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TECHNICAL MANUAL

AVIATION UNIT MAINTENANCE (AVUM) AND AVIATION INTERMEDIATE MAINTENANCE (AVIM) MANUAL

FOR

GENERAL AIRCRAFT MAINTENANCE

(NONDESTRUCTIVE TESTING AND FLAW DETECTION PROCEDURES AND PRACTICES)

VOLUME 7

*This manual together with TM 1-1500-204-23-1 through TM 1-1500-204-23-6 and TM 1-1500-204-23-8 through TM 1-1500-204-23-10, dated 31 July 1992, supersedes TM 55-1500-204-25/1, dated 6 April 1970, including all changes.

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HEADQUARTERS, DEPARTMENT OF THE ARMY
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CHANGE

NO. 1

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DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 30 December 1993

**AVIATION UNIT MAINTENANCE (AVUM)
AND AVIATION INTERMEDIATE
MAINTENANCE (AVIM) MANUAL**

FOR

GENERAL AIRCRAFT MAINTENANCE

**(NONDESTRUCTIVE TESTING AND FLAW DETECTION
PROCEDURES AND PRACTICES)**

VOLUME 7

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PRECAUTIONARY DATA

Personnel performing Instructions involving operations, procedures, and practices which are included or implied in this technical manual shall observe the following Instructions. Disregard of these warnings and precautionary information can cause serious Injury, death, or an aborted mission.

WARNINGS, CAUTIONS, and NOTES are means of attracting attention to essential or critical information in a manual. Definitions are outlined as follows:

WARNING: An operating or maintenance procedure, practice, condition, statement, etc., which if not strictly observed, could result in injury or death of personnel.

CAUTION: An operating or maintenance procedure, practice, condition, statement, etc., which if not strictly observed, could result in damage to, or destruction of, equipment or loss of mission effectiveness or long term health hazards to personnel.

NOTE. An essential operating or maintenance procedure, condition, or statement, which must be highlighted.

WARNING

ELECTRICAL TESTS

Electrical power up to 500 volts is used in testing the equipment. Exercise extreme caution during these tests.

ELECTRICAL EQUIPMENT

All switches and electrical equipment shall be of the enclosed explosion-proof type. All metal apparatus shall be grounded to avoid the danger of Igniting test fluid fumes or creating electrical shock.

USING SOLVENTS/PAINTS

Standard precautions such as fire prevention and adequate ventilation shall be exercised when using solvents or applying primer and coating Wear gloves or gauntlets when handling solvents as solvents may cause skin disorders.

Cements and solvents used to repair liferafts are flammable and shall be treated as such Never smoke or permit any type of open flame near when using cements or solvents.

Dichloromethane (methylene chloride) vapor is heavier than air; adequate ventilation shall be provided for working personnel. Dichloromethane (methylene chloride) is toxic when vapors are inhaled over an extended period of time.

Acrylic monomer and polymer base adhesive, MIL-A-8576, contains a volatile liquid which may prove toxic when vapors are inhaled over extended periods. Use only with adequate ventilation.

Observe fire precautions when using aliphatic naphtha, Federal Specification TT-N-95.

HANDLING PLASTICS

Wear gloves to protect hands while handling hot plastic. Boiling water shall not be used for heating acrylate base plastics.

Provide adequate ventilation when working with Furane Plastics, Epocast H-991-A, Furane hardener 941, or equivalents as these materials are toxic.

LUBRICATING OIL

Lubricating oil, MIL-L-7808 or MIL-L-23699, contains an additive which is poisonous and absorbed readily through the skin. Do not allow oil to remain on skin any longer than necessary.

FUEL

When servicing aircraft or support equipment, clean up spilled fuel with cotton mops or cotton rags. Wash off any fuel on hands, body, or clothing.

HANDLING ACID

Wear protective clothing when mixing acid with water. Always pour acid into water, never water into acid.

MAGNESIUM ALLOY FIRE

Do not use water or any standard liquid or foam-type fire extinguishers on a magnesium alloy fire, as they may cause an explosion. Use dry sand or talcum powder, Federal Specification U-T-30.

REMOVING CORROSION

Take precautions to prevent possible dust explosions when removing corrosion from steel alloys. Use goggles or face shield when removing paint or corrosion with a wire brush or by the grinding method.

TIRES AND WHEELS

If it is necessary to approach a wheel with a hot brake, do so either from directly In front or directly behind the aircraft.

Use extreme caution when prying out foreign material imbedded in tire tread.

Do not use air bottles or booster pumps not designed for tire inflation.

OXYGEN SYSTEM

Do not allow petroleum base products to come in contact with oxygen system components, as an explosion or fire may result.

Do not use masking tape to seal openings in oxygen regulators Masking tape constitutes a safety hazard when used on either serviceable or repairable oxygen equipment.

Do not use drycleaning solvent, Federal Specification P-D-680, near oxygen storage or transfer systems, the combination of these two will form a highly explosive mixture

GROUND SUPPORT EQUIPMENT

Do not attempt to lift any load when the hydraulic axle jack is tilted. To prevent accidental falls, appropriate maintenance platforms/safety stands Illustrated in appropriate workstand manuals or any other approved locally procured/manufactured safety stands/restraint equipment will be used when working (above 10 feet) on aircraft In a non-tactical environment.

Install safety lock when an adjustable-height maintenance platform is In use

Ensure the air hose used with compressed air is safe for the pressure being handled.

Release air pressure In air compressor tank before performing maintenance on air compressors

Disconnect power before changing belts on electrically-driven compressors.

Disconnect electrical power before opening or disassembling any part of electrical equipment.

RADIOGRAPHIC EQUIPMENT

Exercise extreme caution when performing radiographic Inspections to prevent personnel from coming in contact with radiation. Radiation from X-ray units and radioisotope sources is extremely destructive to living tissue.

FIRE EXTINGUISHERS

Halon type fire extinguishers, Monobromotrifluoromethane (CF3BR) and Bromochloromethane (CB) are odorless gasses. When used in confined areas, available oxygen for breathing may be depleted. Use supplied breathing air when using these gasses in enclosed spaces.

HYDRAULIC FLUID

To avoid contamination, do not use previously opened cans of hydraulic fluid. A new, sealed can of fluid must be opened and used. When opening can, clean top and use a clean sharp, unplated instrument to prevent contamination

COMPRESSED AIR

Compressed air shall not be used for cleaning purposes except if reduced to less than 30 psi and then only with effective chip-guarding and personal protective equipment.

TECHNICAL MANUAL

No. 1-1500-204-23-7

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON D.C., 31 July 1992

Aviation Unit Maintenance (AVUM) and Aviation Intermediate Maintenance (AVIM) Manual for General Aircraft Maintenance Manual

(Nondestructive Testing and Flaw Detection Procedures and Practices)

Volume 7

REPORTING OF ERRORS AND RECOMMENDING IMPROVEMENTS

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual direct to: Commander, U.S. Army Aviation and Troop Command, ATTN: AMSAT-I-MP, 4300 Goodfellow Blvd., St. Louis, MO 63120-1798. A reply will be furnished to you.

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CHAPTER 1

INTRODUCTION

1-1. Purpose. This volume provides general information pertaining to nondestructive testing and flaw detection procedures and practices. Specific aircraft application, usage, and substitution is found in the individual aircraft maintenance manual. This volume is maximum benefit to the mechanic who desires general information about nondestructive testing and flaw detecting procedures and practices. Refer to TM 55-1500-335-23 for general application of various nondestructive inspection methods. This volume should not be used to perform nondestructive inspection procedures. This volume is not requisitioning authority, and applicable repair parts and special tools list should be consulted to obtain the unit of issue and National Stock Number of the items required for maintenance.

1-2. Scope. General information to guide aircraft maintenance personnel is covered in this volume; however, no attempt has been made to include special parts or equipment which are applicable only to individual or special aircraft. General information is covered in Chapter 2. Penetrant inspections are discussed in Chapter 3 and magnetic particle inspections in Chapter 4. Information regarding radiography is presented in Chapter 5. Chapter 6 covers ultrasonic inspections. Finally, electromagnetic inspections are presented in Chapter 7.

1-3. Consumable Materials. Refer to TM 1-1500-204-23-6 for consumable materials in this volume.

CHAPTER 2

GENERAL

2-1. General. The field of Nondestructive Inspection (NDI), testing, and flaw detection is varied and complex.

It cannot be covered in detail in this volume. This chapter will provide a brief description of the various, methods available, shop and personnel requirements, and an explanation of special terms. The effectiveness of a particular method of testing and inspection depends upon the skill, experience, and training of the mechanic doing the test. Additionally, each method is limited in its usefulness as an inspection tool by its adaptability to the component being tested.

2-2. General Shop Rules. The practices and procedures described in this chapter pertain to the repair functions of aviation activities and are applicable to all levels of maintenance Because of the many types of Army aircraft, each shop within the manufacturing and repair section must, of necessity, have personnel trained in general practices and procedures to the extent that different type and model aircraft do not upset a smooth running shop.

a. Responsibility. All supervisory personnel in the manufacturing section are responsible for a continuing and effective shop safety program. To implement and maintain this program, shop supervisors will utilize bulletin boards, signs, and any other effective method. Shop personnel will cooperate In the shop safety program by making helpful recommendations and continually exercising care and caution in the operation of all shop equipment. All shop personnel will strive to improve the safety program and be especially alert to observe and correct hazardous conditions and unsafe shop practices. All accidents, no matter how minor, shall be reported to the shop supervisor, and all published instructions regarding safety shall be strictly adhered to. Also, safety engineers and safety officers will ensure that proper safety procedures are adhered to in accordance with AR 385-10, Army Safety Program; AR 385-30, Safety Color Code Markings and Signs, AR 385-32, Protective Clothing and Equipment; The Occupational Safety and Health Act of 1971, OSHA 1910.251; all applicable fire codes, NFPA 410; and other accepted civilian and military safety practices.

b. Shop Housekeeping. Housekeeping is the yardstick by which the shops in the manufacturing section are judged. A clean, well-arranged shop is a safe shop and reflects credit on all personnel concerned with Its operation. The following shop practices shall be observed.

(1) Oil pans or drip pans shall be used where leaking oil, grease, and similar material may cause hazardous accumulations on equipment or floors. All spills shall be cleaned up immediately Approved sweeping compound may be used to remove these materials from the floor.

CAUTION

Floors shall not be cleaned with volatile or flammable liquids. A flammable film may remain and cause a fire hazard.

(2) Floors shall be maintained smooth and clean, free of all obstructions and slippery substances Holes and irregularities In floors shall be repaired to maintain a level surface free from tripping hazards

(3) All unnecessary materials on walls shall be removed and projections shall be kept to a minimum

(4) Aisles shall be clearly defined and kept free of hazardous obstructions. Where possible, aisles shall be suitably marked by painting.

(5) All machines, work benches, aisles, etc, shall be adequately illuminated

c. Shop safes. Unsafe equipment and fire hazards are the main factors to be observed while planning safety procedures.

(1) Equipment safety. Unsafe equipment shall be reported immediately. The following equipment safety practices shall be observed:

(a) Machines shall be located to provide operators with sufficient space to handle materials and perform job operations without interference

(b) Bolt down all machinery that can move or walk due to vibration (drill press, bench grinder, etc).

(c) Substantial low resistance conductors shall be used to ground all stationary and portable machines, equipment, or other devices in which static charges may be generated or which require electrical circuits of a hazardous nature.

(d) Shop machinery shall be operated only by qualified personnel observing safe practices

(e) Safety devices, such as guards, interlocks, automatic releases, and stops, shall always be kept in operating condition

(f) Ensure that all unauthorized personnel are clear of area before opening valves or energizing electrical circuits for starting machinery

(g) Suitable mechanical guards, such as enclosures or barricades, shall be permanently installed on all machinery not already equipped with such to eliminate danger of injury from moving parts.

(h) Machinery shall not be adjusted, repaired, oiled, or cleaned while machine is in operation or power is on.

(i) Personnel operating machinery shall wear protective clothing as prescribed. A protective face shield or goggles shall be worn when operating a grinder regardless of whether grinder is equipped with attached shields.

(j) Jewelry shall not be worn while performing any maintenance

(2) Fire safety. A constant vigilance must be maintained to seek out fire hazards. Fire hazards are constantly present in the shop where sparks, friction, or careless handling can cause an explosion that may destroy equipment or buildings, and injure or kill personnel. Refer to AR 385-10, The Army Safety Program and The Occupation Safety and Health Act of 1971. The following fire safety practices shall be observed.

(a) NO SMOKING signs shall be placed in areas where smoking could create a fire hazard.

(b) Personnel shall be trained in the use, knowledge, and location of shop fire fighting equipment.

(c) Each shop shall be equipped with fire extinguishers suited for type of fire most likely to occur.

(d) Use correct fire extinguishers for class of fire as follows: · Class A fire (wood, paper, trash, etc.). Use water or soda-acid fire extinguisher.

- Class B fire (oil, paint, fuel, grease, etc.). X Use bromotrifluoromethane or carbon dioxide fire extinguisher.
- Class C fire (electrical equipment). Use bromotrifluoromethane or carbon dioxide fire extinguisher
- Class D fire (combustible metals-magnesium, titanium, zirconium, sodium, lithium, and potassium). Use dry powder type fire extinguisher

(e) Oily waste, rags, and similar combustible materials shall be discarded in self-closing metal containers which shall be emptied daily.

(f) Flammable materials shall not be stored in the shop

(g) Use only approved cleaning solvents

d. Shop Tools and Materials. Handling tools and materials require observance of the following common safety practices:

(1) Do not leave tools or objects in elevated positions from which they can fall or be knocked off.

(2) Do not point a compressed air stream toward any part of the body

(3) All unserviceable tools will be plainly marked and removed from service

(4) Electrical cables and air hoses to portable units will be laid out so there is no danger of tripping

(5) Electrical tools must be connected to a low resistance ground.

(6) Keep bench tops covered with material hard enough to prevent chips and other foreign material from becoming imbedded. Keep bench tops clean and free from chips and filings.

(7) Keep vise jaws covered with soft metal jaw caps

e. Maintenance of Shop Equipment. Maintenance of shop equipment consists of cleaning, preventive maintenance, and replacement of defective parts. Preventive maintenance includes before-operation, during-operation, after-operation services performed by operator, and scheduled services to be performed at designated intervals. Consult the operation and service Instructions manual for specific maintenance instructions on particular types of equipment

2-3. NDI Shop Requirements. A typical NDI shop facility consists of various rooms adapted for specific NDI tests. Proper electrical and plumbing connections must be provided for smooth shop operation Refer to TM 55-1500-335-23 for room and equipment schedules

2-4. Types of Inspections. Destructive and nondestructive inspections and tests are accomplished to detect flaws and defects. The following paragraphs explain both types.

a. Destructive Tests. Destructive tests are used to detect flaws and defects in aircraft components. Damage caused by this type of test renders the part unserviceable. Brinell, Rockwell, and Vickers hardness tests are examples of destructive tests.

b. Nondestructive Tests. NDI testing methods are those methods which may be applied to a structure or component to determine its integrity, composition, physical, electrical, or thermal properties, or dimensions without causing a change in any of these characteristics These methods include.

- Liquid penetrant methods
- Magnetic particle methods
- Electromagnetic methods
- Ultrasonic methods
- Penetrating radiation methods

c. Need For Both Types of Tests. Destructive and nondestructive tests are both used to perform inspection functions. No method should ever be considered conclusive. Limits for acceptance and rejection are as much a part of an inspection as the method Itself Refer to the applicable maintenance manual for correct testing method.

2-5. Personnel Requirements. Effective utilization of NDI can be attained only by highly trained and well experienced personnel. Commanders will ensure that properly trained and qualified personnel will be available The training requirements are waived for the black lights, ultrasonic leak detector, and optical equipment This qualification may be met through the NDI basic technician course

2-6. Use of Data. The information gathered from nondestructive tests can be used to develop specifications and standards for new items before they are procured This historical data can provide a diagnostic trail which will highlight the effects of various stress or use conditions on an item. The data can also distinguish the best NDI technique to use on the new item, based on its composition and Intended application.

2-7. Flaw Detection. The various types of cracks that can be detected are defined in tables 2-1 and 2-2.

Table 2-1. Flaw Detection

Flaw	Definition
Cold cracks-	Appear as a straight line, usually continuous throughout its length and generally exist singly. These cracks start at the surface.
Cooling cracks -	In bars of alloy or tool steels, are the result of uneven cooling after rolling and usually are deep in a longitudinal direction, but are not straight.
Crack contaminant -	Material which fills a crack and which may prevent penetrants from entering.
Fatigue cracks -	Progressive cracks which develop in the surface caused by the repeated loading and unloading of the part or by what is called reverse bending.
Forging cracks -	Cracks developed in the forging operation due to forging at too low a temperature, resulting In rupturing of the steel.
Grinding cracks -	Thermal cracks due to local overheating of the surface being ground, generally caused by lack of coolant, Improper coolant, dull wheel, too rapid a feed, or too heavy a cut.
Heat treatment cracks -	Ruptures produced in the tempering of metal due to uneven cooling and contracting of one portion of a part
Hot cracks -	Same as cold cracks but developing before the casting has completely cooled.
Machining cracks -	A surface defect generally called machining tear and caused by too heavy a cut, a dull tool, chatter, or dragging the tool over the metal when not cutting cleanly
Open cracks -	Those flaws which can be detected by contrast penetrant inspection techniques.
Pickling cracks-	Cracks caused by the release of internal stresses due to metal removal by immersion in acid or chemical solutions.
Plating cracks -	A crack developed by the plating process, usually occurring In parts having high internal stresses

Table 2-1. Flaw Detection - CONT

Flaw	Definition
Quenching cracks -	Ruptures produced in the tempering of metal due to uneven cooling and contracting of one portion of a part.
Service cracks -	Ruptures that occur on a part after all fabrication has been completed and the part placed in service. Failure may be due to fatigue, corrosion, overstressing, or undetected processing discontinuities.

Table 2-2. Honeycomb, Fiberglass, and Composite Defects

Type	Defect
Type I	Unbonds or voids in an outer skin-to-adhesive Interface.
Type II	Unbonds or voids at the adhesive-to-core interface.
Type III	Voids between layers of a laminate.
Type IV	Voids in foam adhesive or unbonds between the adhesive and a closure member at core -to-closure member joints
Type V	Water in the core.

CHAPTER 3

PENETRANT INSPECTIONS

3-1. General. This chapter describes the basic principles of penetrant inspection methods, the reason for penetrant inspection, and the capabilities of penetrant inspection.

3-2. Purpose. Penetrant inspection is a quick and reliable nondestructive test method used for detecting various types of discontinuities which are opened to the surface of an object or part.

3-3. Basic Principles of Penetrant Inspection. The basic principle of penetrant inspection is to increase the visible contrast between the discontinuity and its background. This is done by treating the whole object with an appropriate searching liquid of high mobility and penetrating power and then encouraging the liquid to emerge from the discontinuity to reveal the flaw pattern to the inspecting personnel.

3-4. Limitations. Penetrant inspections only detect defects that are on the surface on the item. Defects below the surface, such as casting voids, can not be detected by penetrant inspection. Also, penetrant inspection does not work well on absorbent items, such as some plastics, rubber and synthetic parts.

3-5. Importance of Skilled Operators. Since correct evaluation of a defect depends on accurate interpretation, the operator is the key man in the inspection process. The success and reliability of penetrant Inspection depends upon the thoroughness with which the operator prepares the part from the pre-cleaning process all the way through to the final interpretation of the indications. Penetrant inspection is not a method by which a part is processed through a machine which separates the good parts from the bad. The operator must carefully process the part, search out indications, and then decide the seriousness of defects found, to determine the disposition of parts according to the severity of the flaw indications. Remember poor processing can be worse than no inspection; because, if improper processing yields no indications for the operator to detect, the part is considered satisfactory whether it is or not.

3-6. General Procedures for Penetrant Inspections. The following general procedures are for penetrant inspections:

a. The appropriate inspection process shall be determined by the testing facilities available, the type and amount of parts to be tested, and the results anticipated and desired.

b. If the part to be tested could be affected by oil, sulphur or chlorine, tests shall be performed to ensure that the parts are not damaged when placed under penetrant inspection method tests

c. The part to be inspected shall be precleaned in order to achieve reliable penetrant inspection.

d. Parts which have been precleaned shall be dried to achieve reliable penetrant inspection

e. Penetrant shall be applied to a part under test In a manner appropriate to the type of part or facilities available. Sufficient dwell time shall be allowed for optimum penetration

f. Penetrant shall be removed from the surface of the part under test in the manner dictated by the type of penetrant used.

g. Developer shall be applied to the part under test as appropriate to the process being used and the configuration of the part under test. Sufficient dwell time shall be allowed for optimum results.

h. The part shall be inspected and the discontinuity interpreted.

I. The developer shall be removed after inspection interpretation and prior to returning the part to service.

3-7. Precautions In Penetrant Inspections. Precautions to be taken during penetrant inspections are described in the following paragraphs.

a. <u>Pre-operative Precautions</u>. Precautions to be taken prior to performing penetrant inspections are as follows:

(1) Perform quality inspection of penetrant liquids.

(2) Inspection process liquids and techniques selected should be rechecked to ensure that process is appropriate for results desired and anticipated.

(3) Production line equipment shall be properly set up and sequenced.

(4) An inspector shall prepare himself and the area.

b. Operative Precautions. Precautions to be taken during penetrant inspections are as follows:

(1) Avoid contamination of inspection liquids

(2) Maintain the wet developer bath at the concentration recommended by the supplying manufacturer.

(3) Observe temperature limitations described in paragraph 3-5c

(4) Perform a waterbreak test on a piece of polished steel to ensure the developer has sufficient wetting agent

c. Temperature Limitations. The temperature of the penetrant, wet developer, dryer, and. part should be observed to ensure the temperature does not exceed the limitations. Limitations for each are explained in the following paragraphs.

(1) Penetrant temperature. Most penetrants operate satisfactorily at temperatures as low as 40°F (4 to 5°C), but operation much below this temperature can result in unsatisfactory conditions. Most penetrants designed for use in open tanks are reasonably stable at temperatures up to about 1 000F (380C).

CAUTION

If a penetrant is heated to the point where some of its lighter constituents are driven off, the sensitivity of inspection may be greatly reduced. Volatile fumes may create a fire or health hazard. Heating the penetrant is therefore not recommended.

(2) Wet developer temperature. Wet developer, being a water mixed solution, cannot operate below the freezing temperature of water. Heating wet developer above 90°F (320C) does not improve its function.

(3) Dryer temperature. The desired temperature of the dryer oven is 150 to 1 80°F (66 to 82°C). Parts should be removed from the dryer as soon as they are dry. If overheated prior to the application of the penetrant, excessive evaporation of the penetrant may occur. If the part is allowed to remain In the dryer oven too long after the penetrant has been applied, the sensitivity may be reduced. Temperatures above 180°F (82°C) or excessive drying times may decrease the sensitivity of certain fluorescent penetrants.

(4) Temperature of part Warming parts to approximately 100°F (380C) will minimize the required penetrant dwell time. The warm part reduces the viscosity of the penetrant, permitting the penetrant to more readily enter the discontinuities.

d. Safety Precautions. The following safety precautions shall be observed when performing penetrant Inspection.

WARNING

Prolonged or repeated inhalation of vapors or powders may result in irritation of mucous membrane areas of the body.

(1) Adequate ventilation shall be used when handling cleaner, emulsifiers, penetrants or developers.

(2) The following precautions shall be used when handling cleaners, emulsifiers, penetrants, or developers:

WARNING

Continual exposure to penetrant inspection products may cause skin irritation.

(a) Avoid contact of penetrant inspection products by wearing neoprene gloves.

(b) Keep insides of neoprene gloves clean.

(c) Wash exposed areas of body with soap and water.

(d) Check for traces of fluorescent penetrants on skin, clothes and gloves using blacklight source.

(e) When using penetrant, emulsifier, and developers the operator should wear a protective face shield or goggles

WARNING

Injury to eyes and skin may occur when blacklight is not used in accordance with manufacturer's instructions. Unfiltered light sources (if filter is required) may possibly damage the eyes.

(3) Follow manufacturer's instructions when using blacklight sources and filter all light sources requiring filtering.

WARNING

- **The temperature of some operating black light bulbs reaches 750°F (3990C) or more during operation. This is above the ignition or flashpoint of fuel vapors. These vapors will burst into flame If they contact the bulb. These black lights SHALL NOT be operated when flammable vapors are present.**
- **The bulb temperature also heats the external surfaces of the lamp housing. The temperature is not high enough to be visually apparent, but is high enough to cause severe burns with even momentary contact of exposed body surfaces. Extreme care must be exercised to prevent contacting the housing with any part of the body.**

WARNING

Temperatures in excess of 120°F (49°C) may cause bursting of the pressurized can and injury to personnel.

(4) Store all pressurized spray cans in a cool, dry area protected from direct sunlight. Avoid exposure of pressurized spray cans to open flames.

WARNING

- **Volatile fumes may occur, creating both a fire and health hazard**
- **Do not place used chemicals In drainage systems, surface waters, land fills, or dumps. Contamination of these areas can cause severe, and possibly fatal, health problems.**

(5) Exercise caution when handling penetrants which have been heated to the point where some of their lighter constituents are driven off 3-8. Quality Control of Penetrants. Compatibility and availability of penetrants are covered In the following paragraphs.

a. Compatibility. Each penetrant Inspection material's manufacturer has its own formulation for penetrants, lipophilic emulsifiers and hydrophilic removers Penetrants and lipophilic emulsifiers or hydrophilic remover combinations produced by a single manufacturer are considered a system, therefore, the components are not interchangeable from one manufacture to another. Mixing of manufacturers will not provide for optimum performance and in some cases this practice will eliminate any chance of detecting defects. The following system concept conditions apply to the use of developers and solvent removers'

(1) Different types of developers or solvent removers (i.e. soluable and suspended developers or solvent based and oil based removers) shall not be used or mixed together.

(2) Developers and removers from different manufacturers shall not be used or mixed together even if they are the same type.

(3) Developers and removers with different part numbers, but the same type and manufacturer shall not be used or mixed together.

b. Availability of Penetrants The use of the group of penetrants made by one manufacturer is commonly referred to as the system concept This concept requires special considerations when replacement penetrants are required. Activities should plan to purchase penetrant systems periodically on a competitive basis. The perpetual procurement of replacement penetrants from a single or sole source should be avoided.

3-9. Selection of Inspection Process. The selection of a suitable penetrant inspection process is dependent on seven basic factors These are as follows:

- Requirements previously established by component drawings or applicable documents on material or parts to be placed under test.
- Penetrant sensitivity required.
- Surface condition of part to be tested.
- Configuration of part to be tested.
- The number of parts to be tested
- Testing facilities and equipment available.
- Effect of the penetrant chemicals on material or system being tested

3-10. Pretesting, Precleaning, Drying, Application, and Removal. The following paragraphs describe pretesting, precleaning, drying, application, and removal These are used for the preparation of parts prior to, during, and after penetrant inspection.

a. Pretesting. The purpose of pretesting is to ensure that the parts to be tested will not be damaged by the inspection or preparation process described in this section, to establish emulsifier dwell times (if applicable), and to provide a reference sample The following procedures are used for pretesting

(1) Select the penetrant Inspection process to be used on all parts.

(2) Select a part identical to the parts to be placed under test.

(3) Perform penetrant inspection on the part selected In step 2 in the same manner In which all parts will be Inspected.

(4) Concurrently with step 3 and after each inspection process procedure, check the part for damage or adverse effects.

NOTE

This procedure will, in effect, provide a reference sample, for other identical parts to be tested.

(5) If damage occurs, or adverse effects are noted, select an inspection process which will eliminate the problem.

b. Precleaning. The purpose of precleaning a part is to remove all foreign matter which will prevent detection of defects or confuse or alter defect indications Cleaning shall be accomplished in accordance with TM 55-1500-335-23.

NOTE

Detection and indication of any defect depends upon the flow of the dye penetrant into what may be only a microscopic crack It is apparent that such flow cannot take place if the crack is already filled with carbon, oil, engine varnish, dirt, water, paint, oxide, plating, or similar coatings that may cover or fill the defect. Therefore, unless the part is clean and free from foreign matter that may cover or confuse the indications, reliable inspection may not be accomplished.

c. Drying. The purpose of the drying process is twofold. After cleaning or rinsing, the drying process is used to assure the evaporation of any water, solvents, or cleaning solutions which might be loaded in a crack or defect. After the application of wet developer, the drying process is critical and is used to secure a uniform developer coating. It may also assist in the development of the flaw indication.

d. Penetrant Application. Type I and II penetrants can be applied by one of the following methods

- Dipping
- Flow-on
- Spraying
- Brushing
- Any other method which completely covers the area of Inspection.

e. Draining. After the part is coated with the penetrant, the part is set aside to drain. The length of time during which the part is allowed to drain (penetration time) and the position of the part during draining are extremely important factors for reliable penetrant inspection.

f. Penetration Times. The minimum penetration time, in minutes, of penetrants on materials under test are shown In table 3-1. Longer penetration time, or additional penetration application, may be necessary for questionable parts to ensure full indication of defects.

g. Emulsifier Application. Type I and II Method B emulsifiers can be applied by one of the following methods:

- Dripping
- Flow-on
- Spraying
- Any other method which will rapidly cover all the penetrant

CAUTION

Brushing on emulsifiers is not recommended since the brushing action mixes the emulsifier with the penetrant prematurely and irregularly, and makes accurate control of emulsification time Impossible

h. Emulsifier Draining. After the emulsifier is applied to the penetrant-coated part or material under test, the part or material is removed to a rising station for immediate rinsing at the end of the emulsifier dwell time In effect, therefore, there is no emulsifier drain time.

i. Emulsifier Dwell Time. The emulsifier dwell time is explained in the following paragraphs.

(1) Type I, method B emulsifiers. The optimum emulsifier dwell time shall be determined and established by trial on Identical or similar parts or materials The optimum time shall be as follows.

- The minimum time necessary to remove the surplus penetrant for detecting wide shallow defects
- The minimum time necessary to remove the surplus penetrant from the machine marks, dents, or other shallow surface roughness condition for detecting fine cracks.
- The maximum dwell time possible without over-emulsification

NOTE

The maximum dwell time of five minutes shall be used for Type I Emulsifiers.

(2) Type ll., method B emulsifiers. The optimum emulsifier dwell time shall be determined In the same manner as Type I emulsifiers, except the optimum time shall be held to the absolute minimum time necessary to remove the surplus penetrant.

NOTE

Some Type II emulsifiers require rinsing within a few seconds after application

j. Developer Application Aqueous wet, nonaqueous wet, and dry developers can be applied by the following methods.

NOTE

The wet developer solution should be constantly agitated while In use to keep the developer powder In suspension. For open tanks, a circulation pump, motor driven Impeller, or air agitation are satisfactory For pressurized spray cans, the can should be shaken vigorously before each use until the agitator in the can rattles.

(1) Aqueous wet developers. Aqueous wet developers can be applied by one of the following methods.

- Dipping (normal method)
- Flow-on (normal method)
- Spraying (for high sensitivity)

Table 3-1. Minimum Penetration Time For Penetrants

Material	Form	Type of discontinuity	Water washable penetration time (minutes)	Post emulsified penetration time (minutes)[1]
Aluminum	Castings	Porosity	5 to 15	5[2]
		Cold shuts	5 to 15	5[2]
	Extrusions and forgings	Laps	N/R	10
	Welds	Lack of fusion	30	5
		Porosity	30	5
	All	Cracks	30	10
		Fatigue cracks	N/R	30
Magnesium	Castings	Porosity	15	5[2]
		Cold shuts	15	5[2]
	Extrusions and forgings	Laps	N/R	10
	Welds	Lack of fusion	30	10
		Porosity	30	10
	All	Cracks	30	10
	All	Fatigue cracks	N/R	30

See footnotes at the end of table.

Table 3-1. Minimum Penetration Time For Penetrants

Material	Form	Type of discontinuity	Water washable penetration time (minutes)	Post emulsified penetration time (minutes)1
Steel	Castings	Porosity	30	10[2]
		Cold shuts	30	10[2]
	Extrusions and forgings	Laps	N/R	10
	Welds	Lack of fusion	60	20
		Porosity	60	20
	All	Cracks	30	20
	All	Fatigue cracks	NR	30
Brass and bronze	Castings	Porosity	10	5[2]
		Cold shuts	10	5[2]
	Extrusions and forgings	Laps	N/R	10
	Brazed parts	Lack of fusion	15	10
		Porosity	15	10
	All	Cracks	30	10

See footnotes at the end of table.

Table 3-1. Minimum Penetration Time For Penetrants

Material	Form	Type of discontinuity	Water washable penetration time (minutes)	Post emulsified penetration time (minutes)1
Plastics	All	Cracks	5 to 30	5
Glass	All	Cracks	5 to 30	5
Carbide-tipped tools		Lack of fusion	30	5
		Porosity	30	5
		Cracks	30	20
Titanium and high temperature alloys	All		N/R	20 to 30
All metals	All	Stress or intergranular corrosion	N/R	240

[1]For parts having a temperature of 60°F or higher.
[2]Precision castings only

(2) Nonaqueous wet developers. Nonaqueous wet developers can be applied by one of the following methods:

- Dipping
- Spraying (whenever possible)
- Dusting
- Brushing (not preferred)
- Flow-on

(3) Dry developers. Dry developers can be applied by one of the following methods:

NOTE

Dusting may be accomplished by air fluffing the dry powder in a sealed chamber so that the circulation of air deposits the absorbant powder on the vertical sides as well as on the bottom horizontal surfaces of the object being inspected

k. Developer Draining. Wet developers for Type I and II penetrants when applied, shall be allowed to drain prior to drying. The part shall be positioned during draining (and drying) to ensure that pools of developer do not form and mask indications.

l. Developer Dwell Time. Developer dwell time will depend on the type of penetrant developer and type of defect. Sufficient time should be allowed for an indication to form, but the penetrant should not be allowed to bleed into the developer in such quantities to cause a loss of definition.

NOTE

Developer dwell time will vary from a few minutes to an hour or more. A good rule of thumb is that development time for any given material or type of defect is about one-half of that considered proper for penetration dwell time.

m. Removal Methods. Type I and II, Method A penetrants shall be removed from the surface of the part under test by rinsing as follows

(1) A spray nozzle discharging a coarse spray and a high volume of water shall be held approximately 12 inches away from the part under test.

NOTE

Water shall be cold and under low pressure (20-30 psi).

(2) The rinse time for water-washable penetrants shall be the minimum time necessary to remove background color or fluorescence.

NOTE

Water rinsing of Type I, Method A penetrants shall be accomplished with the aid of black light to ensure that the penetrant is completely removed from the surface. Washing must be done in a darkened area.

3-11. Specific Procedures for Fluorescent Penetrant Inspection. Specific procedures for fluorescent penetrant inspections are described in the following paragraphs.

a. Inspection Conditions. Ensure all preinspection conditions are met prior to performing penetrant Inspection. Refer to TM 55-1500-335-23 for specific information.

b. Surface Preparation. Prepare surface of part by removing dirt, dust, loose scale, and oil or grease. Any foreign matter left on surface may cause erroneous indications

c. Lighting and Facilities. Complete darkness is desired for maximum visibility and contrast, since even minute points of light emission are readily seen in complete darkness. A light-proof room is not necessary or possible. Absolute darkness is never achieved, since the black light lamps give off some visible violet light. This small amount of violet light is actually not a disadvantage, as it makes it possible to see the part being handled. Indications, which glow with a bright yellowgreen, are in good contrast with the violet, and are easily seen.

WARNING

Ultraviolet radiation below the 3000A wavelength is harmful to the eyes. Cracked or improperly positioned filters shall not be used.

d. Black Light. The fluorescent quality of the penetrant is most brilliant when viewed under light of sufficient intensity in a particular wave length. Good inspections cannot be performed unless adequate lights are used. Since the light used is almost invisible, it is called black light. It must, however, be of proper wave length and intensity at the point of inspection or the effectiveness of the inspection will be greatly reduced

(1) Sources. The sources of black light are carbon arc system, low pressure fluorescent bulbs, and high pressure mercury bulbs.

(a) Carbon arc system. This system uses two carbon rods which are electrified individually and brought almost together at the tips. As the tips are brought close together, an intense, hot, bright arc is formed. Filters on the containers exclude visible light.

(b) Low pressure fluorescent bulb. This is a tubular electric lamp which has a coating of fluorescent material on its inner surface. The vapor inside the bulb is bombarded by electrons from the cathode and produces ultraviolet light.

(c) High pressure mercury bulbs. The most common black lights currently in use are 100and 400-watt quartz mercury arc lights. They are sealed into a housing which includes reflectors, and which is covered with a special filter glass. The filter transmits black light, but excludes nearly all visible light and is opaque to the short wave length ultraviolet light. The 100-watt lights are furnished in two types of reflectors, either spot or flood, but only the spot type is recommended for Inspection work.

(2) Generation of black light. Black light is a form of electromagnetic radiation. As electromagnetic radiation is absorbed from a source that has a greater unit energy, light is produced in both the visible and invisible ranges. Filters are then used to exclude light with specific wave lengths and allow only the black, or nearly invisible, light to pass.

(3) Black light fixtures. Fixtures used with black light lamps are holders, filters, and on occasion, constant-voltage transformers. The holders can be similar to desk-type fluorescent lights (i e, movable, adjustable arms or hood) or to service station trouble lights (i.e. portable).

(4) Filters. The glass filter used separate out the 3650A wave-length is a dark red-purple color. It is selected to effectively remove practically all visible light from the energy given off by the mercury arc. At the same time, it also removes all radiation of wave length below 3000A that is, it eliminates all the harmful short-wave ultraviolet. It passes near ultraviolet radiation in the range from 4000A (the lower edge of the range of visible violet) down to 3200A. The radiation passed by the filter peaks at 3650A, the optimum for energizing most of the fluorescent dyes used in liquid penetrants and magnetic particle inspections. The black light filters shall be kept clean. Dust and dirt collecting on the filter glass will reduce the black light output significantly. Care shall be taken against breakage of the filter. The glass gets very hot from the heat of the mercury arc and even though the glass has been heat treated to minimize the effect of thermal shock, a splash of moisture or contact with a cold object can crack it.

(5) Intensity. The intensity of the black light radiation used to energize a fluorescent object determines the amount of visible light which the object emits. Doubling the intensity of the black light at an indication will double the brightness of the indication. Therefore, black light available at the indication must not fall below a safe minimum. Approximately 800 microwatts per square centimeter is adequate in darkened inspection areas, but for critical work, it should be greater than this. This intensity is obtainable with the 100 watt spot light over a six inch diameter circle when the lamp is held approximately 15 inches from the surface of the part. However, testing of black light intensity with the lamp at a specific distance is used only for procurement of lights or bulbs. When a hand-held portable light is being used, much greater intensities are obtainable by holding the light closer to the work, or a small part can be held closer to the lamp The operator should remember that a very little black light, 200 microwatts per square centimeter, is sufficient to light up gross indications In the dark, but without sufficient intensity, a fine Indication may go entirely unseen.

CAUTION

The black light filter looks deceptively cool; however, it becomes extremely hot once the light is turned on. The operator must exercise caution not to touch the filter or bump into It with any exposed part of the body; otherwise, a severe bum may result. Flammable items must also be kept away from the filter surface.

(6) Dark adaptation. Fluorescent indications are viewed in darkness or dim light where the sensitive eye mechanisms function. The dark adaptation of the eyes (pupil dilation) necessary to see fine fluorescent indications requires from five to ten minutes in the dim light before it is well attained. Dark adaptation occurs slowly. The reverse, eye accommodation to light, occurs rapidly. This means the eyes must readjust each time the operator leaves the inspection booth. Once the eyes are dark adapted, minute light sources too small to be seen in a bright light appear relatively brilliant and easily seen. The ability to perceive small light sources, such as fluorescent indications, is increased by the fact that the eye is drawn to any source of light in a dark background

NOTE

Personnel wearing light sensitive eye glasses are prohibited from wearing these eyeglasses while performing fluorescent magnetic particle inspections. Light transmission losses of 16 to 45 percent have been revealed when wearing light sensitive glasses exposed to ultraviolet light. These light transmission losses may adversely affect the ability of the inspector to detect small indications.

3-12. Inspection and Interpretation. The following paragraphs describe inspection and interpretation of the penetrant inspection testing.

a. Inspection. Inspection preparation, basic inspection principles, and flaw indications are discussed in the following paragraphs.

(1) Inspection preparation. The inspector shall perform the following steps prior to inspection:

(a) The inspector shall check to ensure that the area is clean and contains no items which will contaminate the part under test, particularly in fluorescent light.

(b) The inspector shall prepare himself to ensure hands and clothing are not contaminated with penetrant.

(c) The intensity of illumination for the surface used for inspection shall be checked for a minimum of 90 foot-candles measured at a distance of 15 inches.

(d) When working in a darkened area the inspector shall place himself in a darkened area, to be dark conditioned, for at least five minutes each time the darkened area is entered from white light or the inspector looks into the direct beam of black light.

(2) Basic inspection principles. There are five principles which apply to all penetrant processes that each operator should remember at all times. Each of these principles is discussed in one of the following paragraphs.

(a) Cleaning. Cleaning the part is essential to remove contamination from out of the flaws or discontinuities. This facilitates more effective entrance of the penetrant liquid into the flaw cavities. Surface openings that are uncontaminated, regardless of how fine, are seldom difficult to detect with suitable penetrant inspection processes.

(b) Penetration. The penetrant must enter the defect in order to produce an indication. It is always important to allow sufficient penetration time so that the penetrant can fill the defect. It is also essential that the defect be clean and free of contaminants so that the penetrant is free to enter.

(c) Washing. If all penetrant is washed out of a defect, an indication cannot be formed. During the washing operation prior to developing, it is possible that the penetrant may be removed from within the defect as well as from the surface. If this happens, less intense indications will be formed. The use of non-water-washable penetrants should considerably increase the accuracy of penetrant inspection for shallow defects or fine cracks, since the penetrant is not water removable. In this case, only the surface penetrant can be removed by water rinsing because the application of emulsifier combines only the excess surface penetrant to render it water rinseable. Excess surface penetrant should never be removed by the use of solvent wash or vapor degreasers, because these procedures are too effective and may remove penetrant from defects to the extent that proper flaw indications cannot be obtained.

(d) Defect size. The smaller the defects, the longer the penetrating time. Fine apertures require a longer penetrating time than larger defects, such as pores. The fact that they are smaller means that the penetrant will enter more slowly.

(e) Special considerations. Wide openings require special techniques. Refer to TM 55-1500-33523 for these techniques. In general, if a surface discontinuity is wider than it is deep, the washing or rinsing operation may remove the penetrant and produce less visible indications.

(3) Flaw indications. There are five basic types of indications which may be seen by the inspector. Each is explained in one of the following paragraphs.

(a) Continuous line. A crack, a cold shut, and a forging lap usually show as continuous line indications. A crack will appear as a sharp or faint jagged line, straight line, or intermittent line. Cold shuts will usually appear as smooth, straight, narrow lines. Scratches and die marks will also appear as straight lines, but the bottom of the discontinuity is usually visible.

(b) Intermittent line. The same defects that appear as straight lines may also appear as linear intermittent indications This condition is caused by the defect being partially closed at the surface due to metal working such as machining, forging, extruding, peening, grinding, etc

(c) Rounded areas. Defects of this nature indicate porosity caused by gas holes or pin holes or a generally porous metal depending on the extent of the indication. Deep crater cracks in welds frequently show up as rounded indications, since there is a large amount of dye penetrant entrapped. The indications may appear rounded because of the volume of penetrant entrapped, although the actual defects may be irregular in outline

(d) Small dots Defects of this nature result from a porous condition of the metal. Such indications may denote small pin holes or excessively coarse grains in casting or may be caused by micro-shrinkage of certain cast alloys.

(e) Diffuse or weak indications. Diffuse indications may be caused by a porous surface, insufficient cleaning, incomplete removal of dye penetrant, or excess developer Weak indications extending over a wide area should be viewed with suspicion. When this condition is encountered, the operation should be repeated.

b. Interpretation. Defect interpretation and types of defects are discussed In the following paragraphs.

(1) Defect interpretation. Of the detectable defects, the most visible discontinuities or cracks are more dangerous in that they readily promote eventual failure by inducing high stress concentrations in the surface of the part. Wide, shallow defects that are rounded present less of a problem as far as contributing to the failure of a part. Sharp, shallow defects are serious problems because they may grow in service to deep cracks, and especially so if they are fatigue cracks The surface defect Is more dangerous than subsurface defects This is because, regardless of depth, surface defects create a more serious stress condition. In the following paragraphs, developer dwell time and questions to be answered for accurate interpretations are covered.

(a) Developer dwell time. While many flaws can be detected almost instantaneously after the developer has been applied or has dried, sufficient time should be allowed for all discontinuities to be revealed A good rule of thumb is that the developer dwell time should not be less than one-half the minimum dwell time shown for the penetrant in table 3-1.

(b) Questions to be answered for accurate interpretations. Three basic questions must be answered to facilitate proper interpretations of the flaw indications. Each question is listed below:

- What type of defect would cause the indication?
- What is the extent of the defect?
- hat effect will this defect have on the anticipated service of the part?

NOTE

The answers to the first two questions are prime responsibility of the inspector The answer to the third question, unless specific acceptance criteria are specified, usually requires special assistance.

(2) Types of defects. Defects can be divided into five basic types. Each is explained in the following paragraphs

(a) Fine, tight surface cracks. Such cracks may be shallow or deep, but their most significant characteristic is their very small and tight surface opening. Deep cracks of this type, once well penetrated, may provide a reservoir of penetrant, and, therefore, may be easier to show than shallow cracks.

(b) Broad, open surface defects. Defects of this type may be shallow or relatively deep. Their significant characteristic is their width which tends to permit penetrants to be removed when removal techniques are employed Care must be taken to ensure this does not occur.

(c) Porosity. Generally speaking, porosity defects are defects having a cavity below the surface which is connected to the surface by minute channels These defects are typically found in aluminum and magnesium sand castings.

(d) Shrinkage. Micro- or sponge-shrinkage in magnesium castings (wheels) which is opened to the surface by machining and etching is very hard to differentiate from cracks. Much care must be used in evaluating this type indication.

(e) Leaks or through cracks. Defects of this type are cracks or openings which pass from one surface to another.

(3) False indications. False, or non-relevant, indications can appear to be actual defect Indications. The typical ways that false indications occur are poor cleaning, press-fit, and poor developer removal

(a) Poor cleaning. If all the surface penetrant is not completely removed in the washing or rinse operation, the remaining penetrant may produce false indications. This is true for both the fluorescent (Type I) and visible dye penetrants (Type II). Evidence of incomplete washing is usually easy to identify, since the penetrant will be in broad areas rather than in the sharp patterns found in true indications. When accumulations of unwashed penetrant are found on parts, these parts would be completely reprocessed In such cases, recleaning of the part before reprocessing is recommended to remove all traces of surface penetrant.

NOTE

The danger of poorly washed parts lies in the fact that there may be actual cracks under the improperly washed areas which are masked by the penetrant on the surface. A properly washed part with no defects should have no areas of fluorescence, or random visible penetrant on it A well processed part should show fluorescence or visible dye penetrant only at areas of the defects.

(b) Press-fit parts. A condition which may create false indications is when parts are press-fitted into each other. If a wheel is press-fitted onto a shaft, penetrant will show an indication at the fit line. This is perfectly normal since the two parts are not welded together The only problem with such indications is that penetrant from the press-fit may bleed out and mask a true defect.

CAUTION

Where penetrant bleed out may mask defects on press-fit parts, the time between application of developer and inspection should be held to a minimum to prevent excessive bleed out.

(c) Developer removal. Sharp fillets, threads, and keyways will often retain penetrant at the base despite a good washing removal technique, and give indications. This is particularly so when Type I or 1, II, Method B is employed. Because heat-treating or fatigue cracks often do occur at such locations It is essential that the inspector check these locations very critically.

3-13. Types of Fluorescent Penetrant Processes. There are three general types of penetrant inspection processes These are known as type I, type II, and type Ill. Type I processes use fluorescent penetrants, type II uses visible penetrants and type III uses visible and fluorescent penetrant (dual mode). Within each type, there are four methods of removal known as method A, B, C, and D Table 3-2 list the various types and methods of penetrant inspection.

CAUTION

The Army prohibits the use of dual mode (visible and fluorescent) and visible dye penetrants on aircraft, engine, and missile parts except for those with specific engineering approval.

3-14. Type I, Method C Penetrant Inspection. The type I, Method C inspection process for use In field (portable) operations is a penetrant Inspection using a fluorescent dye with nonaqueous developer and solvent remover It can be used in a field (portable) operation and is described in the following paragraphs.

a. Precleaning Process. The precleaning process makes the part or item clean and free from foreign matter that may cover or confuse the indications. Effective cleaning methods that may be employed to remove soils or contaminates from the surfaces of parts and defects are as follows:

(1) Alkaline cleaning. Alkaline cleaners are nonflammable water solutions containing specially selected detergents for wetting, penetrating, emulsifying, and saponifying various types of soils When thoroughly used, they leave a water-break-free surface which is both chemically and physically clean. Due to their special wetting and dissolving powers, they also pull contamination from the flaws, thus preparing them to absorb the dye penetrant

(2) Water cleaning with detergents. Washing machines using hot water and detergents may be used to clean parts. The use of this method, however, will depend greatly on the type of soil present. Oil and grease-filled defects may not be satisfactorily cleaned by this method.

Table 3-2. Penetrant Inspection Materials

MIL-1-25135D DESIGNATION	DESCRIPTION
TYPE I	FLUORESCENT DYE PENETRANT
TYPE II	VISIBLE DYE PENETRANT
TYPE III	VISIBLE AND FLUORESCENT PENETRANT (DUAL MODE)
METHOD A	WATER WASHABLE (WW)
METHOD B	POST EMULSIFIABLE, LIPOPHILIC
METHOD C	SOLVENT REMOVABLE
METHOD D	POST EMULSIFIABLE, HYDROPHILIC
SENSITIVITY LEVEL 1.	LOW SENSITIVITY
SENSITIVITY LEVEL 2.	MEDIUM SENSITIVITY
SENSITIVITY LEVEL 3.	HIGH SENSITIVITY
SENSITIVITY LEVEL 4	ULTRA-HIGH SENSITIVITY
FORM a.	DRY POWDER DEVELOPER
FORM b.	WATER SOLUBLE DEVELOPER
FORM c.	WATER SUSPENDABLE DEVELOPER
FORM d.	NONAQUEOUS (WET) DEVELOPER
FORM e	SPECIFIC APPLICATION NON-AQUEOUS WET DEVELOPER
CLASS (1.)	HALOGENATED SOLVENT REMOVER
CLASS (2)	NON-HALOGENATED SOLVENT REMOVER
CLASS (3)	SPECIFIC APPLICATION SOLVENT REMOVER

(3) Steam cleaning Steam cleaning is a modification of the hot-tank, alkaline-cleaning method which can be used for preparation of large unwieldy parts

(4) Vapor degreasing. Vapor degreasing is a highly preferred method of cleaning, especially when heavy oils and grease may fill surface defects Inorganic contamination is generally best removed by the alkaline cleaning process, but organic soils often respond better to vapor degreasing.

(5) Ultrasonic cleaning. When cracks are filled with some hard contaminate such as oxide, carbon, or engine varnish, ultrasonic cleaning may be used to break up (or remove) these contaminates in order that the dye penetrant may enter.

(6) Solvent cleaning. Solvent-type cleaners can be specially selected for wiping parts when vapor degreasing equipment, alkaline hot tanks, and steam cleaning equipment may not be available. The solvent may be applied by hand but care must be taken to ensure that all defects and surfaces are free from contamination.

(7) Mechanical cleaning. Abrasive blasting shall be used to clean metals only if the surface of the metal is not peened by the process or if surface defects are not sealed or contaminated with the abrasive material.

(8) Paint removal. Paint shall be removed by the application of an approved paint stripper using recommended instructions Paint films can be removed by bond-release, solvent paint strippers, or dissolving type hot-tank paint strippers In all cases the paint film must be completely removed down to the surface of the metal.

b. Application of Cleaner. When the precleaning process is chosen, follow the appropriate maintenance manual or manufacturers instructions when applying the cleaner.

c. Penetrant Application. Type I penetrants can be applied by dipping, flow-on, spraying, brushing, or any method which completely covers the area of inspection.

(1) Dipping. In the dipping method of application, the part, or basket of parts, is dipped into the applicable solution. Dipping is generally preferred in hand operations and is used for applying penetrants, emulsifiers, and aqueous wet, and dry developers to the part or material under test.

(2) Flow-on. In the flow-on method of application, the applicable solution Is poured or flowed on the part or material under test. Flowing on the solution is generally preferred in automatic equipment operations, and is used for applying penetrants, emulsifiers, and aqueous wet developers to the part or material under test

(3) Spraying In the spraying method of application, the applicable solution is sprayed on the part or material under test using a spray gun or pressurized cannister. Spraying can be used in hand or automatic equipment operations, and is used for applying penetrants, emulsifiers, and is the best method for applying aqueous and non-aqueous wet developers to the parts or material under test.

(4) Brushing. In the brushing method of application, the applicable solution is applied with a brush. Brushing is used only in hand operations, and is used for applying penetrants.

d. Removal of Excess Penetrant. After the penetrant dwell time is completed, the excess penetrant shall be removed by hand wiping with a dry, lint-free cloth.

e. Application of Developer. This group of penetrants carry only nonaqueous wet developers. The nonaqueous wet developer only should be used for stress or intergranular corrosion defect because of its high degree of penetrant occurancy. Apply the nonaqueous wet developer as follows:

(1) Prior to application, mix developer thoroughly.

(2) Apply developer using the spray method whenever possible, otherwise use brushing method. Spray gun can be vibrated to increase sensitivity.

(3) Drain developer and allow for developer dwell time.

f. Inspection of the Part. Follow procedures in paragraph 3-12a to inspect the part.

g. Evaluate Discontinuity. Follow procedures in paragraph 3-12b to evaluate and interpret the discontinuity.

h. Removal of Developer. Follow the procedures In paragraph 3-14a to remove the developer prior to returning a serviceable part to service. It is just as important to remove all of the developer after inspection as it was to remove all dirt and grime prior to inspection.

CHAPTER 4

MAGNETIC PARTICLE INSPECTIONS

4-1. General. This chapter explains what magnetic particle inspection is and what its purposes and capabilities are. Magnetic field characteristics are described as well as the various methods and techniques of magnetization and demagnetization used in magnetic particle inspection in conjunction with the magnetizing and demagnetizing equipment.

4-2. Theory of Magnetism. Magnetism is defined as the property of an object to attract certain metallic substances. In general, these substances are ferrous metals; that is, metals composed of iron or iron alloys, such as soft iron, steel, and alnico. These metals, sometimes called magnetic metals, today include at least three nonferrous elements: nickel, cobalt and gadolinium, which are magnetic to a limited degree. All other substances are considered nonmagnetic, and a few of these nonmagnetic substances can be classified as diamagnetic since they are repelled by both poles of a magnet.

4-3. Basic Terminology. To discuss the magnetic particle inspection process, certain terms and the essential principles of magnetism must be defined and understood. The following paragraphs define these terms.

a. Ferromagnetic Metals. The attraction or repulsion of most metals when under the influence of a magnet is very slight. A few metals, particularly iron, steel, cobalt and nickel are strongly attracted. These metals, permeable to magnetic flux, are called ferromagnetic. In magnetic particle testing, we are concerned only with ferromagnetic metals.

b. Leakage Field. The magnetic field forced out into the air by the distortion of the field within a part caused by the presence of a discontinuity or change in section configuration is the leakage field.

c. Magnetism. The property of some metals, chiefly iron and steel to attract other pieces of iron or steel is called magnetism. While most metals are magnetic to some degree, only iron and steel and some of their alloys are sufficiently affected for the application or use of magnetic particle inspection.

d. Magnetic Substances. Magnetic substances are those which are attracted by magnetism, or which are permeable to magnetic flux.

e. Magnetic Flux. Magnetism may be considered a force which tends to produce a magnetic field. Magnetic flux is a condition in this magnetic field which accounts for the effect of the field on magnetic objects. To picture a magnetic field in a diagram, magnetic flux is commonly represented by flux lines that form a pattern or series of curved lines within the magnetic field flowing through the magnet and air around the magnet. The stronger the field, the greater the number of flux lines. These lines are also called lines of force.

f. Permeability. The ease with which a metal or metallic part can be magnetized is called permeability. A metal that is easy to magnetize is said to have high permeability or to be highly permeable. A metal that is difficult to magnetize is said to have low permeability. Soft iron and iron with a low percentage of carbon are usually easy to magnetize and are highly permeable. Hard steel with a high percentage of carbon content is usually hard to magnetize and, therefore, is usually lower in permeability. Permeability and retentivity are inversely related characteristics. The higher the permeability the lower the retentivity and the lower the permeability the higher the retentivity.

g. Residual Magnetism. The magnetic field that remains in the parts when the magnetizing force has been reduced to zero or the magnetizing current is shut off is called the residual field. The magnetism which remains is called residual magnetism.

h. Retentivity. The property of any magnetic metal to keep or retain a magnetic field after the magnetizing current is removed is called its retentivity. Metals such as hard steel with a high percentage of carbon which keep a strong magnetic field have high retentivity or are said to be highly retentive. Those metals, such as soft iron or iron with a low percentage of carbon, which lose most of their magnetism as soon as the magnetizing current is removed have poor retentivity.

4-4. Fundamentals of Magnetic Particle Inspection. Magnetic particle inspection is a method of nondestructive testing which uses very small magnetic particles to reveal discontinuities in parts capable of being magnetized. It reveals surface, and near subsurface, discontinuities in parts made of magnetic substances. It consists of three basic operations.

- Establishment of suitable magnetic field.
- Application of magnetic particles.
- Examination and evaluation of the particle accumulations.

4-5. Capabilities and Limitations. Magnetic particle inspection can detect discontinuities in parts made of magnetic substances. If the part is made from an alloy which contains a high percentage of iron and the part can be magnetized, it is in a class of metals called ferromagnetic and it can be inspected by this method If the part is made of an element which is non-magnetic, it cannot be inspected by this method. The magnetic particle inspection method will detect surface discontinuities including those that are too fine to be seen with the naked eye, those that lie slightly below the surface, and when special equipment is used, the more deeply seated discontinuities.

4-6. Inspection Preparation. Parts or surfaces should be clean and dry before they are subjected to any magnetic particle inspection process. The cleaning process used must not affect the part in any way that will reduce the effectiveness of the inspection process. The cleaning process is required to remove all contaminants, foreign matter and debris that might interfere with the application of current or the deposit of the magnetic particles on the test surface.

4-7. Particles and Methods of Application. The particles and their methods of application in magnetic particle inspections are covered in the following paragraphs.

a. Particles. Particle composition and sizes are explained in the following paragraphs.

(1) Particle composition. The particles used in magnetic particle testing are made of magnetic elements, usually combinations of iron and iron oxides, having a high permeability and low retentivity. Particles having high permeability are easily magnetized by and attracted to the low-level leakage fields at discontinuities. Low retentivity is required to prevent the particles from being permanently magnetized Strongly retentive particles tend to cling together and to any magnetic surface, resulting in reduced particle mobility and increased background accumulation.

(2) Particle sizes. Particle sizes are very small ranging from about 0 0002 inch to 0.0006 inch in commonly used formulations. Each magnetic particle formulation always contains a range of sizes and shapes to produce optimum results for the intended use. The smallest particles are more easily attracted to and held by the low-level leakage fields at very fine discontinuities; larger particles can more easily bridge across coarse discontinuities where the leakage fields are usually stronger. Elongated particles are included, particularly in the case of dry powders, because these rod-shaped particles easily align themselves with leakage fields not sharply defined such as occur over subsurface discontinuities. Globular shapes are included to aid the mobility and uniform dispersion of particles on a surface.

b. Methods of Application. Magnetic particles may be applied as a dry powder or wet, using either water or a high flash point petroleum distillate as a liquid vehicle carrier. Dry powders are available in various colors so the user can select the color which contrasts best with the color of the surfaces upon which they are used. Colors for use with ordinary visible light are red, gray, black or yellow. Red and black colored particles are available for use in wet baths with ordinary light and yellow-green fluorescent particles for use with black light. Fluorescent particles are widely used in wet baths since the bright fluorescent indications produced at discontinuities are readily seen against the dark backgrounds which exist in black light inspection areas.

(1) Dry powder application. Dry powder can be applied by hand and compressed air guns. Each is explained in the following paragraphs.

(a) Hand application. Magnetic particles in dry form may be applied by hand using rubber squeeze bulbs or plastic squeeze bottles equipped with perforated caps similar to an ordinary salt shaker but with smaller holes. The objective is to lay down a light cloud of powder on the part being inspected, this is usually accomplished by using a combination of bulb squeezing and tossing the powder toward the area being inspected.

WARNING

Never point a compressed air tool at another person. Airborne particles may cause blindness or serious injury.

(b) Compressed air gun application. Dry powder is also applied using hand held guns and compressed air. One such device has the gun integral with the powder container and operates from an ordinary compressed air line. Using the trigger, the operator controls the discharge of a powder cloud. Low velocity air removes excess powder to better reveal indications. A more elaborate gun-type powder blower has a motor driven compressor integral with a powder container and air-powder mixer. A multichannel rubber hose connects to the gun. A work light is contained in the gun tip to illuminate the inspection area. A trigger on the gun controls the discharge of the powder-air mixture and blow-off air. More elaborate production systems have been built using this same principle of operation. In these cases the discharge nozzles are mechanically controlled as is the movement of parts through the machine. Spent powder is automatically retrieved and reused.

(2) Wet bath application. Many methods are used to apply wet bath magnetic particles. The methods range from a simple hand pouring of a bath onto a part to large industrial systems in which the bath is applied automatically either by dumping or spraying. The most common method for application is through the use of a hand-held nozzle and recirculating pump on stationary units. Occasionally small, hand-held, lever operated sprayers are used. Aerosol-type containers similar to those used to spray paint are also available.

WARNING

When using aerosol type spray containers, the area shall be well ventilated to prevent the build-up of flammable vapors.

4-8. Current and Particle Application. Two methods of processing are used in magnetic particle inspection. The method to use in a given case depends upon the magnetic retentivity of the part being inspected and the desired sensitivity of the inspection to be made. Highly retentive parts may be inspected using what is called the residual method. The continuous method must be used on parts having low retentivity. For a given magnetizing current or applied magnetizing field, the continuous method offers the greatest sensitivity for revealing discontinuities a. Residual Method. The residual method is a method of inspection in which magnetic particles are applied to parts after the parts have been magnetized.

a. Residual Method. The residual method is used only when parts are magnetized with dc. This method of inspection is used only when parts have sufficient retentivity to form adequate magnetic particle indications at discontinuities. This method is used with both longitudinal and circular magnetization techniques, either of which cause the direct contact or central conductor method. Residual inspection requires the parts to be retentive enough to hold magnetic particle Indications at discontinuities. Usually, the use of the residual method is limited to the search for discontinuities which are open to the surface, such as cracks. Detection of subsurface discontinuities requires the stronger leakage fields at discontinuities which exist while the part is being magnetized, as when the continuous method is used. Residual inspection permits the magnetizing of parts at one time and the application of magnetic particle media at some subsequent convenient time. When the central conductor method is used, inspection of holes or bores is facilitated since Inspection takes place after removal of the central conductor.

b. Continuous Method. This method implies that the magnetizing force is acting which the magnetic particles are applied. When the current is on, maximum flux density will be created in the part for the magnetizing force being employed. In some cases, usually when ac or half-wave dc is the magnetizing current being used, the current is actually left on, sometimes for minutes at a time, while the magnetic particles are applied. This is more often needed in dry method application than in wet. Leaving the current on for long durations of time is not practical in most instances nor is it necessary. The heavy current required for proper magnetization can cause overheating of parts and contact burning or damage to the equipment if allowed to flow for any appreciable length of time. In practice, the magnetizing current is normally on for only a fraction of a second at a time. All that is required is that a sufficient number of magnetic particles are in the zone and are free to move while the magnetizing current flows. The bath ingredients are so selected and formulated that the particles can and do move through the film of liquid on the surface of the part and form strong, readable indications. This is one reason why the viscosity of the bath and bath concentration are so important, since anything that tends to reduce the number of available particles or to slow their movement tends to reduce the build-up of indications.

c. Field Direction. The proper orientation of the magnetic field in the part in relation to the direction of the defect is a more important factor than the value or amount of the magnetizing current. For reliable inspection, the magnetic lines of force should be at right angles to the defect to be detected. If the magnetic lines of force are parallel to the defect there will be magnetic leakage at the defect and therefore, if any indication is formed it is likely to be extremely small.

d. Field Measurement. The measurement of magnetic flux or field strength, either within a part or at the part's surface, is extremely difficult. There have been several attempts at developing practical methods or devices. These methods or devices have all been limited in success and contain serious limitations They do serve a purpose in technique development if their limitations are understood. A procedure or technique will be developed for a particular part using rule of thumb and past experience. The actual part will then be subjected to the proposed procedure and the devices or method used to check the field strength at critical points.

e. Sensitivity Level. Any factor that affects the formation of magnetic indications at a discontinuity affects the sensitivity of that magnetic particle inspection. Two of the most important of these factors are the amperage of the magnetizing current and the control of the magnetic particle Inspection media.

(1) Amperage. The formation of magnetic particle indications at discontinuities depends upon the strength of the leakage fields at the discontinuities. Since the leakage fields are a part of the field generated by the magnetizing current, the greater the magnetizing current, the greater will be the strength of the leakage fields. Thus the sensitivity of a magnetic particle inspection is directly related to the current amperage. Too low an amperage may produce leakage fields too weak to form readily discernable indications. Too high an amperage creates a heavy background accumulation of particles which may mask an indication. In circular magnetization, too high an amperage may burn current contact points of a part. In actual practice, amperage requirements are not normally calculated. The more direct approach of estimating the magnetizing current or determining it by experiment is sufficiently accurate for the purpose.

(2) Inspection media. Sensitivity level is affected not only by the current amperage but also by the kind of magnetic particle inspection media, its control and its applications.

4-9. Circular Magnetization. Circular magnetization Is used for the detection of radial discontinuities around edges of holes or openings in parts. It is also used for the detection of longitudinal discontinuities which lie in the same direction as the current flow either in part or in a part which a central conductor passes through.

a. Technique. Two techniques are used to obtain circular magnetization in parts: by passage of electric current through the parts themselves, called the direct contact method, or, by passage of the current through a central conductor that passes through the part, called the central conductor method. Each is explained In the following paragraphs.

(1) Direct contact method. Direct contact to parts is generally made by placing them between clamping heads. Lead face plates or copper braid pads must be used to prevent arcing, overheating, and splatter. Wetting of the contact plates with the suspension vehicle prior to current application helps prevent overheating.

(2) Central conductor method. A part can be circularly magnetized by passing electrical current through a conductor positioned coaxially in a hole or opening in a part. A magnetizing field does exist outside a central conductor carrying current so the walls surrounding a central conductor become magnetized making possible the detection of discontinuities which parallel the central conductor. Central conductors are any high conductive material, such as a copper bar or cable, placed in the center of the part to be magnetized. The central conductor method shall be used if longitudinal discontinuities on the inside of tubular or cylindrically shaped parts are to be detected.

b. Amperage. The magnetizing force at any point on the outside surface of a part through which electric current is flowing will vary with the current amperage. The greater the amperage, the greater will be this magnetizing force. Inside the part, just under the point on the surface, the magnetic flux density will be the product of this magnetizing force and the magnetic permeability of the part at that point. It is this magnetic flux density which determines the leakage field strengths at discontinuities. Thus current amperage is directly related to the strength of leakage fields at discontinuities and it is these leakage fields which capture and hold magnetic particles. The more difficult the discontinuities are to detect, the weaker the leakage fields for a given amperage, and greater amperage will be required to form discernible magnetic particle indications. The discontinuities referred to in this case are those which approximately parallel the direction of current flow with all or part of the circular field generated by current crossing them.

(1) Selection of amperage. A number of factors must be considered when determining what current amperage to use for circular magnetization. Some of the more important of these factors are:

- The type of discontinuity being searched for and its expected ease or difficulty of being found.
- The part size, shape and cross-sectional area through which the current will flow.
- The amount of heating that can be tolerated in the part at the current contact areas.

(2) Direct contact amperage selection. A rule of thumb suggesting 1,000 amperes per inch of part diameter is useful when the part is reasonably uniform and cylindrical in shape. Except for some special alloys and cast irons, the use of 1,000 amperes per inch of diameter will usually assure more than enough field strength to detect surface and near surface discontinuities. In highly permeable material, lower amperage per inch of diameter will produce an adequate field strength within the part.

(3) Central conductor amperage selection. Amperage requirements using a central conductor will depend upon the part size and the diameter of the opening through which the conductor is to be located. In the case of a centrally located conductor, amperage requirements may range from 100 amperes per inch of hole diameter to as much as 1000 amperes per inch depending upon part material and the nature of the suspected discontinuities. A reasonable amperage figure to use is 500 amperes per inch of hole, bore or opening diameter. This should be sufficient for the detection of surface type discontinuities on the inside of such openings. Keeping in mind that the magnetizing field strength around a central conductor decreases with distance away from the conductor, higher amperages than these are required to detect discontinuities which lie on the outside of a part. This limits the wall thickness that may be inspected on the exterior to approximately 1/2 inch. Not only discontinuities which are parallel with the central conductor are detectable using the central conductor method, but radial discontinuities at the ends of holes and openings can be detected since some portion of the magnetic lines of force will Intercept these discontinuities.

4-10. Longitudinal Magnetization. Longitudinal magnetization is used for the detection of circumferential discontinuities which lie in a direction transverse to, or at approximately right angles to a part axis. Circumferential discontinuities around a cylinder for example, are detected by magnetizing the cylinder longitudinally in a direction parallel with its axis. A portion of the longitudinal field will cross the discontinuities creating leakage fields which can capture and hold magnetic particles to form indicators at the discontinuities

a. Technique. Longitudinal magnetization is accomplished in a number of ways, magnetization in a coil being the most widely used method. Parts can be magnetized longitudinally by placing them between the pole pieces of a pair of electromagnets with the fields of the tow electromagnets being directed in the same direction through the part. Still another method is the magnetizing of parts between the feet of yoke or prove using either the electromagnetic or permanent magnet type.

(1) Coil shot. The usual way to longitudinally magnetize a part is to place the part in a rigid coil in a stationary magnetic particle inspection unit. The part may be laid on the bottom inside of the coil where the field is strongest or the part may be supported in the coil by the contact heads of the units for long heavy parts permitting rotation of parts for inspection Coils are usually mounted on rails permitting movement along a long part for multiple inspections (multiple coil shots). Because the effective field extends only six to nine inches on either side of a coil, multiple inspections are needed on long parts.

(2) Cable wrap. Cable wrapping a coil around large or heavy parts is a common practice. Flexible, insulated copper cable Is used. A cable-wrapped coil is connected to a magnetic particle mobile or portable power pack or it can be connected to the contact heads of a stationary Inspection unit. The type of power source to be used will depend upon the kind of current and amperages needed to magnetize the part for the particular desired inspection, and then demagnetize it.

b. Amperage. The magnetizing field strength in the center of the magnetizing coil, increases or decreases with either the coil current or its number of turns. It can also be seen that the field strength will decrease if the coil radius Is made larger or will increase if the radius is made smaller. The field is theoretically zero in the coil center and increases to a maximum at the inside edge of the conductor. Thus a part placed against the inside of a coil, for example lying in the bottom of the coil, will experience a greater magnetizing field strength than when it is centered in the coil.

(1) Selection of amperage. A number of factors must be considered when determining current amperage for longitudinal magnetization of parts. Some of the more important factors are:

- The coil diameter and the number of turns.
- The length to diameter ratio of the part.
- The size, shape, and composition of the part.
- The orientation of position of the part within the coil.
- The kind of discontinuities being sought and their ease of detection.

(2) Coil shot amperage selection. Two rules of-thumb have been developed for use in determining coil amperages to use for longitudinal magnetization. One is for a part centered in a coil and the other for when the part is lying in the bottom of a coil. The rule-of-thumb formulas apply particularly to regular cylindrically shaped parts, the diameters of which do not exceed about one tenth that of the coil (example: 1-1/4 inch diameter in a 12 inch coil) and the part length to diameter ratio, (UD) does not exceed fifteen. Long parts having UD ratios greater than 15 must receive more than one Inspection along their length since the most effective longitudinal field In a part only extends about nine inches on each side of the coil. Amperages calculated using the rule-of-thumb formulas will produce in cylindrically shaped steel parts a flux density of about 70,000 lines per square inch (10,850 gauss) which density is sufficient for detection of most surface and near surface discontinuities. Refer to TM 55-1500-335-23 for other formulas.

(3) Cable wrap coil. Cables used are commonly 2/0 or 4/0 AWG (American Wire Gauge), flexible stranded, insulated copper cable. The number of turns used is kept low, from 3 to 5 turns, to minimize cable resistance in the case of dc and coil impedance when ac is used.

c. Applications. Longitudinal magnetization is used to inspect ferromagnetic components having material permeabilities of about 500 or greater. This Includes most steel alloys. A simple test to determine whether or not a part is magnetic is to place a permanent magnet against a part to be tested. If the pull or attraction of the magnet can be felt, the part is sufficiently magnetic for magnetic particle inspection.

d. Equipment A variety of equipment is available which can be used for either circular or longitudinal magnetization. The equipment ranges in size from small general purpose portable units capable of being carried by hand to large, custom-built stationary units with separate power supplies.

4-11. Magnetic Particle Indicators. Magnetic particle indication definitions and steps of Inspection are explained in the following paragraphs.

a. Definitions. The operator who is to perform magnetic particle inspections should understand certain definitions which are used in connection with this inspection method. These are defined in the following paragraphs.

(1) Indication. In magnetic particle inspection, an indication is an accumulation of magnetic particles being held by a magnetic leakage field to the surface of a part. The indication may be caused by a discontinuity (an actual void or break in the metal) or It may be caused by some other condition that produces a leakage field.

(2) Discontinuity. A discontinuity is an interruption in the normal physical structure or configuration of a part. These discontinuities may be cracks, laps in the metal, folds, seams, inclusions, porosity, and similar conditions. A discontinuity may be very fine or it may be quite large; it will generally be a definite separation or void in the metal.

(3) Defect. A defect is a discontinuity which interferes with the usefulness of a part.

b. Steps of Inspection. Magnetic particle inspection can be divided into producing an indication, interpreting the indication, and evaluating the indication. Each is explained below in the following paragraphs.

(1) Producing an indication. In order to produce a proper Indication on a part, it is necessary to have some knowledge of the principles of magnetism, the materials used In inspection, and the technique employed.

(2) Interpreting the indication. After the indication is created, it is necessary to interpret the indication. Interpretation is deciding what caused that indication and what magnetic disturbance has attracted the particles in the particular pattern found on the part. If the operator knows something about metal processing, it is possible to determine from the appearance and location of an indication the cause of the indication.

(3) Evaluating the indication. Lastly, after the indication has been formed and has been interpreted, it must be evaluated. It is necessary for the operator to decide whether that particular location on that particular part will affect the usefulness of the part. Evaluation is the determination of whether the part can be used in spite of the indication, whether the cause of the indication can be remove without affecting the strength of the part, or whether the part must be scrapped.

4-12. Methods of Recording Indications. The full value of magnetic particle inspection can be realized only if records are kept of parts inspected and the indications found. The size and shape of the indication and Its location on the part should be recorded along with other pertinent information, such as rework performed or disposition. The inclusion of some visual record of the indications on a report makes the report much more complete. Various methods of recording indications are explained in the following paragraphs.

a. Fixing Indications with Lacquer. One of the advantages of magnetic particle inspection is that the indication is formed directly on the part at the exact spot of the magnetic leakage field. This makes it possible to retain the part Itself for record purposes, but it is necessary to fix or preserve the indication on the part so that the part can be handled and examined without smudging or smearing the indication. One method of fixing the indication semipermanently on the part is by using clear lacquer. In order to do this, the part must be dry, if the wet method has been used to develop the indication, the oil should be allowed to evaporate. Normal evaporation can be accelerated by heating the part; it is also possible to flow on carbon tetrachloride or other solvent which will evaporate rapidly and leave the indication dry on the part. It is usually desirable to thin out the clear lacquer by adding lacquer thinner. The lacquer should either be sprayed on the part or flowed on since brushing would smear the indication.

b. Applying Transparent Tape. It is also possible to preserve an Indication on a part by covering it with transparent pressure sensitive tape (such as Scotch brand). This method is not as neat looking as the lacquer method but it is easier to apply. Before applying the tape, the oil used in the wet method should be removed In the same manner as when using lacquer.

c. Dry Particle Indications. If the indication is formed of dry powder particles, excess powder should be removed from the surface by gentle blowing. Use a piece of tape larger than the indication and gently cover the indication with the tape, sticky side toward the indication. Gentle pressure should be applied so that the adhesive will pick up the particles; do not press too or the indication will be flattened too much and the tape may be difficult to remove. Carefully lift the tape form the part and press it onto the record sheet or report. Tape preserved indications are usually a little broader than indications on the part because of the flattening effect of the tape. It is easier to remove the tape if a corner of It is not pressed to the part; this leaves a tab for easy removal.

d. Wet Particle Indications. If the indication is formed of particles used with the wet method, it is necessary to dry the surface of the part before applying the tape. Drying the oil can be done by normal evaporation, usually a slow process, or by accelerating the drying by applying heat and a gentle air steam. The oil can also be removed by carefully washing the area with carbon tetrachloride or other volatile solvent and then allowing the solvent to dry. The solvent should be sprayed or flowed on to prevent damage to the indication.

e. Fluorescent Indications. Tape transfers can be taken of fluorescent particle indications but there are some disadvantages to the process. Such preserved indications usually must be viewed under black light to properly interpret them since the number of particles In the suspension is much less than when using visible particles. Some transparent tape is fluorescent and the fluorescence of the tape may mask the fluorescence of the indication.

f. Photographing Indications. Photographs of indications can also be taken to be used for record purposes. Enough of the part should be shown to make it possible to recognize the part and the position of the Indication. It is helpful to include in the picture some common object to show the size of the part Sometimes this can be done with finger pointing at the indication or by placing a ruler along the part to show relative size. In photographing indications on highly polished parts, care must be taken to avoid highlights or reflection which may hide indications. Taking photographs of fluorescent indications calls for special photographic techniques.

4-13. Demagnetization. Any ferromagnetic material subjected to magnetic particle inspection requires demagnetization. When performing magnetic particle inspection of aircraft parts, it is essential to demagnetize the parts. Parts fabricated from ferromagnetic material retain a certain amount of residual magnetism (or remnant field) after application of a magnetizing force This does not affect the mechanical properties of the part. However, it is necessary to reduce the residual magnetism retained in a part by demagnetization. Ferromagnetic air frame parts are demagnetized to prevent magnetic flux from affecting instrumentation.

NOTE

Interference with navigation systems may occur if parts are not demagnetized after inspection.

a. Reasons for Demagnetization. Aircraft ferromagnetic component parts require demagnetization principally to prevent magnetic flux from affecting the instrumentation. This is the primary reason only and there are several secondary reasons supporting demagnetization. These secondary reasons which follow are because the residual magnetic field in a part:

- May interfere with subsequent machining operations by causing chips to adhere to the surface of the part or the tip of a tool which may become magnetized from contact with the magnetized part. Such chips can interfere with smooth cutting by the tool, adversely affecting both finish and tool life.
- May interfere with electric arc welding operations. Residual magnetic fields may deflect the arc away from the point at which it should be applied.
- May interfere with the functioning of the part itself, after it is placed into the service. Magnetized tools, such as milling cutters, hobs etc., will hold chips and cause rough surfaces, and may even be broken by adherent chips at the cutting edge.
- May cause trouble on moving parts, especially those running in oil, by holding particles of metal or magnetic testing particles-for instance, on balls or races of ball bearings, or on gear teeth.
- May prevent proper cleaning of the part after inspection by holding particles magnetically to the surface of a part.
- Demagnetization is likely to interfere with the magnetization of a part at a lower level of field intensity, not sufficient to overcome the remnant field in the part.
- May hold particles which interfere with later applied coating such as plating or paint.

b. Conditions Not Requiring Demagnetization. Demagnetization is not required and is not usually carned out when:

- Non-aircraft parts are of soft steel and have low retentivity. In this case, the residual field is low or disappears after the magnetizing force is no longer acting. An example is low-carbon plate such as that used for low strength weldments, tanks, etc
- The metal in question consists of nonaircraft structural parts such as weldments, large castings, boilers, etc., where the presence of a residual field would have no effect on other components or the proper service performance of the part.
- If the part is to be subsequently processed or heat-treated and in the process will become heated above the Curie Point, or about 1418° (about 770°C). Above this temperature steels become nonmagnetic, and on cooling are completely demagnetized when they pass through the reverse transformation.
- The part will become magnetized anyway during a following process, as, for example, being held on magnetic chuck.
- A part is to be subsequently remagnetized in another direction to the same or higher level at which it was originally magnetized as, for example, between the steps of circular and longitudinal magnetizing, for magnetic particle testing purposes.
- The magnetic field contained in a nonaircraft finished part is such that there are no external leakage fields measurable by ordinary means; i.e., the testing by circular magnetization of welded and seamless pipe.

c. Techniques for Demagnetization. Alternating and direct current are used in demagnetizing aircraft parts after magnetic particle inspection. Although direct current can be used for demagnetization, alternating current demagnetization has been found to be more convenient. Since alternating current does not penetrate very deeply below the surface of magnetic metals, some parts may be difficult to demagnetize completely using alternating current. This is particularly true with large heavy parts, and may also be the case with parts of unusual shape. Direct current can be used to demagnetize if there is provision for current decay or reduction and means of reversing the direction of the current. Demagnetization accomplished with direct current is the most complete and effective possible.

d. limits of Demagnetization. The limits of demagnetization may be considered to be either the maximum extent to which the part can be demagnetized by available procedures, or the level to which the earth's field will permit it to become demagnetized. These limits may be further modified by the practical degree or limit of demagnetization which is actually desired or necessary. A common accepted practice is to consider a part demagnetized when the magnetic field strength of the residual field is at its lowest level possible. However, specification for demagnetization should be examined to consider the preceeding facts. It is unquestionably true that specification for demagnetization called for levels of residual fields lower than are practicable or even possible to attain. If demagnetization of parts is called for, the specification should state a limit of permissible residual field that it is reasonably possible to achieve. Unrealistic requirements should be modified in light of what needs to be or what can be done.

CHAPTER 5

RADIOGRAPHY

5-1. General. X-ray and gamma ray radiographic inspection utilizes the penetrating power of radiation to reveal the interior of objects as recorded on film. The extent of recorded information is dependent upon three prime factors which are responsible for an object to absorb radiation to varying degrees. These are:

- The composition of the object.
- The product of the density and the thickness of the object.
- The energy of the X-ray gamma rays which are incident upon the object. Its discontinuities cause an apparent change in these characteristics and thus make themselves detectable

WARNING

Exposure to excessive radiation is harmful to human beings. While most X-ray equipment is designed to minimize the danger of exposure to direct or stray radiation, certain precautions must be observed. Radiation safety precautions are discussed In paragraph 5-11.

X-rays and gamma rays are forms of electromagnetic radiation, as are visible light, ultraviolet light, infrared waves, radio waves, and cosmic rays. The distinguishing characteristics of X-rays is their short wavelength. The penetrating power of X-rays is dependent upon the wavelength In an inverse relationship; that is, the shorter the wavelength, the higher the energy, and vice versa. Differences in properties and effects between X-rays and gamma rays are largely a matter of degree. The major advantage of using gamma rays is the fact that gamma ray sources are small and provide access to small spaces, thereby simplifying exposure technique.

5-2. Purpose. Radiography is a useful non-destructive inspection method designed to detect internal discontinuities is many parts and substances.

5-3. Advantages. Radiography may be applied to the inspection of castings, welds, and assembled components. Various metals, both ferrous and nonferrous, as well as nonmetallics such as ceramics and plastics, can successfully be inspected.

5-4. Disadvantages. Radiography is not a cure-all and should be used only when conditions are satisfied Multiple film techniques and other special methods make radiography a versatile tool for evaluation.

NOTE

Although radiography will reveal the interior of opaque objects, it cannot detect all types or irregularities or discontinuities. Small defects In thick objects such as fine cracks or laminations are difficult to detect. In applying radiography as an Inspection method, the sensitivity of the method must be kept in mind.

5-5. Applications. There are some basic guidelines that may be used to determine situations to which radiography is applicable. Some of the basic requirements that must be satisfied so that radiography may be successfully applied are:

- The defect which is of interest must cause a detectable change in apparent thickness, density, or composition.
- The part should be reasonably homogeneous, so that an indication of a defect may be observed.
- The configuration of the part to be tested, or the area when surrounds it, must be such that access to both sides is provided.
- The defect to be detected must be properly oriented in the path of the radiation beam.

5-6. Inspection Techniques. The following paragraphs describe various Inspection techniques used in radiography.

a. General. The following paragraphs describe the factors that determine whether or not a particular radiographic inspection is sufficiently sensitive to detect small defects. Sensitive radiography requires maximum subject contrast resulting from correct kilovoltage and alignment of the beam with the plane of the likely flaw; a sharp image due to good geometry and control of secondary radiation; and optimum density to give good film contrast.

b. Film Placement After the film and film holder have been chosen, the film position in relation to the part must be considered. In production radiography of small parts, this is a simple matter of laying the parts on the film holder. With complex structures, film positioning is not usually as simple. The following rules can be of assistance in such inspection situations:

- Always position the film as close to the area of interest as possible.
- Attempt to locate the film so that the plane of the area of interest and the film are perpendicular to the radiation beam. This is to prevent distortion in the final image.

(1) Positioning. In positioning the film, care should be used to prevent sharp bends in the film or applying pressures to the film holder that can produce pressure marks or crimp marks (artifacts) on the final image.

(2) Curved Surfaces. In radiography of curved surfaces, the source and film should be positioned, if possible, to take the best advantage of the inverse square law and to prevent as much distortion as possible. Flexible film holders should be used in order to place the film as near as possible to the surface of the test object.

c. Source-to-Film Distance. The sharpest image would be formed by having a Source-to-Film Distance (SFD) so great that the rays would be parallel at the film plane. However, since radiation intensify or quantity is diminished in relationship to the inverse square of the distance, the radiation quantity available to expose the film would be very small, and exposure times would become impractical. Therefore, in the production of the radiographic image, economics and practicability must be considered. It is recommended that the longest practical SFD be used for critical exposures to improve image sharpness.

d. Degree of Sensitivity. There is a need to be able to quantatively define how sensitive a radiographic image is. The devices which achieve this aim are known as penetrameters. Another description is Image Quality Indicators (IQI). By whatever name, they provide an indication of what the film reader can be expected to see 5-2 in the actual part being inspected. A wide range of penetrameters is specified for use by various industries.

CAUTION

Use only the penetrameter, if any, specified by the inspection technique. Damage to the Image may otherwise result.

e. Thickness Measurement. Sometimes it is impossible to determine the thickness of an object using conventional mechanical measurement technique. In these instances, a special radiographic technique for the measurement of material thickness may be employed. Although the mathematical development of a relationship between film density and the thickness of an absorber is too complex for practical use, an empirical method of thickness measurement has proven useful. By imaging the object of interest and a step wedge of the same material on a single film, it is possible to obtain a good estimate of the thickness of the material section. It is imperative that the composition and structure of the step wedge be the same as that of the material being measured if any accuracy is to be achieved. Thickness is determined by measuring the resultant film density and finding the step on the wedge which is nearest to that density. For best result, the section of interest and the step wedge should be placed as close to one another as possible to avoid variation in the uniformity of the radiation output. This technique may also be employed to measure the dimensions of voids.

f. Best Access to Object. Best access to object being inspected should be made prior to radiographic inspection.

5-7. Special Techniques. Conventional film radiography has its own capabilities and limitations. Special radiographic techniques are used in some situations to provide a more rapid means of imaging. The following paragraphs describe some of these techniques.

a. Fluoroscopy. Fluoroscopy is based on the ability of X-rays and gamma rays to produce fluorescence in some objects. Specially formulated fluorescent screens are used. These fluoresce (emit visible light) in proportion to the amount or radiation striking them. Thus, an instantaneous visible image is produced and the results may be instantly read.

b. Portable X-Ray Units. X-ray vidicon, photoradiography, and the polaroid radiograph are methods which use portable X-ray units to provide a more rapid means of Imaging.

(1) X-ray vidicon. The X-ray vidicon system consists of a specially designed television camera which is sensitive to X-rays. It has a specially coated face which is capable of imaging X-radiation. This coating is amorphous, which provides the capability of very, very fine resolution. The results of this type of inspection are displayed on a television monitor. The sensitive area of the television vidicon tube is generally very small, on the order of 3/8 by 1/2 inch. When this small area is viewed on a 17-inch television monitor, a magnification of 30 times results, thus very high detail resolution is accomplished. These system are used primarily for the Inspection of very fine detail, such as in the inspection of microelectronic circuits. This system is capable of resolving a wire the diameter of a human hair.

(2) Photoradiography. Photoradiography is a combination of fluoroscopy and photography. in this method, the Image of a fluoroscopic or fluorescent screen is photographed by a conventional camera on small or miniature-type film rather than by direct contact. is method has the advantage over fluoroscopy in that the film has the property to integrate and react to the total light emitted by the fluoroscopic screen during the time of exposure, whereas the integration time of the eye is relatively short. Furthermore, the resultant film can be viewed with transmitted light and the photographic process can be used to enhance the contrast of the fluorescent image. In general, this system permits radiographic sensitivity of about four to five per cent. The photoradiography accessory is available as an assembly and usually consists of a light-tight hood, a fluorescent screen assembly and the camera.
Various type cameras are available, some of which employ sheet film and others using 70-mm roll film.

(3) Polaroid radiograph. If a convenient, permanent image is required and the time required for conventional film radiography is prohibitive, alternatives may be considered. One of these is polaroid radiography. Just as polaroid photography facilitates very rapid development of photographic images, there are available polaroid X-ray films which provide the same advantages. These require the special polaroid film holders and a film processor If the larger sizes are used. In some cases, the typical polaroid 4 by 5 inches adapter can be used. Polaroid radiographic films are used just as regular films are used in conventional film radiography. They have their own characteristic curves and an appropriate exposure technique should be used.
However, after the exposure has been made, rather than process the films by conventional techniques, they are dry developed as polaroid photography is, and results are available after about one minute. Presently available polaroid films provide for either viewing by reflected or transmitted light. Polaroid radiographs provide nearly instant interpretation and also provide a permanent image. However, polaroid radiographs are low in contrast and detail resolution compared to conventional film techniques. Polaroid radiographs can be made to establish the geometrical alignment of the X-ray beam with the part before a typical film radiograph is exposed. This technique is useful in those cases where critical alignment is required.

5-8. Film Exposure and Processing. Film exposure and processing are explained in the following paragraphs.

a. Exposure. Exposure is the time the silver salts on the film are exposed and acted upon by radiation. The intensity of the reaction is directly proportional to the amount of radiation received.

b. Processing. Processing consists of the various steps necessary to have a clear radiographic image. Processing is done either manually or automatically.

(1) Manual film processing. The developing procedure for manual film processing is depicted in figure 5-1 and explained in the following paragraphs.

(a) Immerse the film and its hanger in the developing solution. Agitate the hanger by hand at one minute intervals. This must be done the entire developing time.

(b) Remove the film from the developer and immerse in the stop bath for about one minute.

(c) Remove the film from the stop bath solution and Immerse in the fixing solution.

(d) Remove the film from the fixing bath and immerse in the wash water for the recommended time.

(e) Dry the film.

(f) Remove the film from the film hanger (2) Automatic film processing. The advantages of automatic processors are speed and control of the development process. Automatic processing is particularly advantageous when large volumes of film need to be processed. Automatic processing also provides for greater uniformity of development, thus providing more consistent results. However, because the processing cycle is faster and the chemical temperatures are higher In automatic processing than they are with manual processing, the use of automatic processing will have a noticeable effect on the radiographic technique Ap-

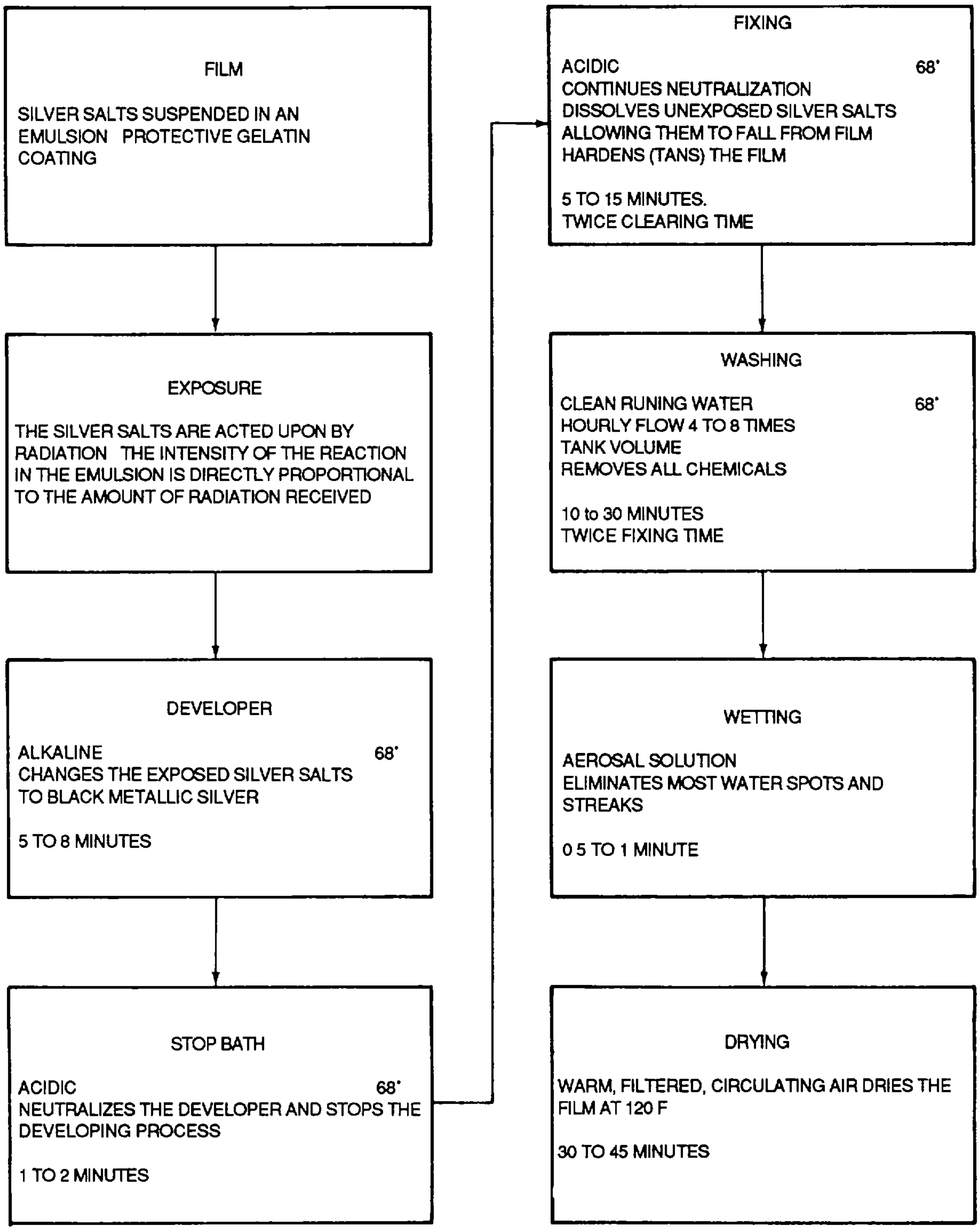

Figure 5-1. Manual Film Processing

parent film characteristics will be significantly altered by the use of automatic processing. It should be noted that film quality, when automatic processing is used, is generally slightly lower than that which is obtainable with manual processing. However, the advantage of speed of processing, lower manpower requirements, and consistency of development generally are felt to be more important in the decision to use automatic processing.

5-9. Radiographic Interpretation. Interpretation of radiographic images cannot be translated into mathematical formulas or routine procedures. The wide variety of test objects and the various fabrication process by which they have been made makes radiographic interpretation a complex subject. Interpretation of the shadow images visible in the radiograph is an acquired skill and there is no substitute for experience. Experience aids the film reader in recognizing discontinuities and in identifying where they can be expected to occur in a particular or structure.

a. Interpretation. Radiographic inspection is conducted to assure that a part has the required integrity to reliably perform the function for which it was designed. This does not mean perfection. All parts and processes are imperfect. Therefore, the purpose of radiography is to determine the degree of Imperfection. The effects of discontinuities or manufacturing deviations must be correlated with the function of the part Specifications are usually used to spell out the discontinuities that may be considered detrimental to the function of the part and the acceptable magnitudes of the discontinuities It is the duty of the film interpreter to recognize the various discontinuities, their magnitudes, and be capable of relating them to the particular specification required. The responsibility and capability of the radiographic interpreter cannot be overemphasized.

(1) Castings. Radiographic examination is ideally suited to the inspection of castings because the most common casting discontinuities are three dimensional and are, therefore, almost independent of angle of inspection. Exceptions in some cases include fine cracks, cold shuts, unfused chills and chaplets. To reveal these, the radiation must be at or near the same parallel plane as the discontinuity. Hairline surface cracks, such as those produced by grinding, are seldom, if ever, revealed by radiography

(2) Welds Most weld discontinuities can be readily detected by radiographic Inspection since they consist of a change in the metal homogeneity Cracks in welds are often detectable since they will usually occur in the direction of the thickness of the plate and will be parallel to the X-ray beam. Stresses created in the metal by welding and not accompanied by a physical separation of material will not be detected by radiography, and cracks not properly oriented may also be missed. Oxides created by the molten metal may be trapped in the weld. This condition results in reduced strength and is subject to review to determine possible implication as a result of the service the weld is expected to yield.

(3) Service inspection. When parts are utilized as required in the design of modern aircraft, there is occasional failure due to fatigue. These failures are a result of overstress of the part due to unusual operating conditions or deterioration of the part. This type of part change is most difficult to detect due to the very nature of the changes and the inaccessibility of the areas In which these changes are most likely to occur in an aircraft. These service type changes in an aircraft are usually due to wear, corrosion, fractures, or shear. Radiography has been used to detect these conditions when they occur in inaccessible areas and are not available for visual inspection

(a) Wear. Rivets and bolts may wear the skin, spar, and frame holes so that there is not a correct fit in the holes for adequates strength in joints or attachments of awing section. This can occur due to continued flexing of components from use or because of severe stress due to unusual operating conditions In turbulent weather or an adverse landing. This condition may also result in radial cracks from bolt holes. This type of failure is extremely difficult to detect by radiography. Any angle of exposure results in superimposition of bolt or nut over crack Loose bolts and rivets have been detected satisfactorily when occurring in position to be located Elongation of rivet holes caused by bearing failure or sheared rivets should not be confused with elongation of holes from drilling. If fatigue is suspected In a riveted joint, the half moon indications should all be on the same side of the rivet and the rivets in the joint should show similar indications of failure. Intermittent indications would normally be considered fabrication tolerance.

(b) Corrosion. Corrosion may occur in an aircraft part which reduces its strength and expedites the possible failure. This deterioration of the metal may be due to electrolytic action, moisture, chemicals or gases which attack the metals, intergranular action due to improper heat treatment at the time of manufacture, or other factors. This condition usually occurs on internal surfaces of such components as tubular supports or housings. Since corrosion represents a change of material and occurs in all directions, it is easily detected by a proper radiographic exposure.

(c) Cracks. Cracks and other crack-like discontinuities are found in numerous parts and structures and are very dangerous discontinuities. This is particularly true where structures are subjected to vibration or fatigue loading, due to propagation of these crack-like discontinuities. Crack-like discontinuities will appear in a radiograph as very straight and sharply outlined dark or black lines. Cracks may also appear as diffused jagged lines. in some cases they have a tree-like pattern. Scatter radiation from the sides of a crack can act as an amplifier of the crack image in a radiograph. This is the most difficult service type failure to detect by radiography since these crack separations are usually not associated with other detectable conditions which give clues to their presence.

(d) Water in honeycomb. A typical condition that occurs in honeycomb structures is the formation of water in the cores. This entrapped water freezes and expands at high altitudes. The expansion distorts the cells and can break the bonds between core and facing sheets. When this condition exists, vibration of the face sheet can occur, causing failure of adjacent bonds and propagation of bond failure. Entrapped water causes corrosion of both face sheet and core structure. Radiographic inspection is conducted to evaluate core damage and water contents as a maintenance inspection.

(e) Foreign objects. Radiography is an excellent method to locate and evaluate foreign objects. Foreign objects may be free rivets, bolts, or other objects that could be detrimental to the function of the part or assembly.

(f) Assemblies. Radiography has found wide use in the evaluation of various assemblies to determine status or condition. If the use of the assemblies produces changes in it which are recordable by an X-ray beam, then radiography may be useful in supplying confirming evidence of the suspected condition.

(g) Workmanship. On occasion, components are misassembled. In some areas it is not possible to check dimensions by physical or visual means. Radiography may be used if precautions are taken to assure proper geometrical relation to determine dimension of internal spacings.

(h) Human error. There is continually the possibility of human error in servicing equipment. This type of error can also be detected by radiography.

b. Misinterpretation. The mistakes in radiographic interpretation most often are a result of misreading film artifacts. There are a number of density patterns which resemble welding and casting defects which are often unjustified causes for rejects. Refer to TM 551500-335-23 for common misinterpretations.

5-10. Filing Radiographs. The final radiographs should be placed In film filing envelopes for final storage. These envelopes are constructed of heavy kraft paper to protect the films. The envelope should be identified as to the radiographs it may contain and filed in a systematic manner to facilitate retrieval If and when necessary. Envelopes should be marked prior to insertion of the film to prevent pressure marks. Films should not be stored in high humidity areas. Film filing cabinets are available for film storage. Ordinary filing cabinets are not sufficiently strong to withstand the heavy loads of filed film.

5-11. Radiography Safety Precautions and Equipment. The following paragraphs explain safety precautions and equipment to be followed by personnel working with radiography.

WARNING

- **Women SHALL NOT perform radiographic procedures or be subjected to industrial ionizing radiation during their term of medically confirmed pregnancy without specific approval. For further guidance consult the Base Bioenvironmenta/Radiological Engineer.**

- **Persons in the general population at any age. Such individuals should not receive an exposure exceeding 0.5 rem per year in addition to natural background and medical exposures (This limit applies to those persons who are not occupationally exposed. This rate equates to 10 percent of that allowable for occupationally exposed/monitored personnel. NCRP Report No. 32, July 1,1966.)**

a. General. Safety is of paramount importance in radiography. Exposure to radiation results in the cumulative buildup of radiation in the body. This buildup must be monitored and controlled.

Table 5-1. Radiation Protection Standards

Occupational exposure	Condition	Dose (rem)
Whole body, head and trunk, blood-forming organs, gonads,	Accumulated dose	5(N-18); N greater than 18 years
lens of the eye	13 weeks	3
Skin and thyroid	Year	30
13 weeks	10	
Hands and forearms, feet	Year	75
and ankles	13 weeks	25
Population		
Individual	Year	0.5 (whole body)

b. Exposure limits. No individual shall ever knowingly expose himself or cause others to be exposed to levels of radiation greater than those specified in table 5-1, except in case of extreme emergency.

c. Radiation Detectors. The following paragraphs describe various radiation detectors.

(1) General. Radiation detectors are used to measure the accumulated dosage of Roentgen Equivalent Mans (rem) of occupationally exposed individuals and to determine the level of radiation of an object or area.

(2) Types. The four most common types of radiation detectors are described in the following paragraphs.

(a) Ionization chamber. The radiation detectors of most ionization clamber type survey instruments are either cylindrical or rectangular in shape with a wire electrode (anode) in the center which runs the length of the chamber. This wire is electrically insulated from the chamber wall (cathode) and an electrical field or charge is established between the wire and the chamber wall. The chamber is filled with air at atmospheric pressure. As X-or gamma radiation penetrates the chamber, ions are produced as a result of interactions (ionization) in the gas in the chamber. Under the influence of the electrical field, the negative ions will move toward the positive electrode (anode), while the positive ions will move toward the negative electrode (cathode). Upon hitting the electrodes, the ions neutralize part of the charge on the electrodes. The extent of the neutralization can be measured and will given an indication of the amount of radiation to which the chamber has been exposed. The relative response of four survey instruments is shown in Table 5-2. The relative response is defined as the indicated exposure rate divided by the true exposure rate. The Victoreen Model 440 and the Heat Pipe Model VR-10 survey meters are now standard instruments for industrial radiography. The Victoreen Model 592B, although still in use, is being phased out, due to its poor energy response.

1 AN/PDR-27 type instrument. It can be concluded from Table 5-2 that the AN/PDR-27 GeigerMueller type survey instrument does not accurately measure X-ray exposure rates. The use of the external probe with the beta shield off results in exposure rates that are higher than the true rates. However, the maximum exposure rate that can be measured using the external probe is 5.0 mR/hr. exposure rates from low energy X-rays cannot be accurately measured since the internal GM tube is shielded by a container which blocks low energy electro magnetic radiation. At 32 kev, for example, this instrument measures only 1% of the true exposure rate. The AN/PDR-27 or other GeigerMueller type survey meters SHALL NOT be used in conjunction with industrial X-ray operations.

2 Victoreen Model 529B instruments. The Victoreen Model 592B survey meter is limited in its ability to detect low energy X or gamma rays. At 33 key, for example, this instrument measures only 23% of the true exposure rate. Thus, this instrument could, in some cases, result in an improper evaluation of the radiation

Table 5-2. Relative Response of Survey Meters

Instrument Model No. FSN	Relative Response Instrument Effective Energy Key					
	22	**32**	**70**	**120**	**170**	**663(a)**
Victoreen Model 440 NSN 6665-00-938-6806	0.94	1.04	1.16	1.18	1.16	1.0
Victoreen Model 592B NSN 6665-00-018-5841	0.23	0.79	1.14	1.20	1.16	1.0
Heat Pipe Corp. Model VR-1 0 NSN 6665-00-581-0220 With Cap Off	1.06	1.16	1.03	1.0	1.03	0.82
AN/PDR-27 NSN 6135-00-164-8753 External Probe Cap Off	1.71	3.8	4.27	2.88	1.52	1.0
External Probe Cap On	-	0.34	1.35	1.94	1.34	1.0
Internal Probe	-	0.01	2.22	2.1	20	1.0

(a) Note that the 663 key response was obtained from Cs-137 gamma rays, which is commonly used for calibration in the USAF.

hazard, causing personnel ro receive an unwarranted exposure to ionizing radiation. Personnel should understand the energy dependence characteristics of the Model 592B survey instrument and should not accept all indicated exposure rates (meter readings) as being true values.

3 Victoreen Model 440 Instrument. In contrast to the Model 592B survey meter, Table 5-2 indicates that the Model 440 instrument is nearly energy independent for the range of X-ray energies encountered in industrial radiography.

(b) Portable geiger counters. Various portable geiger counters are used to measure levels of radiation. Radiation exposure measurement with portable survey instruments may be affected by such factor as ambient temperature, configuration of radiation 5-8 source, (i.e. round, square, rectangular, etc.), isotope source, pressure and relative humidity, direction of radiation beam, radiation quality (effective energy or radiation spectra) and instrument susceptibility to Radio Frequency (RF) radiation.

(c) Pocket dosimeters. The pocket dosimeter, used in conjunction with, but never in lieu of, a film badge or Thermoluminescent Dosimeter (TLD), is a compact, easy to carry device that indicates an individuals accumulated exposure to radiation. The dosimeter is about the size and shape of a large fountain pen and shall be worn between the neck and the waist. The pocket dosimeter, contrary to its name, shall be worn on an outer garment and never be placed inside a pocket.

(d) Film badges. The film badge is used mainly to measure X or gamma radiation and the more energetic beta radiation. However, special TLD or film dosimeters are readily available for measuring neutron radiation. The film badge is meant to provide a permanent record of the cumulative exposure received by an individual while working in a radiation environment. In order that the exposure received by the film badge be a good indication of that received by the whole body of the Individual, the badge shall be worn between the neck and the waist. The film badges shall be worn clipped to the breast pocket of the outer garment, if possible. The badge should never be placed inside a pocket. If exposure to the arms, hands, or head is likely to be different from exposure delivered to the body, special film holders are available.

d. Electrical Precautions. All switches and electrical equipment shall be of the enclosed explosion-proof type. All metal apparatus shall be grounded to avoid the danger of igniting test fluid fumes or creating electrical shock.

CHAPTER 6

ULTRASONIC INSPECTIONS

6-1. General. Ultrasonic is the name given to the study and application of sound wave frequencies higher than those to which the human ear can respond, 20,000 Hz (hertz or cycles per second). In contact ultrasonic testing the most commonly used frequencies range is from 2.25 to 10 MHz (megahertz or million cycles per second). Frequencies below this range and up to about 25 MHz are also used on occasion.

6-2. Advantages. Ultrasonic detection equipment has made it possible to locate defects in all types of parts without damaging the part being inspected. Minute cracks, checks, and voids, too small to be seen by X-ray, are located by ultrasonic inspections. Access to only one surface of the part is necessary.

6-3. Disadvantages. The sound beam is not a straight sided projection of the face of the search unit having uniform intensity. The sound beam spreads out beyond the face of the search unit and varies in intensity. This causes dead zones and other problems. Refer to TM 55-1500-335-23.

6-4. Basic Testing Methods. Contact and immersion methods are used for ultrasonic inspections. In the contact method of ultrasonic inspection, the search unit is placed directly on the test part surface using a thin film of couplant, such as oil, to transmit sound into the test part. In the immersion method, the test part is immersed in a fluid, usually water, and sound is transmitted through the water to the test part.

6-5. Nature of Ultrasonic Waves. Ultrasonic sound beams have properties similar to light beams. For example, when an ultrasonic beam strikes an interrupting object, sound beam energy is reflected from the surface of the interrupting object. The angle of incidence is equal to the angle of reflection. The reflected energy may be picked up by a search unit. This search unit is usually the same search unit used to generate the sound beam, but may be a second search unit. The search unit transforms the received ultrasonic energy into electrical energy. The ultrasonic instrument amplifies this electrical energy and presents it as a vertical deflection on a cathode ray tube.

6-6. Modes of Vibration. Sound energy is propagated in an object by the vibration of particles in the object. Ultrasonic energy is transmitted from one atom to another The direction in which the particles (atoms) vibrate in relation to the direction of the ultrasonic beam propagation is dependent on the mode of vibration.

a. <u>Longitudinal Waves</u>. The longitudinal or compressional wave mode is characterized by particle movement parallel to the direction of sound beam propagation.

b. <u>Transverse Waves</u>. The transverse wave mode is characterized by particle movement perpendicular to the direction of the sound beam propagation. Tranverse waves travel at approximately one half the speed of longitudinal waves. Transverse waves are introduced into a test part by using an angle beam search unit. This type of search unit consists of a transducer element mounted on a plastic wedge, so that ultrasonic waves enter the test part at an angle

c. <u>Rayleigh Waves</u>. Surface waves, or Rayleigh waves, are a special type of shear wave in which the motion of the particles is confined to a thin layer on the free boundary of a solid.

d. <u>Lamb Waves</u>. Lamb wave propagation occurs when ultrasonic waves travel along a test part with thickness less than the wavelength. There are two general classes of Lamb waves: symmetrical and asymmetrical waves. An infinity of modes of each class of vibrations are possible in a given test part Theory shows that the velocity of the lamb waves is dependent on the mode and can exhibit many different velocities.

6-7. Transmission Characteristics. Reflection, refraction and mode conversion, and beam divergence are explained by the following paragraphs.

a. <u>Reflection,</u> When an ultrasonic beam strikes a boundary between two different objects, part of the energy is transmitted to the second medium and part is reflected. The percentage of sound transmitted and reflected is related to the acoustic impedances of the two materials. Acoustic impedance, z, is the product of density, p or rho, and velocity, v, or:

$$z = pv$$

b. Refraction and Mode Conversion. When a sound beam passes from one medium to another with a different velocity at an angle not normal to the interface separating the two media, refraction occurs. The incident and refracted angles follows Snell's law. Snell's law is written for use in ultrasonic Inspection as follows:

$$\frac{\sin \varnothing_1}{\sin \varnothing_2} = \frac{V_1}{V_2}$$ where:

$\varnothing_1$ = angle between the normal to the interface surface and the incident sound beam.
$\varnothing_2$ = angle between the normal to the interface surface and the refracted sound beam.
V_1 = velocity of incident sound beam.
V_2 = velocity of refracted sound beam.

c. Beam Divergence. The sound beam is not a straight-sided projection of the face of the search unit having uniform intensity. The sound beam spreads out beyond the face of the search unit and varies in intensity.

6-8. Ultrasonic Inspection Equipment. The basic types of ultrasonic inspection equipment are explained in the following paragraphs.

a. General. All ultrasonic pulse-echo instruments basically perform the functions of generating, receiving, measuring the amplitude of, and determining the time of electrical pulses. Inspection information is displayed on the cathode ray tube contained in all ultrasonic pulse-echo flaw detection inspection units.

b. Search Units. Search units are devices for generating and receiving ultrasonic energy. The units may contain transducer elements or a microphone and coil.

c. Transducers. Transducers are electo-acoustical devices for converting electrical energy into acoustical energy and vice versa. The most common piezoelectric substances used for transducer elements are:

- Quartz
- Lithium sulfate
- Polarized ceramic materials-barium titanate, lead metaniobate, and lead zirconate titanate

Originally, ultrasonic inspections were performed almost exclusively with quartz transducer elements, but quartz is used very little now because better elements are available. The inspection performance can be improved by selecting different transducer elements for the transmitting transducer element and for the receiving transducer element.

CAUTION

Glycenne, silicones, and graphite greases shall not be used as couplants because they have an unacceptable surface roughness.

d. Couplants. Couplants are substances used between the search unit and test part to permit or improve transmission of ultrasonic energy into the test part. Typical couplant substances include water, oil, grease, and penetrant emulsifier.

6-9. Ultrasonic Inspection Techniques. Ultrasonic inspection can be separated into contact and immersion inspection. Since immersion inspection is not applicable in the field, all information in the following paragraphs is for contact inspection. Straight beam, angle beam, and surface wave methods of contact inspection are described in the following paragraphs.

a. Straight Beam Method. The straight beam method uses longitudinal waves and is generally used on objects 1/2 inch thick or greater. The dead zone interferes with inspection of thinner objects. When required, application of straight beam inspection to thinner objects can be extended by several different methods, such as:

- Inspection of object from opposite sides. The dead zone which is not inspected from the first side is covered when inspecting from the second side.
- Use of dual search units.
- Use of delay line search units.

b. Angle Beam Method. The angle beam method generally uses shear waves with refracted angles in the test part from 30 to 70 degrees. This method is used extensively for field NDI, and can provide for inspection of areas with complex geometry or limited access. This is because angle beams can travel through a part by bouncing from surface to surface. Useful inspection information can be obtained at great distances from the search unit. Angle beam inspections are particularly applicable to Inspections around fastener holes, inspection of cylindrical components, examination of skins for cracks, and inspection of welds.

c. Surface Wave Method. The surface wave method uses surface (Rayleigh) waves. When inspecting thin objects (less than one wave-length thick) with sound propagated perpendicular to the thickness direction, Lamb waves are used.

d. Surface Preparation. The sound entry surface is visually examined to determine if any special preparation is required to provide a suitable condition for ultrasonic inspection. The surface finish should be 250 rhr or smoother. Painted surfaces can normally be inspected without removing the paint if the paint is uniform and adheres tightly to the surface. Loose paint or uneven, patched paint shall be stripped prior to ultrasonic inspection.

e. Inspection of Metal Plates and Sheets. Metal plates and sheets should be inspected for laminations, surface cracks, and weldment defects. These defects are explained in the following paragraphs.

(1) Laminations. Laminations in rolled plate or strip are formed when blowholes or internal fissures are not welded tight during rolling, but are enlarged and flattened into sometimes quite large areas of horizontal discontinuities. Laminations may be detected by magnetic particle testing on the cut edges of plate, but do not give indications on plate or strip surfaces, since these discontinuities are internal and lie in a plane parallel to the surface. Ultrasonic mapping techniques are used to define them. When inspecting parts fabricated from sheet or plate, laminations can be detected by noting a reduction in the distance between back reflection multiples.

(2) Surface cracks. When inspecting for surface cracks, the sound should be directed normal to the expected plane of the discontinuity. The straight beam method is used for laminar discontinuities and the angle beam method for internal discontinuities.

(3) Weldment defects. Several kinds of discontinuities may be formed during welding. Some are at the surface and some are in the interior of the metal Ultrasonic testing can detect some types of weldment defects. Refer to the applicable maintenance manual.

f. Inspection of Bar Stock. Bar stock should be inspected for blow holes and cracks. These are explained in the following paragraphs.

(1) Blow holes. A blow hole is a hole in a casting or weld caused by gas entrapped during solidification.

(2) Cracks. Various types of cracks can be detected by ultrasonic testing methods. Refer to the applicable maintenance manual for detection methods and interpretation.

g. Inspection of Tubes and Pipes. Inspection of tubes and pipes using ultrasonic testing methods should be done in accordance with the applicable maintenance manual.

6-10. Calibration of Ultrasonic Equipment. The most important calibration is the verification of each inspection setup through use of the applicable reference standard. It is essential that this verification be performed for each and every inspection Attenuation measurements should be made using ASTM test block, angle beam blocks, and a surface wave reference standard. This IS done to minimize the scattering of the sound beam. Complete procedures are found in TM 55-1500-335-23.

CHAPTER 7

ELECTROMAGNETIC INSPECTIONS

7-1. General. With magnetic metals such as steel, the reaction of the metal to the applied magnetic field is much more dependent upon the magnetic permeability of the metal than on Its electrical conductivity. When magnetic properties are predominant, the form of testing is more accurately termed magnetoinductive testing. Eddy current testing and magnetoinductive testing are grouped together under the more general classification of electromagnetic testing.

7-2. Purpose. Electromagnetic inspections are 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, stamping, machine parts, forgings, and extrusions.

7-3. Eddy Currents. Eddy currents are electrical currents Induced in a conductor of electricity by reaction with a magnetic field. The eddy currents are circular In nature, and their paths are oriented perpendicular to the direction of the applied magnetic field. In general, during eddy current testing, the varying magnetic field is generated by an alternating electrical current flowing through a coil of wire positioned immediately adjacent to the conductor, around the conductor, or within the conductor. A summary of the uses of eddy current inspection as related to the property or test conditions measured is presented in table 7-1.

7-4. Field Application. Eddy current techniques are particularly well suited for detection of service-induced cracks in the field. Service-induced cracks in aircraft structure are generally caused by fatigue or stess corrosion. Both types of cracks initiate at the surface of a part. If this surface is accessible, eddy current inspection can be performed with a minimum of part preparation and a high degree of sensitivity. Unlike penetrant inspection, eddy current inspection can usually be performed without removing such surface coatings as primer, paint, and anodic films. Eddy current inspection has greatest application for inspecting small localized areas where possible crack initiation is suspected rather than for scanning broad areas of metal for randomly oriented cracks. In some instances, it is more economical to scan relatively large areas with eddy current rather than strip surface coatings, inspect by another method, and then refinish.

7-5. Eddy Current Test Set Model ED-520. The ED-520 eddy current test instrument is a compact, lightweight, battery-operated portable unit designed primarily for the detection of cracks and flaws. The ED-520 is an impedance type instrument where variations in conductivity, permeability, or physical characteristics result in impedance changes in the test coil attached to the bridge circuit. The impedance change causes the bridge to become unbalanced; the unbalanced voltage is amplified and indicated by the panel meter. The instrument can be used with a wide variety of probes and coils. The two-wire system is generally used with a single coil.

a. Operation. Front panel controls consist of a mode switch, lift-off frequency control, sensitivity and balance. The mode switch has six positions: OFF, TEST, LO, MED, HI, and CHG. In the OFF position the meter terminals are short circuited and the battery charger is shut off. In the LO, MED, and HI positions the instrument is turned on and the meter is connected to the output of the bridge circuit. The sensitivity of the instrument is increased by a factor of approximately 2 with each change in position from LO to MED to HI. If ac power is applied to the unit while in any one of these positions, a limited charging current is provided to the unit. When the unit is in the TEST position, the meter is connected directly across the rechargeable batteries and indicates the state of charge of the batteries. When the batteries are adequately charged, the meter will read above the red line on the face of the meter. In the CHG position, maximum charging is applied to the batteries and all other circuits are shut off. The CHARGING light will be on whenever the line voltage is being supplied to the battery charging circuits.

b. Testing Procedure. For testing, the operating frequency is set by the LIFT-OFF/FREQ. control. Defect detection usually requires a procedure which will minimize the effects of lift-off on the eddy current response. This is accomplished by establishing an operating frequency with the LIFT-OFF/FREQ. control which will provide the same probe coil impedance with the probe in contact with bare metal of the part. Operating frequencies for lift-off compensation are determined by adjusting the LIFT-OFF/FREQ. until the same meter reading is obtained with the probe in each of these two positions. More than one frequency may provide lift-off compensation. However, the highest frequency (lowest LIFTOFF/FREQ. setting) usually provides the best

Table 7-1. Uses of Eddy Current Inspection

Variable Measured				
Electrical conductivity	**Magnetic permeability**	**Geometry**	**Homogeneity**	**Magnetic coupling (lift-off or fill factor)**
Alloy Sorting	Alloy Sorting (magnetic materials)	Metal Thickness (thin materials)	Flaw Detection: 1. Cracks 2. Segregation 3. Seams 4. Inclusions 5. Pits 6. Corrosion	Insulation Thickness
Heat-Treat Control	Case Depth			Nonmetallic Coating Thickness
Cladding Thickness	Heat-Treat Condition (magnetic materials)			Proximity Gauge
Plating Thickness	Plating Thickness			Diameter Diameter

sensitivity for defect detection. When using the ED-520 for purposes other than defect detection, frequencies may be selected to minimize variations in parameters other than lift-off. The magnitude of the current change corresponding to a specific change in test coil impedance is regulated by the position of the function switch LO, MED, HI and the SENSITIVITY control.

c. Changing magnitude of Current. In the simplest type of instrumentation, analysis of the signal consists of measuring the change in relative magnitude of the current flowing through the bridge. Changes in the ac current are amplified and converted to a dc current prior to readout. In more sophisticated instrumentation, both amplitude and phase are determined. In this case, a reference signal is provided as a basis of comparison with the amplified signal from the bridge or compensating circuit. Phase is then measured in relation to the reference signal.

d. Needle Deflections. Acceptance of an eddy current probe should be based primarily on crack or flaw detection capability or sensitivity. With the ED-520 adjusted for 3 mils of lift-off and maximum sensitivity, probes should exhibit a static meter deflection of at least 100 units from a 0.60 inch long x 0.020 inch deep Electrical Discharge Machined (EDM) notch in aluminum in order to exhibit adequate sensitivity. Probes that are also to be used on steel or titanium should meet minimum sensitivity requirements for those materials. Response from a 0.060 inch long x 0.010 inch deep EDM notch in steel should be a minimum of 60 meter units. A 0.100 inch long x 0.030 inch deep notch in titanium should yield a meter deflection of 30.

APPENDIX A

REFERENCE

A-1. ARMY REGULATIONS (AR):

AR 385-10	Army Safety Program
AR 385-11	Ionizing Radiation Protection
AR 385-30	Safety Color Code Markings and Signs
AR 385-32	Protective Clothing and Equipment

A-2. FEDERAL HANDBOOK:

H4/H8	Commercial and Government Entity (CAGE) Publication - Name to CAGE

A-3. TECHNICAL MANUALS (TM):

TM 55-1500-335-23	Nondestructive Inspection Methods

GLOSSARY

AMPERAGE -	The strength of a current of electricity measured in amperes.
ATTENUATION (RT) -	Loss of energy caused by scattering of the radiation wave within a material or at an Interface, or an electronic device in or attached to the instrument.
ATTENUATION (UT) -	Loss of energy caused by scattering of the sound beam within a material or at an interface, or an electronic device in or attached to the instrument.
BEAM DIVERGENCE -	Spreading of a beam as it travels through material.
CENTRAL CONDUCTOR -	A conductor made of copper, aluminum, steel, or flexible cable that is passed into or through an opening in a cylindrically-shaped part or other shapes when applicable for the purpose of establishing a circular field on the inside diameter.
CORROSION -	The gradual loss of material which is being eaten away by chemical action.
CURIE POINT -	The temperature at which ferromagnetic metals become non-magnetic and can no longer be magnetized by outside sources.
DEFECT -	A discontinuity which interferes with the usefulness of a part.
DEMAGNETIZATION -	The reduction to can acceptable level of the residual magnetism in ferromagnetic materials.
DISCONTINUITY--	An interruption in the normal physical structure or configuration of a part.
DWELL TIME -	The period of time that the liquid penetrant remains on the surface of the part.
ELECTROMAGNETIC -	The magnetism created In a suitable metal core which has been placed in the magnetic field created by passing electric current through a coil of wire or a central conductor.
ELECTROMAGNETIC TESTING -	The nondestructive testing of materials (including magnetic materials) which uses electromagnetic energy with frequencies less than that of visible light to determine the quality of tested materials. This term includes eddy current testing and magneto-inductive testing.
EMULSIFICATION-	The process of dispersing one liquid in a second immiscible liquid.

GLOSSARY

FERROMAGNETIC METALS - The attraction of repulsion of most metals when under the influence of a magnet is very slight. A few metals, particularly iron, steel, cobalt and nickel are strongly attracted. These metals, permeable to magnetic flux, are called ferromagnetic. In magnetic particle testing, we are concerned only with ferromagnetic metals.

FLUOROSCOPY-- The visual presentation of an X-ray image on a fluorescent screen.

GAMMA RAY - The electromagnetic radiation of high-frequency and short wave-length emitted by the nucleus of an atom during a nuclear reaction. Gamma rays are not affected by electric fields or magnetic fields Although produced differently then X-rays, they are identical in nature and properties to X-rays of the same wavelength.

IONIZATION CHAMBER - An instrument that detects and measures the electrical current created when gas in the chamber is ionized by radiation and becomes an electrical conductor.

LEAKAGE FIELD - The magnetic field forced out into the air by the distortion of the field within a part caused by the presence of a discontinuity or change in section configuration.

MAGNETIC FLUX - Magnetism may be considered a force which tends to produce a magnetic field. Magnetic flux is a condition in this magnetic field which accounts for the effect of the field on magnetic objects. To picture a magnetic field in a diagram, magnetic flux is commonly represented by flux lines that form a pattern or series of curved lines within the magnetic field flowing through the magnet and air around the magnet. The stronger the field, the greater the number of flux lines. These lines are also called lines of force

MAGNETIC METALS - Magnetic metals are those metals which are attracted be magnetism, or which are permeable to magnetic flux.

MAGNETISM - The property of some metals, chiefly iron and steel to attract other pieces or iron or steel is called magnetism. While most metals are affected by magnetism to some degree, only iron and steel and some of their alloys are sufficiently affected for the application or use of magnetic particle inspection.

PENETRAMETER - A device using radiography to ensure that the inspection technique was appropriate. It is not intended to judge the size of discontinuities or to establish acceptance limits for materials or products.

PENETRATION TIME - The time allowed for the penetrant to enter surface discontinuities.

GLOSSARY

PERMEABILITY-- The ease with which a metal or metallic part can be magnetized is called permeability. A metal that Is easy to magnetize is said to have high permeability or to be highly permeable A metal that is difficult to magnetize is said to have low permeability. Soft iron and iron with a low percentage of carbon are usually easy to magnetize and are highly permeable. Hard steel with a high percentage of carbon content is usually hard to magnetize and, therefore, is usually lower in permeability. Permeability and retentivity are inversely related characteristics. The higher the permeability the lower the retentivity and the lower the permeability, the higher the retentivity.

RADIOGRAPHY- A nondestructive test using X-rays or gamma rays to determine the subsurface condition of opaque materials. The information obtained is permanently recorded on a specially prepared film called a radiograph.

RESIDUAL MAGNETISM - The magnetic field that remains in the parts when the magnetizing force has been reduced to zero or the magnetizing current IS shut off is called the residual field. The magnetism which remains is called residual magnetism.

RETENTIVITY- The property of any magnetic metal to keep or retain a magnetic field after the magnetizing current is removed is called its retentivity. Metals such as hard steel with a high percentage of carbon which keep a strong magnetic field have high retentivity or are said to be highly retentive. Those metals such as soft iron or iron with a low percentage of carbon which lose most of their magnetism as soon as the magnetizing current is removed have poor retentivity.

SENSITIVITY - The degree of discontinuity or defect revealed by the Inspection. Higher sensitivity means that smaller defects are detectable

TRANSVERSE WAVE - A wave in which particle motion Is perpendicular to the direction of propagation.

ULTRASONIC - Pertains to mechanical vibrations with frequency greater than 20,000 hertz

X-RAY- Radiant energy produced when a suitable target is bombarded by high voltage electrons in a vacuum. X-rays have wavelengths between 10-11 cm and 10-6 cm

INDEX

INDEX - CONT

INDEX -CONT

INDEX - CONT

INDEX - CONT

INDEX - CONT

INDEX - CONT

INDEX- CONT

INDEX - CONT

Subject | **Paragraph, Figure, Table Number**

T - Continued

U

V

W

By Order of the Secretary of the Army-

GORDON R SULLIVAN
General, United States Army
Chief of Staff

Official

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Secretary of the Army
02556

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The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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