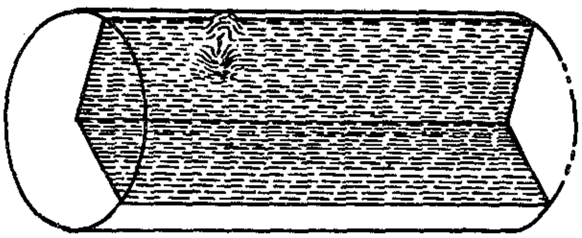


FIGURE 10–2. Flux leakage at longitudinal discontinuity.

Preparation of Parts for Testing

Grease, oil, and dirt must be cleaned from all parts before they are tested. Cleaning is very important, since any grease or other foreign material present can produce nonrelevant indications due to magnetic particles adhering to the foreign material as the suspension drains from the part.

Grease or foreign material in sufficient amount over a discontinuity may also prevent the formation of a pattern at the discontinuity. It is not advisable to depend upon the magnetic particle suspension to clean the part. Cleaning by suspension is not thorough, and any foreign materials so removed from the part will contaminate the suspension, thereby reducing its effectiveness.

In the dry procedure, thorough cleaning is absolutely necessary. Grease or other foreign material would hold the magnetic powder, resulting in nonrelevant indications and making it impossible to distribute the indicating medium evenly over the part's surface.

All small openings and oil holes leading to internal passages or cavities should be plugged with paraffin or other suitable nonabrasive material.

Coatings of cadmium, copper, tin, and zinc do not interfere with the satisfactory performance of magnetic particle inspection, unless the coatings are unusually heavy or the discontinuities to be detected are unusually small.

Chromium and nickel plating generally will not interfere with indications of cracks open to the surface of the base metal but will prevent indications of fine discontinuities, such as inclusions.

Because it is more strongly magnetic, nickel plating is more effective than chromium plating in preventing the formation of indications.

Effect of Flux Direction

In order to locate a defect in a part, it is essential that the magnetic lines of force pass approximately perpendicular to the defect. It is, therefore, necessary to induce magnetic flux in more than one direction, since defects are likely to

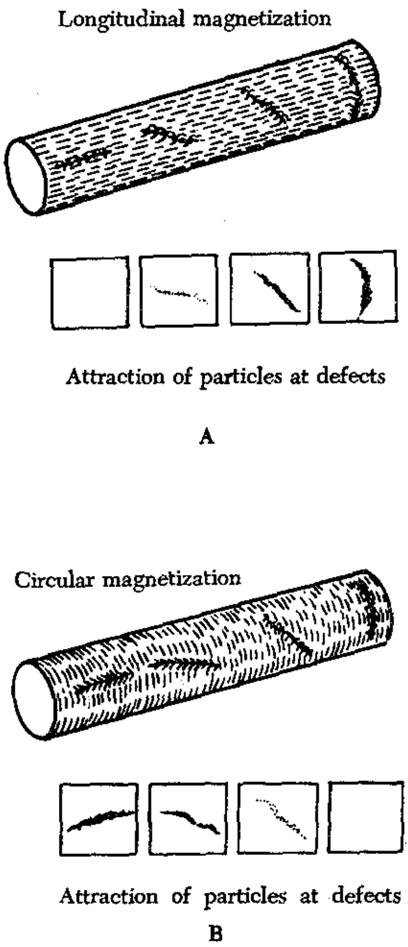


FIGURE 10–3. Effect of flux direction on strength of indication.

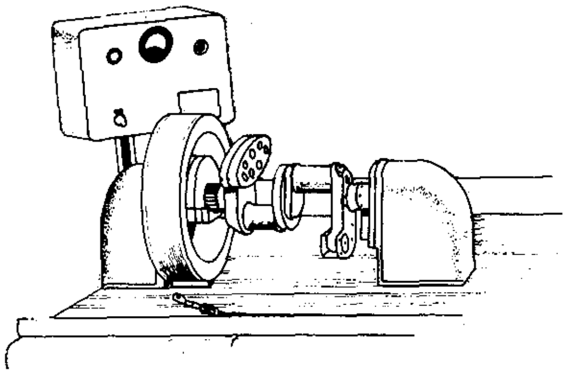


FIGURE 10–4. Circular magnetization of crankshaft.

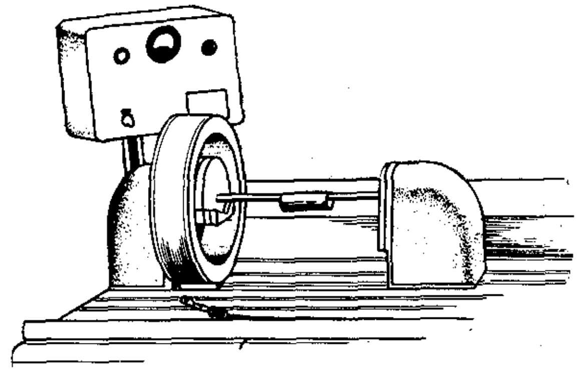


FIGURE 10–5. Circular magnetization of piston pin with conductor bar.

exist at any angle to the major axis of the part. This requires two separate magnetizing operations, referred to as circular magnetization and longitudinal magnetization. The effect of flux direction is illustrated in figure 10–3.

Circular magnetization is the inducing of a magnetic field, consisting of concentric circles of force about and within the part, by passing electric current through the part. This type of magnetization will locate defects running approximately parallel to the axis of the part.

Circular magnetization of a part of solid cross section is illustrated in figure 10–4. Each head of the magnetizing unit is electrically connected to a pushbutton control, so that when contact is made the magnetizing current passes from one head to the other through the part.

Figure 10–5 illustrates circular magnetization of a hollow part by passing the magnetizing current through a conductor bar located on the axis of the part.

In longitudinal magnetization the magnetic field is produced in a direction parallel to the long axis of the part. This is accomplished by placing the part in a solenoid excited by electric current. The metal part then becomes the core of an electromagnet and is magnetized by induction from the magnetic field created in the solenoid.

In longitudinal magnetization of long parts, the solenoid must be moved along the part in order to magnetize it. (See figure 10–6.) This is necessary to ensure adequate field strength throughout the entire length of the part.

Solenoids produce effective magnetization for approximately 12 inches from each end of the coil, thus accommodating parts or sections approximately 30 inches in length.

Longitudinal magnetization equivalent to that

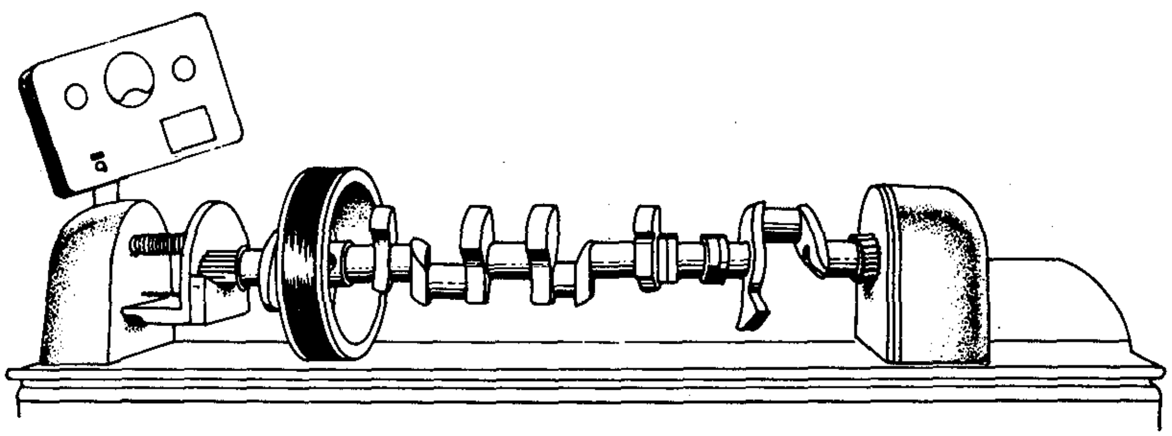


FIGURE 10–6. Longitudinal magnetization of crankshaft (solenoid method).

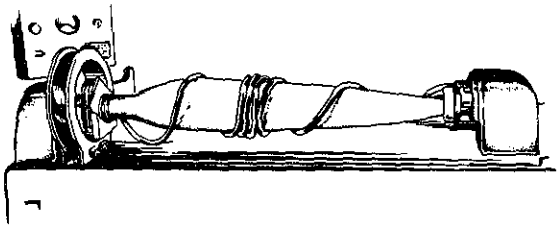


FIGURE 10–7. Longitudinal magnetization of steel propeller blade (cable method).

obtained by a solenoid may be accomplished by wrapping a flexible electrical conductor around the part, as shown in figure 10–7. Although this method is not as convenient, it has the advantage that the coils conform more closely to the shape of the part, thus producing somewhat more uniform magnetization.

The flexible coil method is also useful for large or irregularly shaped parts for which standard solenoids are not available.

Effect of Flux Density

The effectiveness of the magnetic particle inspection also depends on the flux density or field strength at the surface of the part when the indicating medium is applied. As the flux density in the part is increased, the sensitivity of the test increases because of the greater flux leakages at discontinuities and the resulting improved formation of magnetic particle patterns.

Excessively high flux densities, however, may form nonrelevant indications; for example, patterns of the grain flow in the material. These indications will interfere with the detection of patterns resulting from significant discontinuities. It is therefore necessary to use a field strength high enough to reveal all possible harmful discontinuities, but not strong enough to produce confusing nonrelevant indications.

Magnetizing Methods

When a part is magnetized, the field strength in the part increases to a maximum for the particular magnetizing force and remains at this maximum as long as the magnetizing force is maintained.

When the magnetizing force is removed, the field strength decreases to a lower residual value depending on the magnetic properties of the material and the shape of the part. These magnetic characteristics determine whether the continuous or residual method is used in magnetizing the part.

In the continuous inspection method, the part is magnetized and the indicating medium applied while the magnetizing force is maintained. The available flux density in the part is thus at a maximum. The maximum value of flux depends directly upon the magnetizing force and the permeability of the material of which the part is made.

The continuous method may be used in practically all circular and longitudinal magnetization procedures. The continuous procedure provides greater sensitivity than the residual procedure, particularly in locating subsurface discontinuities. The highly critical nature of aircraft parts and assemblies and the necessity for subsurface inspection in many applications have resulted in the continuous method being more widely used.

Inasmuch as the continuous procedure will reveal more nonsignificant discontinuities than the residual procedure, careful and intelligent interpretation and evaluation of discontinuities revealed by this procedure are necessary.

The residual inspection procedure involves magnetization of the part and application of the indicating medium after the magnetizing force has been removed. This procedure relies on the residual or permanent magnetism in the part and is more practical than the continuous procedure when magnetization is accomplished by flexible coils wrapped around the part.

In general, the residual procedure is used only with steels which have been heat treated for stressed applications.

Identification of Indications

The correct evaluation of the character of indications is extremely important but is sometimes difficult to make from observation of the indications alone. The principal distinguishing features of indications are shape, buildup, width, and sharpness of outline. These characteristics, in general, are more valuable in distinguishing between types of discontinuities than in determining their severity. However, careful observation of the character of the magnetic particle pattern should always be included in the complete evaluation of the significance of an indicated discontinuity.

The most readily distinguished indications are those produced by cracks open to the surface. These discontinuities include fatigue cracks, heat-

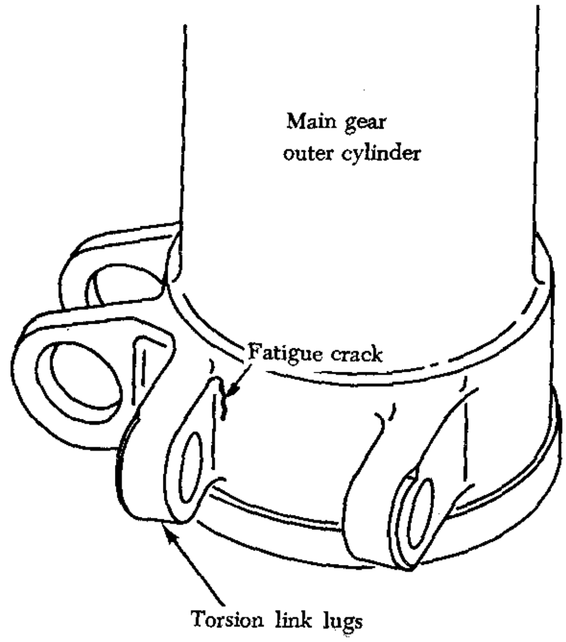


FIGURE 10–8. Fatigue crack in a landing gear.

treat cracks, shrink cracks in welds and castings, and grinding cracks.

Fatigue cracks give sharp, clear patterns, generally uniform and unbroken throughout their length and with good buildup. They are often jagged in appearance, as compared with the straight indications of a seam, and may also change direction slightly in localized areas. Figure 10–8 illustrates a fatigue crack.

Fatigue cracks are found in parts that have been in service but are never found in new parts. They are usually in highly stressed areas of the part or where a stress concentration exists for some reason. It is important to recognize that even a small fatigue crack indicates positively that failure of the involved parts is in progress.

Heat-treat cracks have a smooth outline but are usually less clear and have less buildup than fatigue cracks. On thin sections, such as cylinder barrel walls, heat-treat cracks may give very heavy patterns (figure 10–9). These heat-treat cracks have a characteristic form, consisting of short jagged lines grouped together.

Shrink cracks give a sharp, clear pattern and the line is usually very jagged. Since the walls of shrink cracks are close together, their indications generally build up to less extent than do indications of fatigue cracks.

Grinding cracks are fine and sharp but seldom have a buildup because of their limited depth. Grinding cracks vary from single line indications to a heavy network of lines. Grinding cracks are generally related to the direction of grinding. For example, the crack usually begins and continues at right angles to the motion of a grinding wheel, giving a rather symmetrical pattern. Indications of grinding cracks can frequently be identified by means of this relation.

Indications of seams are usually straight, sharp, and fine. They are often intermittent and sometimes have very little buildup.

Hairlines are very fine seams in which the faces of the seam have been forced very close together during fabrication. Hairline indications are very fine and sharp, with very little buildup. Discontinuities of this type are normally considered detrimental only in highly stressed parts.

Inclusions are nonmetallic materials, such as slag materials and chemical compounds, that have been trapped in the solidifying ingot. They are usually elongated and strung out as the ingot is worked in subsequent processing operations.

FIGURE 10–9. Heat-treat cracks on cylinder barrel wall.

Inclusions appear in parts in varying sizes and shapes, from stringers easily visible to the eye to particles only visible under magnification. In a finished part they may occur as either surface or subsurface discontinuities.

Indications of subsurface inclusions are usually broad and fuzzy. They are seldom continuous or of even width and density throughout their length. Larger inclusions, particularly those near or open to the surface, appear more clearly defined. Close examination, however, will generally reveal their lack of definition and the fact that the indication consists of several parallel lines rather than a single line. These characteristics will usually distinguish a heavy inclusion from a crack.

When cavities are located considerably below the surface of a part, the magnetic particle test is not a reliable method of detecting them. If any indication is obtained, it is likely to be an indistinct and inexact outline of the cavity, with the magnetic substance tending to distribute over the whole area rather than to outline clearly the boundary of the discontinuity. Defects of this type are detected more easily by radiographic procedures.

Laps may be identified by their form and location. They tend to occur at the ends or flash line of a forging. The indications are usually heavy and irregular. Islands and short branch indications usually break a lap indication of any length, and the scale included in the lap invariably gives fuzzy or small fernlike patterns stemming from the main indication.

When an ingot solidifies, the distribution of the various elements or compounds, generally, is not uniform throughout the mass of the ingot. Marked segregations of some constituents may thus occur. As the ingot is forged and then rolled, these segregations are elongated and reduced in cross section. Upon subsequent processing, they may appear as very thin parallel lines or bands, known as banding.

Segregation in the form of banding is sometimes revealed by magnetic particle inspection, particularly when high field strengths are used. Banding is not normally considered significant.

The most serious forms of segregation probably occur in castings. Here the basic condition of the metal remains unaltered in the finished part, and any segregations occur as they were originally formed. They may vary in size and will normally be irregular in shape. They may occur on or below the surface.

Magnaglo Inspection

Magnaglo inspection is similar to the preceding method, except that a fluorescent particle solution is used and the inspection is made under black light. Efficiency of inspection is increased by the neon-like glow of defects, and smaller flaw indications are more readily seen. This is an excellent method for use on gears, threaded parts, and aircraft engine components. The reddish brown liquid spray or bath that is used consists of Magnaglo paste mixed with a light oil at the ratio of .10 to .25 ounce of paste per gallon of oil.

After inspection, the part must be demagnetized and rinsed with a cleaning solvent.

MAGNETIZING EQUIPMENT

Fixed Unit (Nonportable)

A fixed general-purpose unit is shown in figure 10–10. This unit provides direct current for wet continuous or residual magnetization procedures. Either circular or longitudinal magnetization may be used, and it may be powered with rectified a.c. as well as d.c.

The contact heads provide the electrical terminals for circular magnetization. One head is fixed in position. Its contact plate is mounted on a shaft surrounded by a pressure spring, in order that the plate may be moved longitudinally. The plate is maintained in the extended position by the spring until pressure transmitted through the work from the movable head forces it back.

The movable head slides horizontally in longitudinal guides and is motor driven. It is controlled by a switch. The spring allows sufficient overrun of the motor-driven head to avoid jamming it and also provides pressure on the ends of the work to ensure good electrical contact.

A plunger-operated switch in the fixed head cuts out the forward motion circuit of the movable head motor when the spring has been properly compressed.

In some units the movable head is hand operated, and the contact plate is sometimes arranged for operation by an air ram. Both contact plates are fitted with various fixtures for supporting the work.

The magnetizing circuit is closed by depressing a pushbutton on the front of the unit. It is set to open automatically, usually after about one-half second.

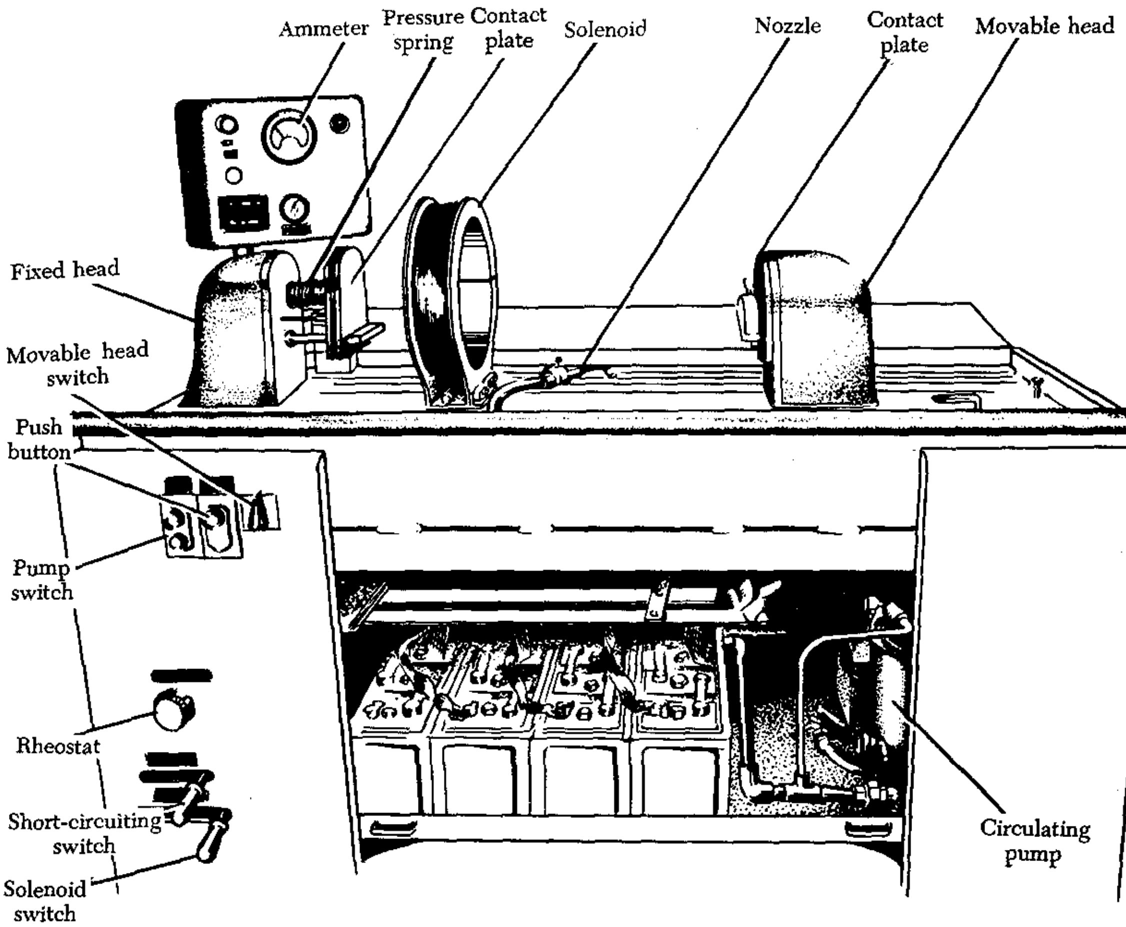


FIGURE 10–10. Fixed general-purpose magnetizing unit.

The strength of the magnetizing current may be set manually to the desired value by means of the rheostat or increased to the capacity of the unit by the rheostat short-circuiting switch. The current utilized is indicated on the ammeter.

Longitudinal magnetization is produced by the solenoid, which moves in the same guide rail as the movable head and is connected in the electrical circuit by means of a switch.

The suspension liquid is contained in a sump tank and is agitated and circulated by a pump. The suspension is applied to the work through a nozzle. The suspension drains from the work through the wooden grill into a collecting pan that leads back to the sump. The circulating pump is operated by a pushbutton switch.

General-Purpose Portable Unit

It is often necessary to perform the magnetic particle inspection at locations where fixed general-purpose equipment is not available or to perform an inspection on members of aircraft structures without removing them from the aircraft. This has occurred, particularly on landing gears and engine mounts suspected of having developed cracks in service. Equipment suitable for this purpose, supplying both alternating-current and direct-current magnetization, is available. A typical example is shown in figure 10–11.

This unit is only a source of magnetizing and demagnetizing current and does not provide a means for supporting the work or applying the suspension. It operates on 200-volt, 60-cycle, alternating current and contains a rectifier for producing direct current when required.

The magnetizing current is supplied through the flexible cables. The cable terminals may be fitted with prods, as shown in the illustration, or with contact clamps. Circular magnetization may be developed by using either the prods or clamps.

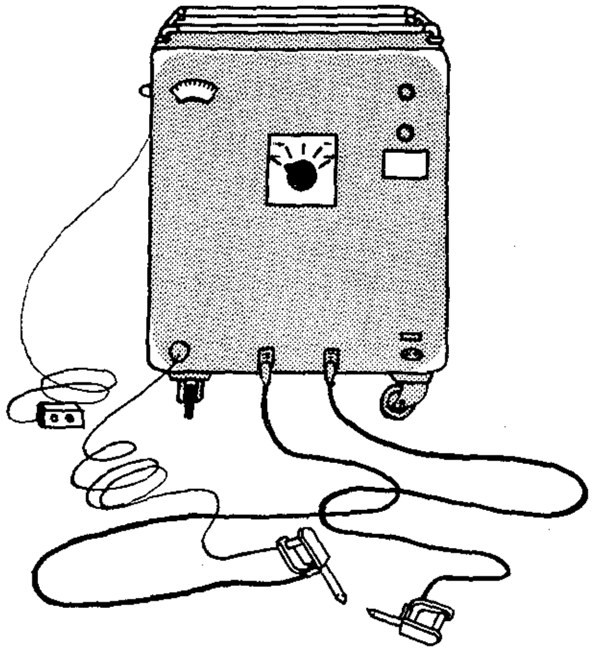


FIGURE 10–11. General-purpose portable unit.

Longitudinal magnetization is developed by wrapping the cable around the part.

The strength of the magnetizing current is controlled by an eight-point tap switch, and the length of time for which it is applied is regulated by an automatic cutoff similar to that used in the standard general-purpose unit.

This portable unit also serves as a demagnetizer and supplies high-amperage, low-voltage, alternating current for this purpose. For demagnetization, the alternating current is passed through the part and gradually reduced by means of a current reducer.

In testing large structures with flat surfaces where current must be passed through the part, it is sometimes impossible to use contact clamps. In such cases contact prods are used.

Prods can be used with the standard general-purpose unit as well as the portable unit. The part or assembly being tested may be suspended above the standard unit and the suspension hosed onto the area; excessive suspension drains into the tank. The dry procedure may also be used.

Prods should be held firmly against the surface being tested. There is a tendency for a high-amperage current to cause burning at contact areas, but with proper care, such burning will usually be slight. For applications where prod magnetization is acceptable, slight burning is normally not objectionable.

When it is desired to use cable with the standard general-purpose unit as a source of power, a contact block is useful. This consists of a wooden block fitted at each end with copper plates spaced to receive the terminals of the cable.

When the contact block is placed between the heads of a standard unit, the regular controls and timing switches of the unit can be used to regulate the magnetizing current. This provides a convenient way of connecting the cable to the source of power and eliminates the necessity for bolted connections.

When magnetizing current is passed through a steel propeller blade for circular magnetization, it is possible to burn the blade tip if necessary precautions are not taken. This possibility can be avoided by the use of a hinged clamp attached to the movable head of the inspection unit.

The clamp is lined with copper braid, which provides good electrical contact by conforming to the curvature of the propeller blade faces. This fixture avoids electrical contact at the thin edge of the blade tip and eliminates high current intensities which may cause burning at the point. The butt end of the blade is supported by a plug mounted on the other head.

Indicating Mediums

The various types of indicating mediums available for magnetic particle inspection may be divided into two general types: wet process materials and dry process materials. The basic requirement for any indicating medium is that it produce acceptable indications of discontinuities in parts.

The contrast provided by a particular indicating medium on the background or part surface is particularly important. The colors most extensively used are black and red for the wet procedure; and black, red, and gray for the dry procedure.

For acceptable operation, the indicating medium must be of high permeability and low retentivity. High permeability ensures that a minimum of magnetic energy will be required to attract the material to flux leakage caused by discontinuities. Low retentivity ensures that the mobility of the magnetic particles will not be hindered; that is, by the particles themselves becoming magnetized and attracting one another.

The magnetic substance for the wet process is usually supplied in paste form. The red paste improves visibility on dark surfaces. Although the exact amount of magnetic substance to be added may vary somewhat, a concentration of 2 ounces of paste per gallon of liquid vehicle has been found generally acceptable. The paste must not be dumped into the suspension liquid in the tank, since the unit agitator and pump cannot be depended on to do the mixing.

The proper procedure for preparing a suspension is to place the correct amount of paste in a container and add small quantities of the suspension liquid, working each addition with a flat paddle until the paste has been diluted to a uniform watery mixture which can then be poured into the tank.

It is important that new magnetic substance always be used in preparing suspensions. When the suspension becomes discolored or otherwise contaminated to the extent that the formation of magnetic particle patterns is interfered with, the unit should be drained, cleaned, and refilled with clean suspension.

DEMAGNETIZATION

The permanent magnetism remaining after inspection must be removed by a demagnetization operation if the part is to be returned to service. Parts of operating mechanisms must be demagnetized to prevent magnetized parts from attracting filings, grindings, or chips inadvertently left in the system, or steel particles resulting from operational wear.

An accumulation of such particles on a magnetized part may cause scoring of bearings or other working parts. Parts of the airframe must be demagnetized so they will not affect instruments.

Demagnetization between successive magnetizing operations is not normally required unless experience indicates that omission of this operation results in decreased effectiveness for a particular application. Previously, this operation was considered necessary to remove completely the existing field in a part before it was magnetized in a different direction.

Demagnetization may be accomplished in a number of different ways. Possibly the most convenient procedure for aircraft parts involves subjecting the part to a magnetizing force that is continually reversing in direction and, at the same time, gradually decreasing in strength. As the decreasing magnetizing force is applied first in one direction and then the other, the magnetization of the part also decreases.

Standard Demagnetizing Practice

The simplest procedure for developing a reversing and gradually decreasing magnetizing force in a part involves the use of a solenoid coil energized by alternating current. As the part is moved away from the alternating field of the solenoid, the magnetism in the part gradually decreases.

A demagnetizer as near the size of the work as practicable should be used; and, for maximum effectiveness, small parts should be held as close to the inner wall of the coil as possible.

Parts that do not readily lose their magnetism should be passed slowly in and out of the demagnetizer several times and, at the same time, tumbled or rotated in various directions. Allowing a part to remain in the demagnetizer with the current on accomplishes very little practical demagnetization.

The effective operation in the demagnetizing procedure is that of slowly moving the part out of the coil and away from the magnetizing field strength. As the part is withdrawn, it should be kept directly opposite the opening until it is 1 or 2 feet from the demagnetizer.

The demagnetizing current should never be cut off until the part is 1 or 2 feet from the opening; otherwise, the part will usually be re-magnetized.

Another procedure used with portable units is to pass alternating current through the part being demagnetized and gradually reduce the current to zero.

DYE-PENETRANT INSPECTION

Penetrant inspection is a nondestructive test for defects open to the surface in parts made of any nonporous material. It is used with equal success on such metals as aluminum, magnesium, brass, copper, cast iron, stainless steel, and titanium. It may also be used on ceramics, plastics, molded rubber, and glass.

Penetrant inspection will detect such defects as surface cracks or porosity. These defects may be caused by fatigue cracks, shrinkage cracks, shrinkage porosity, cold shuts, grinding and heat-treat cracks, seams, forging laps, and bursts. Penetrant inspection will also indicate a lack of bond between joined metals.

The main disadvantage of penetrant inspection is that the defect must be open to the surface in order to let the penetrant get into the defect. For this reason, if the part in question is made of material which is magnetic, the use of magnetic particle inspection is generally recommended.

Penetrant inspection depends for its success upon a penetrating liquid entering the surface opening and remaining in that opening, making it clearly visible to the operator. It calls for visual examination of the part after it has been processed, but the visibility of the defect is increased so that it can be detected. Visibility of the penetrating material is increased by the addition of dye which may be either one or two types—visible or fluorescent.

The visible penetrant kit consists of dye penetrant, dye remover-emulsifier and developer. The fluorescent penetrant inspection kit contains a black light assembly as well as spray cans of penetrant, cleaner, and developer. The light assembly consists of a power transformer, a flexible power cable, and a hand-held lamp. Due to its size, the lamp may be used in almost any position or location.

Briefly, the steps to be taken when performing a penetrant inspection are:

1. Thorough cleaning of the metal surface.
2. Applying penetrant.
3. Removing penetrant with remover-emulsifier or cleaner.
4. Drying the part.
5. Applying the developer.
6. Inspecting and interpreting results.

Interpretation of Results

The success and reliability of a penetrant inspection depends upon the thoroughness with which the part was prepared. Several basic principles applying to penetrant inspection are:

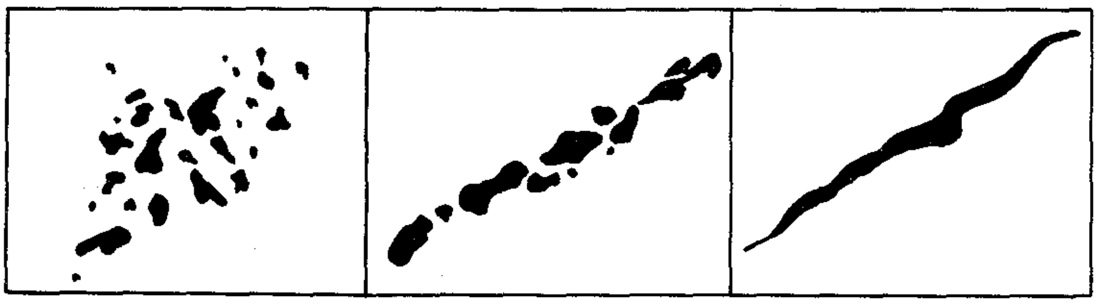
1. The penetrant must enter the defect in order to form an indication. It is important to allow sufficient time so the penetrant can fill the defect. The defect must be clean and free of contaminating materials so that the penetrant is free to enter.
2. If all penetrant is washed out of a defect, an indication cannot be formed. During the washing or rinsing operation, prior to development, it is possible that the penetrant will be removed from within the defect, as well as from the surface.
3. Clean cracks are usually easy to detect. Surface openings that are uncontaminated, regardless of how fine, are seldom difficult to detect with the penetrant inspection.
4. The smaller the defect, the longer the penetrating time. Fine crack-like apertures require a longer penetrating time than defects such as pores.
5. When the part to be inspected is made of a material susceptible to magnetism, it should be inspected by a magnetic particle inspection method, if the equipment is available.
6. Visible penetrant-type developer, when applied to the surface of a part, will dry to a smooth, even, white coating. As this developer dries, bright red indications will appear where there are surface defects. If no red indications appear, there are no surface defects.
7. When conducting the fluorescent penetrant-type inspection, the defects will show up (under black light) as a brilliant yellow-green color and the sound areas will appear deep blue-violet.
8. It is possible to examine an indication of a defect and to determine its cause as well as its extent. Such an appraisal can be made if something is known about the manufacturing processes to which the part has been subjected.

The size of the indication, or accumulation of penetrant, will show the extent of the defect, and the brilliance will be a measure of its depth. Deep cracks will hold more penetrant and, therefore, will be broader and more brillant. Very fine openings can hold only small amounts of penetrants and, therefore, will appear as fine lines. Figure 10–12 shows some of the types of defects that can be located using dry penetrant.

False Indications

With the penetrant inspection there are no false indications in the sense that such things occur in the magnetic particle inspection. There are, however, two conditions which may create accumulations of penetrant that are sometimes confused with true surface cracks and discontinuities.

The first condition involves indications caused by poor washing. If all the surface penetrant is not removed in the washing or rinsing operation following the penetrant dwell time, the unremoved penetrant will be visible. Evidences of incomplete washing are usually easy to identify since the penetrant is in broad areas rather than in the sharp patterns found with true indications. When accumulations of unwashed penetrant are found on a part, the part should be completely repro-



Pits of porosity — Tight crack or partially welded lap — Crack or similar opening

FIGURE 10–12. Types of defects.

cessed. Degreasing is recommended for removal of all traces of the penetrant.

False indications may also be created where parts press-fit to each other. If a wheel is press-fit onto a shaft, penetrant will show an indication at the fit line. This is perfectly normal since the two parts are not meant to be welded together. Indications of this type are easy to identify since they are so regular in form and shape.

RADIOGRAPHY

X- and gamma radiations, because of their unique ability to penetrate material and disclose discontinuities, have been applied to the radiographic (X-ray) inspection of metal fabrications and nonmetallic products.

The penetrating radiation is projected through the part to be inspected and produces an invisible or latent image in the film. When processed, the film becomes a radiograph or shadow picture of the object. This inspection medium, in a portable unit, provides a fast and reliable means for checking the integrity of airframe structures and engines.

Radiographic inspection techniques are used to locate defects or flaws in airframe structures or engines with little or no disassembly. This is in marked contrast to other types of nondestructive testing, which usually require removal, disassembly, and stripping of paint from the suspected part before it can be inspected. Due to the nature of X-ray, extensive training is required to become a qualified radiographer, and only qualified radiographers are allowed to operate the X-ray units.

Three major steps in the X-ray process discussed in subsequent paragraphs are: (1) Exposure to radiation, including preparation, (2) processing of film, and (3) interpretation of the radiograph.

Preparation and Exposure

The factors of radiographic exposure are so interdependent that it is necessary to consider all factors for any particular radiographic exposure. These factors include, but are not limited to, the following:

(a) Material thickness and density.
(b) Shape and size of the object.
(c) Type of defect to be detected.
(d) Characteristics of X-ray machine used.
(e) The exposure distance.
(f) The exposure angle.
(g) Film characteristics.
(h) Types of intensifying screen, if used.

Knowledge of the X-ray unit's capabilities should form a background for the other exposure factors. In addition to the unit rating in kilovoltage, the size, portability, ease of manipulation, and exposure particulars of the available equipment should be thoroughly understood.

Previous experience on similar objects is also very helpful in the determination of the overall exposure techniques. A log or record of previous exposures will provide specific data as a guide for future radiographs.

Film Processing

After exposure to X-rays, the latent image on the film is made permanently visible by processing it successively through a developer chemical solution, an acid bath, and a fixing bath, followed by a clear water wash.

The film consists of a radiation-sensitive silver salt suspended in gelatin to form an emulsion. The developer solution converts radition-affected elements in the emulsion to black metallic silver.

These black metallic particles form the image. The longer the film remains in the developer, the more metallic silver is formed, causing the image to become progressively darker. Excessive time in the developer solution results in overdevelopment.

An acid rinse bath, sometimes referred to as a stop bath, instantly neutralizes the action of the developer and stops further development. Due to the soft emulsion and the nonabsorbent quality of the base of most negative materials, only a very weak acid bath is required.

The purpose of the fixing bath is to arrest the image at the desired state of development. When a radiation-sensitive material is removed from the developing solution, the emulsion still contains a considerable amount of silver salts which have not been affected by the developing agents. These salts are still sensitive, and if they are allowed to remain in the emulsion, ordinary light will ultimately darken them and obscure the image. Obviously, if this occurs, the film will be useless.

The fixing bath prevents this discoloration by dissolving the salts of silver from the developed free-silver image. Therefore, to make an image permanent, it is necessary to fix the radiation-sensitive material by removing all of the unaffected silver salt from the emulsion.

After fixing, a thorough water rinse is necessary to remove the fixing agent which, if allowed to remain, will slowly combine with the silver image to produce brownish-yellow stains of silver sulfide, causing the image to fade.

NOTE: All processing is conducted under a subdued light of a color to which the film is not readily sensitive.

Radiographic Interpretation

From the standpoint of quality assurance, radiographic interpretation is the most important phase of radiography. It is during this phase that an error in judgment can produce disastrous consequences. The efforts of the whole radiographic process are centered in this phase; the part or structure is either accepted or rejected. Conditions of unsoundness or other defects which are overlooked, not understood, or improperly interpreted can destroy the purpose and efforts of radiography and can jeopardize the structural integrity of an entire aircraft. A particular danger is the false sense of security imparted by the acceptance of a part or structure based on improper interpretation.

As a first impression, radiographic interpretation may seem simple, but a closer analysis of the problem soon dispels this impression. The subject of interpretation is so varied and complex that it cannot be covered adequately in this type of document. Instead, this chapter will give only a brief review of basic requirements for radiographic interpretation, including some descriptions of common defects.

Experience has shown that, whenever possible, radiographic interpretation should be conducted close to the radiographic operation. It is helpful, when viewing radiographs, to have access to the material being tested. The radiograph can thus be compared directly with the material being tested, and indications due to such things as surface condition or thickness variations can be immediately determined.

The following paragraphs present several factors which must be considered when analyzing a radiograph.

There are three basic categories of flaws: voids, inclusions, and dimensional irregularities. The last category, dimensional irregularities, is not pertinent to these discussions because its prime factor is one of degree, and radiography is not that exacting. Voids and inclusions may appear on the radiograph in a variety of forms ranging from a two-dimensional plane to a three-dimensional sphere. A crack, tear, or cold shut will most nearly resemble a two-dimensional plane, whereas a cavity will look like a three-dimensional sphere. Other types of flaws, such as shrink, oxide inclusions, porosity, etc., will fall somewhere between these two extremes of form.

It is important to analyze the geometry of a flaw, especially for such things as the sharpness of terminal points. For example, in a crack-like flaw the terminal points will appear much sharper than they will for a sphere-like flaw, such as a gas cavity. Also, material strength may be adversely affected by flaw shape. A flaw having sharp points could establish a source of localized stress concentration. Spherical flaws affect material strength to a far lesser degree than do sharp-pointed flaws. Specifications and reference standards usually stipulate that sharp-pointed flaws, such as cracks, cold shuts, etc., are cause for rejection.

Material strength is also affected by flaw size. A metallic component of a given area is designed to carry a certain load plus a safety factor. Reducing this area by including a large flaw weakens the part and reduces the safety factor. Some flaws are often permitted in components because of these safety factors; in this case, the interpreter must determine the degree of tolerance or imperfection specified by the design engineer. Both flaw size and flaw shape should be considered carefully, since small flaws with sharp points can be just as bad as large flaws with no sharp points.

Another important consideration in flaw analysis is flaw location. Metallic components are subjected to numerous and varied forces during their effective service life. Generally, the distribution of these forces is not equal in the component or part, and certain critical areas may be rather highly stressed. The interpreter must pay special attention to these areas. Another aspect of flaw location is that certain types of discontinuities close to one another may potentially serve as a source of stress concentrations; therefore, this type of situation should be closely scrutinized.

An inclusion is a type of flaw which contains entrapped material. Such flaws may be either of greater or lesser density than the item being radiographed. The foregoing discussions on flaw shape, size, and location apply equally to inclusions and to voids. In addition, a flaw containing foreign material could become a source of corrosion.

Radiation Hazards

Radiation from X-ray units and radioisotope sources is destructive to living tissue. It is universally recognized that in the use of such equipment, adequate protection must be provided. Personnel must keep outside the primary X-ray beam at all times.

Radiation produces changes in all matter through which it passes. This is also true of living tissue. When the radiation strikes the molecules of the body, the effect may be no more than to dislodge a few electrons, but an excess of these changes could cause irreparable harm. When a complex organism is exposed to radiation, the degree of damage, if any, depends on which of its body cells have been changed.

The more vital organs are in the center of the body; therefore, the more penetrating radiation is likely to be the most harmful in these areas. The skin usually absorbs most of the radiation and, therefore, reacts earliest to radiation.

If the whole body is exposed to a very large dose of radiation, it could result in death. In general, the type and severity of the pathological effects of radiation depend on the amount of radiation received at one time and the percentage of the total body exposed. The smaller doses of radiation may cause blood and intestinal disorders in a short period of time. The more delayed effects are leukemia and cancer. Skin damage and loss of hair are also possible results of exposure to radiation.

ULTRASONIC TESTING

Ultrasonic detection equipment has made it possible to locate defects in all types of materials without damaging the material being inspected. Minute cracks, checks, and voids, too small to be seen by X-ray, are located by ultrasonic inspection. An ultrasonic test instrument requires access to only one surface of the material to be inspected and can be used with either straight line or angle beam testing techniques.

Two basic methods are used for ultrasonic inspection. The first of these methods is immersion testing. In this method of inspection, the part under examination and the search unit are totally immersed in a liquid couplant, which may be water or any other suitable fluid.

The second method is called contact testing, which is readily adapted to field use, and is the method discussed in this chapter. In this method the part under examination and the search unit are coupled with a viscous material, liquid or a paste, which wets both the faee of the search unit and the material under examination.

There are two basic ultrasonic systems: (1) Pulsed and (2) resonance. The pulsed system may be either echo or through-transmission; the echo is the most versatile of the two pulse systems.

Pulse-Echo

Flaws are detected by measuring the amplitude of signals reflected and the time required for these signals to travel between specific surfaces and the discontinuity. (See figure 10–13.)

The time base, which is triggered simultaneously with each transmission pulse, causes a spot to sweep across the screen of the CRT (Cathode ray tube). The spot sweeps from left to right across the face of the scope 50 to 5,000 times per second, or higher if required for high-speed automated scanning. Due to the speed of the cycle of

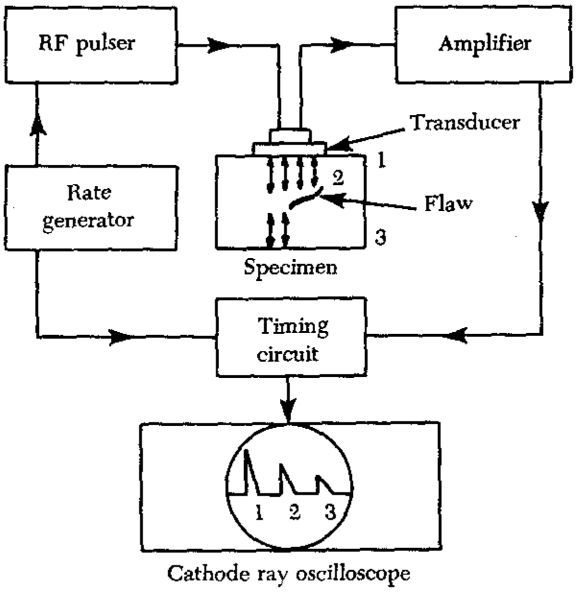


FIGURE 10–13. Block diagram of basic pulse-echo system.

transmitting and receiving, the picture on the oscilloscope appears to be stationary.

A few microseconds after the sweep is initiated, the rate generator electrically excites the pulser and the pulser in turn emits an electrical pulse. The transducer converts this pulse into a short train of ultrasonic sound waves. If the interfaces of the transducer and the specimen are properly orientated, the ultrasound will be reflected back to the transducer when it reaches the internal flaw and the opposite surface of the specimen. The time interval between the transmission of the initial impulse and the reception of the signals from within the specimen is measured by the timing circuits. The reflected pulse received by the transducer is amplified, then transmitted to the oscilloscope, where the pulse received from the flaw is displayed on the CRT screen. The pulse is displayed in the same relationship to the front and back pulses as the flaw is in relation to the front and back surfaces of the specimen. (See figure 10–14.)

The Reflectoscope is a pulse-echo type instrument. The Reflectoscope can be used for the detection of defects such as cracks, folds, inclusions, delaminations, partial welds, voids, shrinks, porosity, flaking, and other subsurface defects.

The principle of operation is pictured in figure 10–15, where electrical pulses are transformed by the crystal into ultrasonic vibrations which are transmitted into the material. The portion of the electrical pulse delivered to the cathode-ray tube causes an initial pulse indication, as shown in figure 10–15, view A. The back reflection has formed in view B, the vibrations having traveled to the bottom of the part and reflected back to the searching unit, which transforms them back into electrical pulses. The screen's vertical indication of their return is known as the "first back-reflection indication." If a defect is present (figure 10–15, view *C*), a portion of the vibrations traveling through the material is reflected from the defect, causing an additional indication on the screen. The horizontal-sweep travel indicates the time elapsed since the vibrations left the crystal.

This type of operation, referred to as straight-beam testing, is suitable for the detection of flaws whose planes are parallel to the plane of the part. By means of angle-beam testing, also referred to as shear-wave testing, the usefulness of the Reflectoscope includes the following:

1. Flaws whose planes lie at an angle to the plane of the part.
2. Discontinuities in areas that cannot be reached with the standard straight-beam technique.
3. Some internal defects in plate and sheet stock.
4. Some types of internal defects in tubing, pipe and bar stock, such as inclusions and small cracks near the surface.
5. Cracks in parent metal resulting from welding.
6. Some defects in welds.

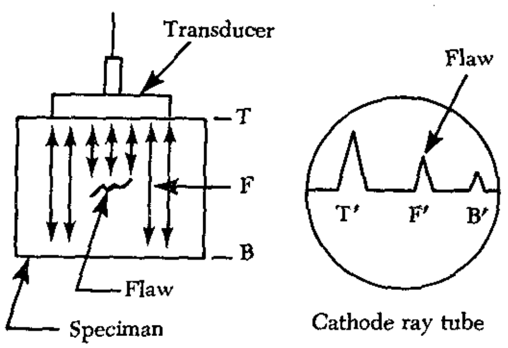


FIGURE 10–14. Oscilloscope display in relationship to flaw location.

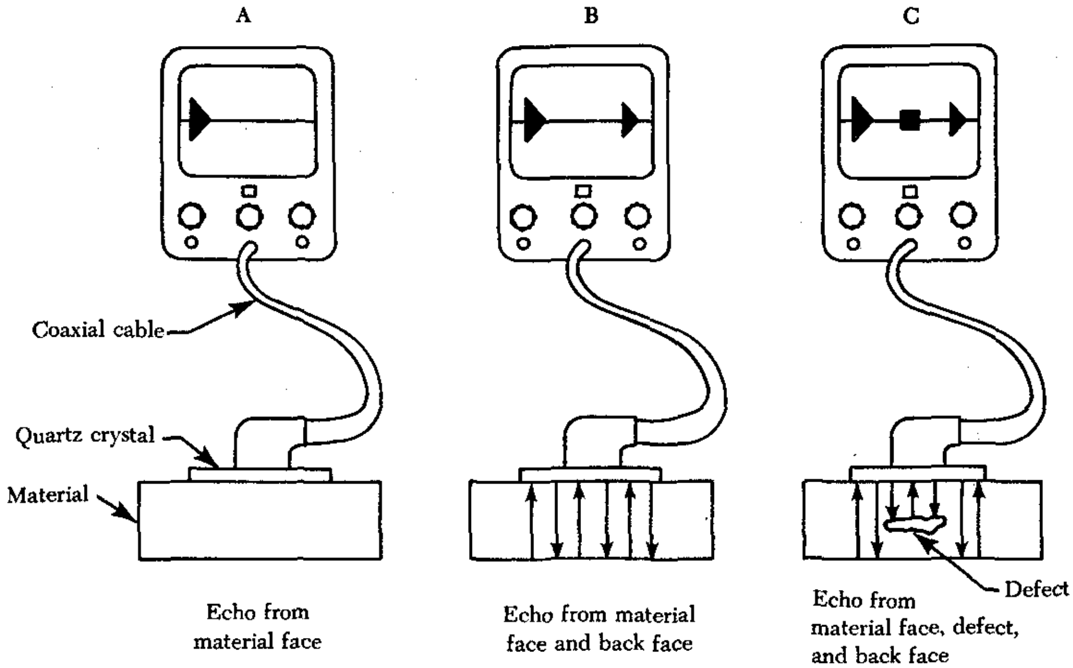


FIGURE 10–15. Reflectoscope operation—straight-beam testing.

Angle-beam testing differs from straight-beam testing only in the manner in which the ultrasonic waves pass through the material being tested. As shown in figure 10–16, the beam is projected into the material at an acute angle to the surface by means of a crystal cut at an angle and mounted in plastic. The beam or a portion thereof reflects successively from the surfaces of the material or any other discontinuity, including the edge of the piece. In straight-beam testing, the horizontal distance on the screen between the initial pulse and the first back reflection represents the thickness of the piece; while in angle-beam testing, this distance represents the width of the material between the searching unit and the opposite edge of the piece.

Resonance System

This system differs from the pulse method in that the frequency of transmission is, or can be, continuously varied. The resonance method is principally used for thickness measurements when the two sides of the material being tested are smooth and parallel. The point at which the frequency matches the resonance point of the

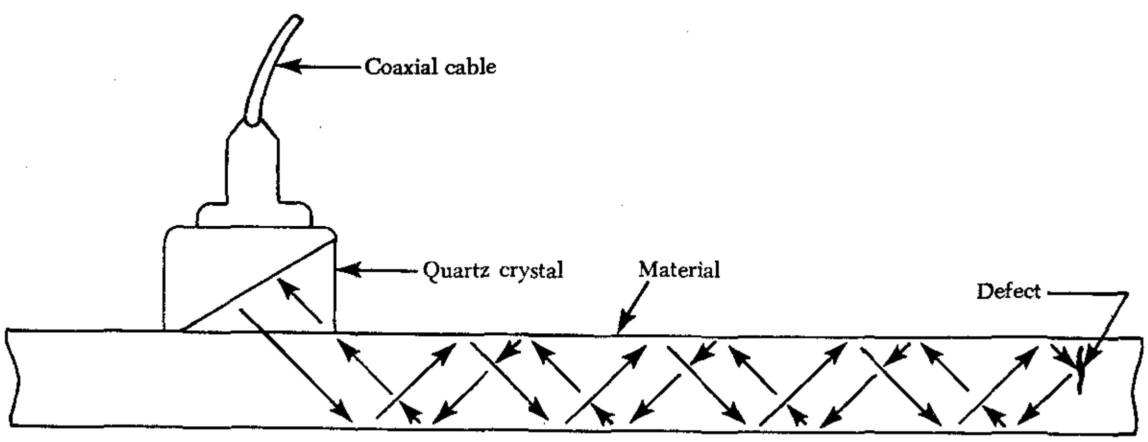


FIGURE 10–16. Reflectoscope operation—angle-beam testing.

material being tested is the thickness-determining factor. It is necessary that the frequency of the ultrasonic waves, corresponding to a particular dial setting, be accurately known. Checks should be made with standard test blocks to guard against possible drift of frequency.

If the frequency of an ultrasonic wave is such that its wavelength is twice the thickness of a specimen (fundamental frequency), then the reflected wave will arrive back at the transducer in the same phase as the original transmission so that strengthening of the signal, or a resonance, will occur. If the frequency is increased so that three times the wavelength equals four times the thickness, then the reflected signal will return completely out of phase with the transmitted signal and cancellation will occur. Further increase of the frequency, so that the wavelength is equal to the thickness again, gives a reflected signal in phase with the transmitted signal and resonance occurs once more.

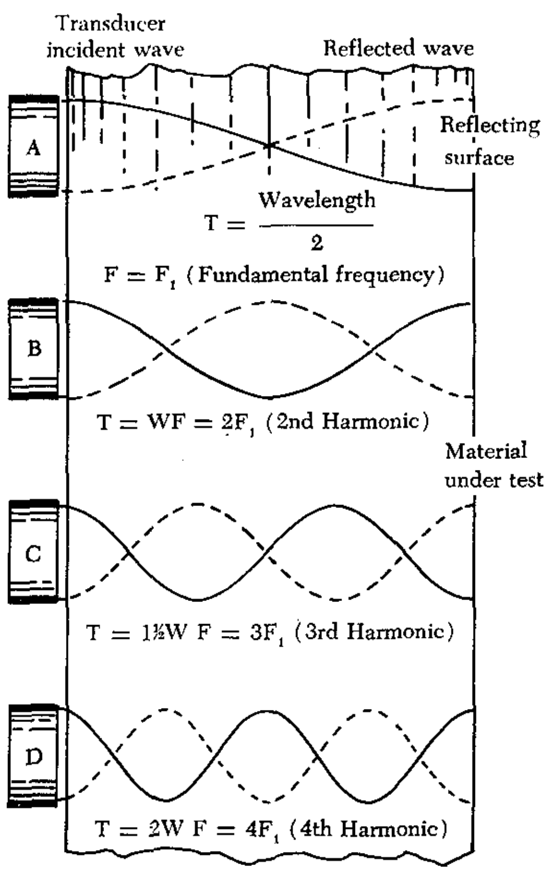


FIGURE 10–17. Conditions of ultrasonic resonance in a metal plate.

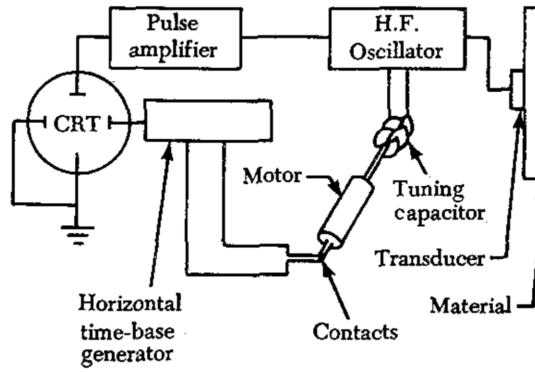


FIGURE 10–18. Block diagram of resonance thickness measuring system.

By starting at the fundamental frequency and gradually increasing the frequency, the successive cancellations and resonances can be noted and the readings used to check the fundamental frequency reading. (See figure 10–17.)

In some instruments, the oscillator circuit contains a motor-driven capacitor which changes the frequency of the oscillator. (See figure 10–18.) In other instruments, the frequency is changed by electronic means.

The change in frequency is synchronized with the horizontal sweep of a CRT. The horizontal axis thus represents a frequency range. If the frequency range contains resonances, the circuitry is arranged to present these vertically. Calibrated transparent scales are then placed in front of the tube, and the thickness can be read directly. The instruments normally operate between 0.25 mc. and 10 mc. in four or five bands.

The resonant thickness instrument can be used to test the thickness of such metals as steel, cast iron, brass, nickel, copper, silver, lead, aluminum, and magnesium. In addition, areas of corrosion or wear on tanks, tubing, airplane wing skins, and other structures or products can be located and evaluated.

Direct-reading, dial-operated units are available that measure thickness between .025 inch and 3 inches with an accuracy of better than ±1 percent.

Ultrasonic inspection requires a skilled operator who is familiar with the equipment being used as well as the inspection method to be used for the many different parts being tested.

EDDY CURRENT TESTING

Electromagnetic analysis is a term which describes the broad spectrum of electronic test methods involving the intersection of magnetic fields and circulatory currents. The most widely used technique is the eddy current.

Eddy currents are composed of free electrons, which are made to "drift" through metal, under the influence of an induced electromagnetic field.

Eddy current is used in aircraft maintenance to inspect jet engine-turbine shaft and veins, wing skins, wheels, bolt holes, and spark plug bores for cracks, heat or frame damage. In aircraft manufacturing plants, eddy current is used to inspect castings, stampings, machine parts, forgings, and extrusions.

Basic Principles

When an alternating current is passed through a coil it develops a magnetic field around the coil which in turn induces a voltage of opposite polarity in the coil and opposes the flow of original current. If this coil is placed so that the magnetic field passes through an electrically conducting specimen, eddy currents will be induced into the specimen. The eddy currents create their own field which varies the original field's opposition to the flow of original current. Thus the specimen's susceptibility to eddy currents determine the current flow through the coil (see figure 10–19).

The magnitude and phase of this counter field is dependent primarily upon the resistivity and permeability of the specimen under consideration, and it is this fact that enables us to make a qualitative determination of various physical properties of the test material. The interaction of the eddy current field with the original field results is a power change that can be measured by utilizing electronic circuitry similar to a wheatstone bridge.

The specimen is either placed in or passed through the field of an electromagnetic induction coil, and its effect on the impedance of the coil or on the voltage output of one or more test coils is observed. The process—whereby electric fields are made to explore a test piece for various conditions—involves the transmission of energy through the specimen much like the transmission of X-rays, heat, or ultrasound. In the transmission of X-rays, heat, or ultrasound, the energy flows in beams having a recognizable direction and intensity and obeys the laws of absorption, reflection, diffraction, and diffusion. Receiver elements can be placed into the beams and a direct measurement of energy flow is possible. However, in electromagnetic tests, the energy distributes itself in a vaguely known manner and undergoes a transformation in the process, from magnetic to electric energy, and subsequently, back to magnetic energy. Since the induced currents flow in closed circuits, it is neither convenient nor generally possible, to intercept them at the specimen boundaries.

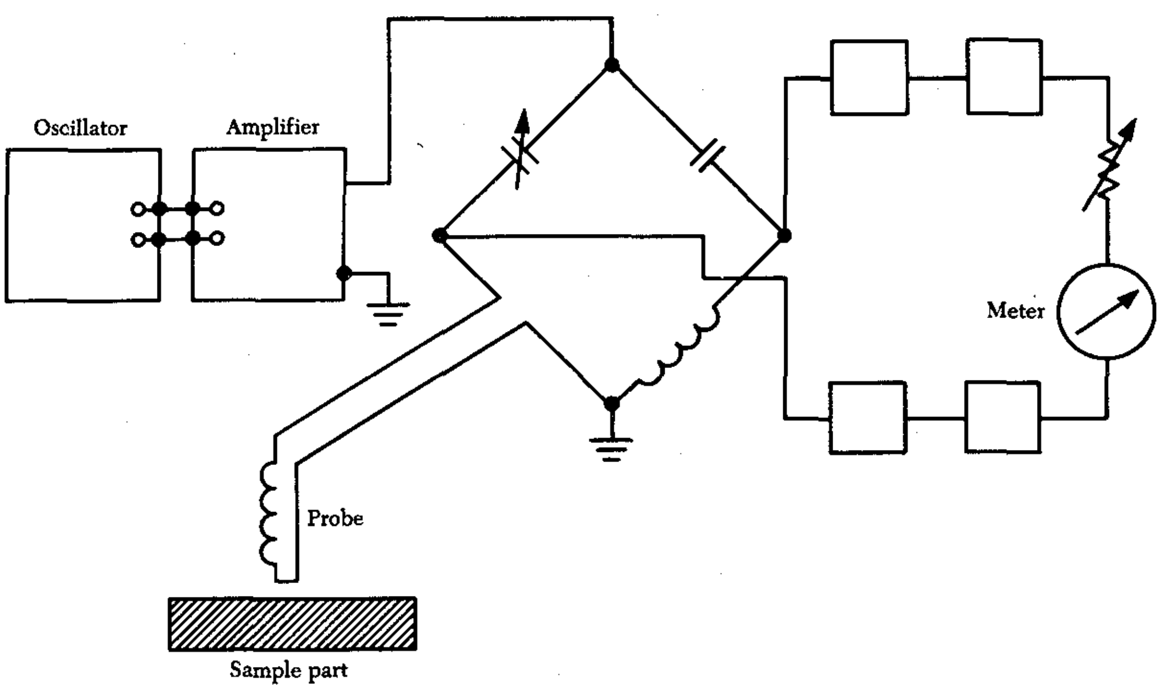


FIGURE 10–19. Eddy current inspection circuit.

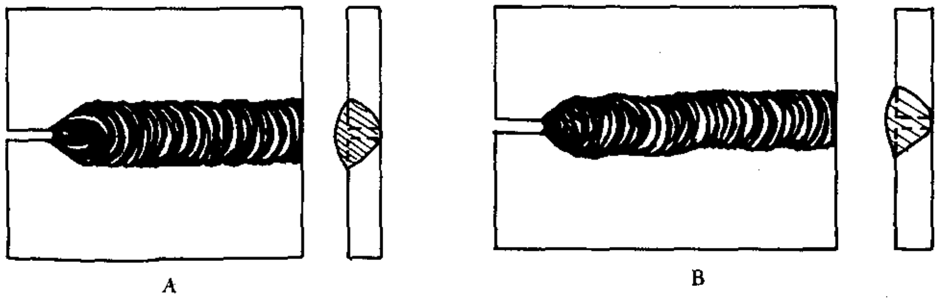


FIGURE 10–20. Examples of good welds.

VISUAL INSPECTION

Nondestructive testing by visual means is the oldest method of inspection. Defects which would escape the naked eye can be magnified so they will be visible. Telescopes, borescopes, and magnifying glasses aid in performing visual inspection.

A discussion of visual inspection in this chapter will be confined to judging the quality of completed welds by visual means. Although the appearance of the completed weld is not a positive indication of quality, it gives a good clue to the care used in making it.

A properly designed joint weld is stronger than the base metal which it joins. The characteristics of a properly welded joint are discussed in the following paragraphs.

A good weld is uniform in width; the ripples are even and well feathered into the base metal, which shows no burn due to overheating. (See figure 10–20.) The weld has good penetration and is free of gas pockets, porosity, or inclusions. The edges of the bead illustrated in figure 10–20 (B) are not in a straight line, yet the weld is good, since penetration is excellent.

Penetration is the depth of fusion in a weld. Thorough fusion is the most important characteristic which contributes to a sound weld. Penetration is affected by the thickness of the material to be joined, the size of the filler rod, and how it is added. In a butt weld the penetration should be 100 percent of the thickness of the base metal. On a fillet weld the penetration requirements are 25 to 50 percent of the thickness of the base metal. The width and depth of bead for a butt weld and fillet weld are shown in figure 10–21.

To assist further in determining the quality of a welded joint, several examples of incorrect welds are discussed in the following paragraphs.

The weld shown in figure 10–22 (A) was made too rapidly. The long and pointed appearance of the ripples was caused by an excessive amount of heat or an oxidizing flame. If the weld were

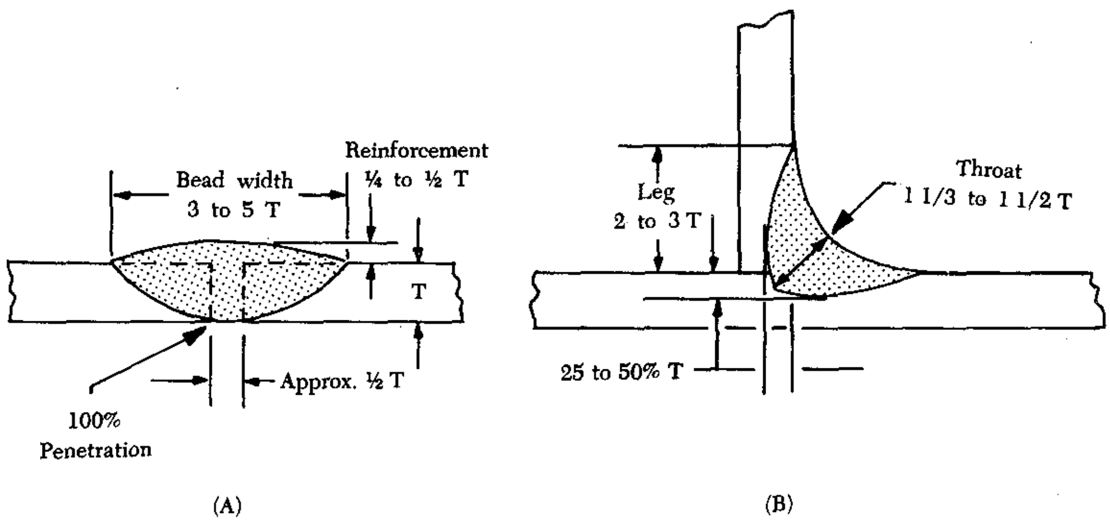


FIGURE 10–21. (A) Butt weld and (B) fillet weld, showing width and depth of bead.

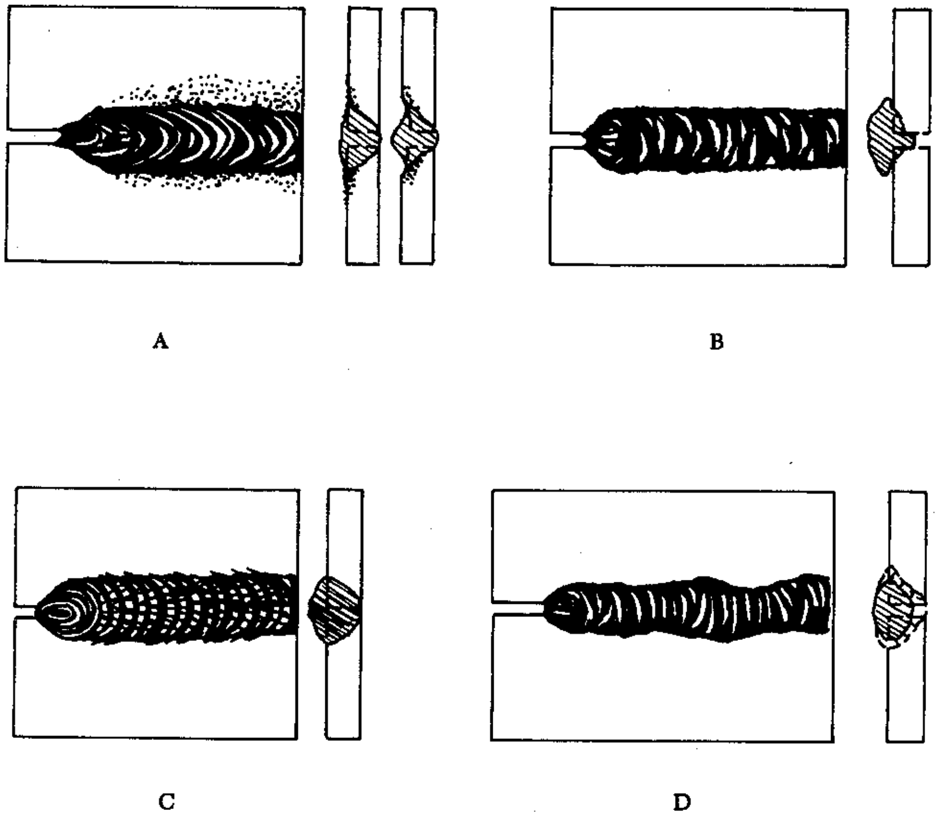


FIGURE 10–22. Examples of poor welds.

cross-sectioned, it probably would disclose gas pockets, porosity, and slag inclusions.

Figure 10–22 (B) illustrates a weld that has improper penetration and cold laps caused by insufficient heat. It appears rough and irregular and its edges are not feathered into the base metal.

The puddle has a tendency to boil during the welding operation if an excessive amount of acetylene is used. This often leaves slight bumps along the center and craters at the finish of the weld. Cross-checks will be apparent if the body of the weld is sound. If the weld were cross-sectioned, pockets and porosity would be visible. Such a condition is shown in figure 10–22 (C).

A bad weld with irregular edges and considerable variation in the depth of penetration is shown in *D* of figure 10–22. It often has the appearance of a cold weld.