(f) During service inspection, found several fuselage top skin cracks between stringers 10L and 10R. Cracks at spot welds between tear strips and stringers. Replaced affected fuselage panels per Boeing instructions. TAT 30,944 hours.

(g) During scheduled inspection, found nosegear door torque tube support P/N 65-22475-2 RH corner broken off at station 294.5. Replaced support assembly. TAT 10,933 hours.

(h) Several skin and stringer cracks at fuselage station 960 to 1240 from stringers 10L to 10R. Skin and stringers replaced. TAT 31,627 hours.

(i) Found 3/4 inch crack in radius of chord angle fuselage bulkhead, station 1440 between stringers 3R and 3L. Repaired with external strap with Boeing approval.

(j) On the lower nose walkway pressure web found 3-inch crack on the lefthand side at station BS 320. TAT 27,263 hours.

(k) X-ray inspection revealed 1/2-inch crack across outer flange of FS 1241 fuselage beltframe between stringers 4 and 5. Repaired per repair manual. TAT 17,754 hours.

(l) Found a one-inch longitudinal crack on fuselage exterior skin at skin lap at forward righthand carrier of nosewheel well cutout at stringer 28, BS 259.5. Subsequent inspection of area revealed additional cracks as follows:

<u>1</u> Crack across the forward flange of fuselage former T angle between stringers 27 and 28 at BS 259.5.

<u>2</u> A crack on forward side former station 259.5 nonpressure web progressing up from former T angle between stringer 27 and 28.

<u>3</u> Cracks across the vertical and horizontal flange of attaching forward side from station 259.5 between stringers 27 and 28. Repairs accomplished per repair manual. TAT 22,537 hours.

(m) Found bottom fuselage skin cracked at aft edge of radio altimeter antenna cutoff. Crack extended aft 1-1/2 inches. Repaired by doubler installation. TAT 24,289 hours.

(n) During MBC found 9-inch crack in web fuselage station 360 rightside between nosewheel well and vertical member at RBL 13, web also buckled badly from wheel-well outboard 18 inches. TAT 24,405 hours.

(o) Found cracks in upper cargo door latch support fitting P/N 65-27187-1, one at fuselage (body) station 500 and one at station 520. Fittings located just below bottom door sill. TAT 12,914 hours. (B-707-300 series).

(p) In cruise at 35,000 feet, Captain's outer windshield cracked and small piece blew out. P/N 5-7176-1-3015. TAT 24,981 hours, TSL1 48 hours.

(q) Outer pane of number 3 left cockpit window cracked. A short time later, inner pane cracked. Pressure differential reduced to 2PSI and landed without further incident. Changed window P/N 121-71763-13.

(r) Captain's apostrophe windshield shattered in cruise. Suspect arcing cause of shattering. Changed windshield Boeing P/N 5-71761-3019. Operation then normal.

(2) Wing.

(a) During routine service, found right wing top skin at station 226 cracked from trailing edge forward to fastener hole No. 139 in rear spar. Repaired per structural repair manual. TAT 16,742 hours.

(b) Evidence of fuel leak revealed chordwise crack extending between the splice plate tab fasteners in right lower wing skin inboard of No. 3 pylon WS 392, 2-1/2 inches aft of front spar. Crack repaired in accordance with Boeing Service Bulletin 1995 R6. Aircraft total time 24,875 hours.

(c) During scheduled ultrasonic inspection of right upper wing skin at rear spar, fasteners found cracked at fasteners Nos. 5, 7, and 48. The crack emanating from No. 5 fastener extends forward 1/8 inch. Crack from No. 7 fastener extends aft 1/8 inch. Repaired in accordance with Service Bulletin 2427. TAT 9,951 hours.

(d) During check, found approximately an 8-inch spanwise crack at upper front spar cap on right wing at WS727. Repaired per Boeing drawing 65-70144. TAT 33,967 hours.

(e) During routine X-ray inspection of rear spar area, a crack was found in fastener hole NR 102 as shown on Boeing Drawing 65-68301 at WS 208 left wing. The crack extended forward at 10 o'clock position to edge of upper spar cap and aft approximately .25 inches. Internal repair was made per Boeing Drawing 65-40140. TAT 16,494 hours.

(f) During routine service inspection, found 2-1/2 inch spanwise crack in upper skin of left wing. Crack approximately 8 inches aft of front spar at WS 529. TAT 30,944 hours.

(g) During scheduled inspection, found 1-1/4-inch long crack in No. 1 nacelle front spar fitting aft outboard hole, assembly P/N 65-133475. Replaced fitting assembly.

(h) Ultrasonic inspection found 1/8-inch crack on top of right wing at No. 11 fastener at rear spar. Crack emanates from fastener hole and extends forward. Repaired in accordance with S/B 2427. TAT 21,979 hours.

(i) Ultrasonic inspection of left upper wing skin at rear spar fasteners, found crack at fastener No. 49. Crack approximately 1/8-inch long and emanates from hole in aft direction. Repaired in accordance with Service Bulletin 2427. TAT 22,458 hours.

(j) Ultrasonic inspection of left and right upper skin at rear spar fasteners revealed one crack in left wing and one in right wing. Crack in left wing was at rear spar fastener No. 56. The crack was 1/4-inch long and emanated from fastener hole in the forward direction. Crack in right wing was at fastener No. 9. The crack was 1/16-inch long and emanted from fastener hole in the aft direction. Repaired in accordance with S/B 2427. TAT 21,656 hours.

(k) Inspection of upper skin in accordance with Boeing S/B 2378 found a crack in the upper skin right wing at innermost fastener of stringer 6A. Repaired in accordance with Boeing Drawing WR 65-58379. TAT 22,919 hours.

(l) Crack 3/32-inch long on upper left wing rear spar at aft row of fasteners, inboard of beaver tail fastener No. 8. Repaired per manufacturer's instructions. TAT 11,975 hours.

(m) At scheduled inspection found crack in top wing skin of left wing at interspar skin just aft of front spar station 475. Crack extends fore-and-aft, 1-1/4-inch total length of fastener hole at terminus of No. 19 stringer. Repaired per Boeing instructions. TAT 24,299 hours.

(n) In leading edge skin, lower surface at station 300, left wing, 4-inch long chordwise crack.

(o) Crack 3/32-inch long found on upper right wing rear spar at aft row of fasteners. Fastener No. 8 inboard of beaver tail. TAT 11,975 hours.

(p) Repaired 2-inch crack in left wing skin top at rear spar station 226. Cracked from hole No. 136. Reference Boeing Drawing 65-58301. TAT 12,249 hours.

(q) Out of service due to fuel leak left wing No. 2 fuel tank, found 2-1/4-inch crack in skin at No. 1 aft main fuel boost pump. TAT 30,442 hours.

(r) Crack indication in rear spar chord at fastener hole Nos. 5 and 6 in left wing, and at No. 19 in right wing. Repaired per SB 2427, Part V. TAT 15,810 hours.

(s) Ultrasonic inspection of left upper wing skin at rear spar fasteners found crack at fastener No. 7. Crack approximately 1/8-inch long and emanated from hole in aft direction. Repaired in accordance with Service Bulletin No. 2427. TAT 21,044 hours.

(t) Found upper wing skin center section with intermittent crack over a 12-inch span at stringer 27 approximately 6 inches to left of centerline. Span contained a 3-inch visible crack, plus a 2-1/2-inch eddy current indication separated by 2-inch and 6-inch areas of wing skin. On opening, found several cracks in radius of stringer 26A. Repaired per Boeing recommendations. TAT 25,905 hours.

(u) Nacelle rib station 212. Found 2-inch crack in web of No. 1 nacelle inboard and outboard sides at rear engine mount fittings above horizontal firewall. Repaired per manufacturer's instructions. TAT 23,051 hours.

(v) No. 1 nacelle. Found both end lugs lower spar fitting diagonal brace attach cracked through diagonal brace boltholes. Replaced fitting P/N 5-84468-3005. TAT 23,051 hours.

(w) During service inspection found No. 4 pylon upper cap skin and side panel cracked. Outboard chord angle P/N 64-1071 cracked in two. Crack through fastener hole to forward fasteners through the outboard tang of the front spar fitting P/N 65-13347-5. Spar fitting changed due to crack indications in fastener holes. Repairing chord angle and affected skin.

(x) Found No. 1 engine pylon over wing fitting cracked, completely through, 8 inches aft of forward end. Replaced over wing fitting assembly.

(y) Found crack 1-1/8-in. long at hydraulic line support fitting hole No. 2 strut torque bulkhead web. Also found 6- and 7- inch long crack No. 3 strut torque bulkhead web, same location. TAT 29,825 hours.

(3) Empennage.

(a) During routine service found upper clevis lower lug cracked in right horizontal stabilizer front spar terminal fitting. Replaced fitting P/N 65-3409. TAT 15,810 hours.

(b) Replaced cracked fitting P/N 65-3409-8 horizontal stabilizer right hand forward spar terminal. Fitting was cracked in upper clevis hole inboard to edge. Inspection per Service Bulletin 2330. TAT 12,457 hours.

(c) Found heavy exfoliated corrosion inside of center section of horizontal stabilizer on left fore-and-aft stiffener angle bottom surface. TAT 23,050 hours.

(d) Found heavy exfoliated corrosion on center section of horizontal stabilizer inside on center fore-and-aft stiffener angle bottom surface. Repaired per manufacturer instructions. TAT 23,098 hours.

FUNDAMENTALS OF AIRFRAME INSPECTION

1. MAINTENANCE INSPECTIONS. Basically, visual examinations of the structural members of the aircraft and/or components to determine its airworthiness are maintenance inspections. An inspection program might include walk-around inspections and detailed inspections, involving airframe disassembly and use of complex inspection aids.

   a. The Federal Aviation Regulations (FARs) require maintenance and inspection programs for all United States certificated aircraft.

   b. Certificated aircraft used in general aviation by private and corporate owners must be inspected completely at least once each year.

   c. Annual inspections of general aviation aircraft are conducted by FAA certificated mechanics holding, in addition, an inspection authorization issued by the FAA and by certain certificated repair stations and aircraft manufacturers. It is not practicable for FAA inspectors to conduct such inspections of approximately 190,000 general aviation aircraft.

   d. Air carrier aircraft used in air transportation are subject to FAR provisions requiring that the aircraft be maintained under continuous maintenance programs tailored to the aircraft make/model involved. These programs are sophisticated and comprehensive and provide for frequent inspections of the aircraft.

   e. FAA inspectors perform surveillance and monitor the condition of aircraft to assess the effectiveness of maintenance programs. Moreover, knowledge gained from aircraft accident and incident investigations is used to improve maintenance programs and aircraft design.

      (1) An aircraft inspection program may include a regularly scheduled inspection, post-flight, or preflight inspection by either the mechanic or the crewmember and/or pilot of the aircraft. An inspection program is designed to maintain the aircraft in a continuous airworthy condition. However, if the inspection is conducted in a haphazard or irregular manner, there will invariably be a gradual deterioration of the aircraft condition. As a result, time which must be spent in repairing the aircraft will exceed any time gained in earlier inadequate inspections.

(a) Regularly scheduled inspections and preventive maintenance assure the continuous airworthiness of the aircraft. Failures and malfunctions of equipment are appreciably reduced, if excessive wear or minor defects are detected and remedied early. The importance of inspections and the proper use of records concerning these inspections cannot be overemphasized.

(b) Airframe inspections range from preflight or walk-around inspections to detailed inspections. The time intervals for the inspection periods vary with the models of aircraft involved and type of operation being conducted. When developing maintenance inspection program, the FAA District Office should be contacted.

(c) Airframe inspection program may be based on flight hours, calendar or cycles of usage. The latter usually involves fuselage pressurization cycles or landing gear retractions. Under the calendar system, the inspection is accomplished on the expiration of a specified number of calendar weeks, months, etc. This is an efficient system from a maintenance management standpoint. Scheduled component replacements, which have a stated hour life, are normally accomplished during the calendar inspection which occurs nearest the hour limitation.

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

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

(d) Required inspections. All civil aircraft must be inspected at certain intervals as provided in the Federal Aviation Regulations (FARs) to determine the aircraft condition.

1 Generally, the inspection interval will depend upon the type of operation in which the aircraft is engaged.

2 Some aircraft must be inspected at least once each 12 calendar months, while inspection is required for others after each 100 hours of flight.

3 An aircraft may also be inspected in accordance with an inspection system set up to provide for total inspection of the aircraft over a calendar or flight-time period.

4 In order to determine the specific inspection requirement and rules regarding inspections, reference should be made to the Federal Aviation Regulations which prescribe the requirements for the inspection of aircraft in various categories of operation.

(e) Examples of Airframe Inspections. Before starting an airframe inspection it is recommended that:

1 Be certain that all plates, access doors, fairings, and cowlings have been opened or removed, and the structure should be cleaned.

2 When opening inspection plates, doors, and cowlings, and before cleaning, note for indications of oil or other fluid leakage and/or stains.

3 Always use a check list when performing the inspection. A checklist may be provided by the manufacturer or of local design. The airframe checklist should include the following areas:

(aa) Fuselage group.

i Skin - for deterioration, distortion, other evidence of failure, defective or insecure attachment of fittings and fasteners, and corrosion.

ii Components - for proper installation, apparent defects and satisfactory operation.

(bb) Cabin and Cockpit group.

i. Generally - for cleanliness and/or loose equipment which should be secured.

ii Seat and safety belts - for condition and security.

iii Windows and windshields - for deterioration, cracks, delaminations, scratches, chipping (see Chap 5, windows).

iv Flight (and engine) controls - for proper installation and mounting.

v Batteries - for proper installation, corrosion, and leaking fluid.

vi All systems - for proper installation, general condition, apparent defects and security of attachment.

(cc) Landing gear group.

i All units - for condition and security of attachments.

ii Linkage, trusses, and members - for undue or excessive wear, fatigue and distortion.

iii Retracting and locking mechanism - for proper operation.

iv Wheels - for cracks, defects, and condition of bearings.

v Tires - for wear and cuts.

(dd) Wing and center section.

i All components - for condition and security.

ii Skin - for deterioration, distortion, other evidence of failure and security of attachment, fasteners, corrosion.

iii Internal structure - spars, ribs, compression members for corrosion and security.

iv Movable surfaces - for damage or obvious defects, skin attachment and proper travel.

v Control mechanism - for freedom of movement, alignment and security.

vi Control cables - for proper tension, fraying, wear and routing through pulleys and fairleads.

(ee) Empennage group.

i Fixed surfaces - for damage or obvious defects, loose fasteners, and security of attachment.

ii Movable control surfaces - for damage or obvious defects, loose fasteners or skin distortion.

iii Skin - for abrasion, tears, cuts, defects, distortion, corrosion or deterioration.

(f) Aircraft logbook - this applies to the aircraft log and all supplemental records concerned with the aircraft. The log and records are a history of the aircraft maintenance and operation, control of maintenance schedules, and data for time or cycle replacement of components or accessories.

1 The aircraft logbook is the record in which all data concerning the particular aircraft is recorded. Information accumulated in this log can be used to determine the aircraft condition, date of inspections, and time on aircraft (and engines).

2 It is a history of all significant events which have occurred to the airframe, its components and accessories and it provides a means of indicating compliance with the FAA Airworthiness Directives and manufacturers' service bulletins.

(g) Special Inspections. During the service life of an aircraft, occasions may arise when a landing is made in an overweight condition or during a portion of the flight severe turbulence is encountered. Also, for a variety of reasons, rough landings are experienced.

1 Special inspections procedures should be followed when one or more of the aforementioned situations are encountered to detemine if the aircraft structure has experienced damage.

2 When performing these special inspections, the detailed procedures in the aircraft maintenance manual should be followed.

(h) Hard or Overweight Landing Inspections. The stress induced in a structure by a hard or overweight landing depends both on the gross weight at touchdown and the severity of impact (rate of sink). It is difficult to estimate vertical velocity at the time of impact, and whether a landing has been sufficiently severe to result in structural damage. With this in view, a special inspection should be performed after:

1 A landing is made at a weight known to exceed the design landing weight, or

2 A rough landing regardless of the landing weight.

3 Wrinkled wing skin is a sign of an excessive load which may have been imposed during a landing. Another indication easily detected is fuel leaks and/or fuel stains along riveted seams.

4 Other possible damage locations are spar webs, bulkheads, nacelle skin and attachments, wing and fuselage stringers.

5 If these areas do not indicate adverse effects, probably no serious damage has occurred. A more extensive inspection and alignment is necessary if damage is noted.

(i) Severe Turbulence Inspection. If the combination of gust velocity and airspeed is too severe, the stress induced in structural members can cause damage. Inspection should be performed after a flight through severe turbulence as follows:

1 Upper and lower wing surfaces - inspect for excessive buckles or permanent set wrinkles.

2 Spar webs - inspect for buckling, wrinkles, sheared attachments.

3 Nacelles - Inspect for buckling around nacelle and nacelle skin at the wing leading edge.

4 Fuel leaks - fuel leaks may indicate open rivet seams with broken sealant.

5 Fuselage skin - inspect top and bottom areas for wrinkles which are probably diagonal.

6 Empennage - inspect surfaces for wrinkles, buckling and/or sheared attachments, and also areas of attachment to fuselage. A more extensive inspection and alignment is necessary if damage is noted.

(j) Publications. Aeronautical publications provide information on the maintenance of aircraft. Proper use of these publications will aid in the efficient maintenance of air aircraft.

1 Service Bulletins - This is one type of publication issued by the aircraft manufacturer (see Chap 4, paragraphs a and b) which may include maintenance guidance material.

2 Maintenance Manual - The aircraft maintenance manual is provided by the aircraft manufacturer and contains maintenance instructions for all systems installed in the aircraft. The work is normally performed on installed aircraft systems.

3 Overhaul Manual - The aircraft overhaul manual is provided by the aircraft manufacturer and contains information and step-by-step instructions on work which is performed on a member (or unit) usually removed from the aircraft.

4 Structural Repair Manual - This manual contains information and specific instructions as provided by the aircraft manufacturers for repairing the primary and secondary structure.

5 Illustrated Parts Catalogue - This catalogue presents breakdown of structural components with exploded views and illustrations of specific areas.

CORROSION

1. CAUSES OF CORROSION.

   a. Metal corrosion is the deterioration of the metal by chemical or electrochemical attack. Corrosion can take place internally as well as on the surface of the metal. This deterioration may change the smooth surface, weaken the interior or damage or loosen adjacent parts.

   b. Water or water vapor containing salt and combined with oxygen in the atmosphere produces main source of corrosion in aircraft. Thus, aircraft operating in a marine environment or in areas where the atmosphere contains industrial fumes which are corrosive, are particularly susceptible to corrosive attacks. If unchecked, corrosion can cause eventual structural failure.

2. TYPES OF CORROSION. There are two general classifications of corrosion, direct chemical attack and electrochemical attack. In both types, the metal is converted into an oxide, hydroxide, or sulfate. The corrosion process involves the anode which is oxidized and cathode (or the corrosive agent) which is reduced.

   a. Direct chemical attack. Corrosion by direct chemical attack results from direct exposure to caustic liquids or vapors. The anodic and cathodic change occurs at the same point. Direct chemical attack in aircraft structure deposits are caused by (1) spilled battery acid or fumes, (2) residual flux deposits from welds, and (3) trapped caustic cleaning fluids.

   b. Electrochemical attack. An electrochemical attack is similar to the electrolytic reaction in electroplating or in a dry cell battery. The reaction requires a medium, like moisture, capable of conducting electricity. When a metal comes in contact with a corrosive agent (dissimilar metal) and is connected by a liquid path, the metal decays or corrodes. The electrochemical attack is responsible for most forms of corrosion on aircraft structure.

3. FORMS OF CORROSION. There are many forms of corrosion which depends on the metal involved, size, shape, atmospheric conditions and corrosion producing agents.

   a. Surface corrosion. This may be caused by either direct chemical or electrochemical attack. Surface corrosion appears as a general roughening, or pitting of the surface of a metal accompanied by a powdery deposit of corrosion products.

   b. Dissimilar Metal Corrosion. Extensive pitting damage may result from contact between dissimilar metal parts in the presence of a conductor. A galvanic action like electroplating occurs at points of contact when insulation has broken down or was omitted.

c. Intergranular corrosion. The grain boundaries of an alloy are attacked by this type of corrosion. Intergranular corrosion may exist without visible surface evidence. Severe intergranular corrosion may sometimes cause the surface of a metal to "exfoliate." This is a flaking of the metal at the surface caused by pressure of corrosion residual product buildup.

d. Stress corrosion. This type corrosion occurs as the result of the combined effect of tensile stresses and corrosive environment. Stress corrosion is found in most metals. However, it is a particular characteristic of aluminum, certain stainless steels and high strength steels.

c. Fretting corrosion. This occurs when two mating surfaces are subject to relative motion although normally at rest with respect to each other. It is characterized by surface pitting and generation of finely divided debris.

4. FACTORS AFFECTING CORROSION. Many factors affect the speed, cause, type, and seriousness of metal corrosion which include:

a. Climate.

b. Size and type of metal.

c. Foreign material.

5. PREVENTIVE MAINTENANCE. Corrosion-preventive maintenance includes:

a. An adequate cleaning.

b. Thorough periodic lubrication.

c. Detailed inspection for corrosion and failure of protective systems.

d. Prompt treatment of corrosion and touchup of damaged paint areas.

e. Keeping drainholes free of obstruction.

f. Daily wipedown of exposed critical areas.

g. Sealing of aircraft against water during foul weather and proper ventilation on warm, sunny days.

h. Making maximum use of protective covers on parked aircraft.

FATIGUE FAILURES

1. PREDICTION AND PREVENTION OF FATIGUE FAILURES. Fatigue failure in metals is a very complex subject. The situation is further complicated by variabilities encountered in all aspects of the real, physical world. It is well known that material properties are not the constant characteristics of a material, but they may vary within certain ranges. A basic material property such as mechanical tensile strength will vary among specimens made from supposedly the same material. The variability in material fatigue properties is considerably higher than that of material static properties. This variability or "scatter," in terms of fatigue life, may exceed two orders of magnitude.

   a. When parts or structures are fabricated from the materials, additional variabilities are introduced by the manufacturing processes, and no two "nominally identical" parts are alike in all respects.

   b. Service or field use of identical parts may also vary from part to part. That is, the exact use conditions of the aircraft are not known beforehand.

   c. Actual fatigue behavior of such parts in service is influenced by all of the above factors and associated variabilities.

2. HISTORY OF A FATIGUE FAILURE. The structural members of an aircraft carrying loads may get "tired" from the repetitive stresses inherent in the flight and taxiing operation of the aircraft. This condition is called metal fatigue.

   a. A metal specimen designed to carry a certain load will do so, indefinitely, if the load is steady. If the load is cycled (applied and released) many times, the specimen may break. This can happen even when the load is smaller than the original design load limitation. Repetitive loadings can cause slight deformation or stretching of the metal which results in a small crack. With continued loading and deformation, the crack will spread.

   b. The uncracked area of the part is not strong enough to carry a smaller load and, subsequently, the part breaks. This is briefly, in simple terms, the history of a fatigue failure.

3. FATIGUE FAILURE IN AIRCRAFT. Fatigue failure is the tendency of materials to fracture under many repetitions of stress at levels considerably less than the ultimate static strength. Examples are cracks in wing skin, ribs, stringers, and spars, or in fuselage skin, stringers, longerons, bulkhead frames and webs.

   a. Fatigue is not limited to the wing and fuselage structure, but occurs also in heavy hollow members such as landing gear struts, engine shafts and torque tubes, solid members such as fittings, bell cranks, tie rods, turbine wheels, links, bolts, and other areas.

b. Fatigue occurs when the endurance limit of the material is exceeded. Endurance limit is extent of life, or number of cycles of flight loads or stress levels which a structural member can endure before fracture occurs.

4. STRESS RAISERS. Although the life of a part may be increased by reducing the tensile stress imposed, this would not eliminate premature failures if high localized stresses are present. High localized stresses result from irregularities of form, such as holes, surface notches or nicks, sharp edges and abrupt changes in cross section. These are called stress raisers; the phenomenon is called stress concentration.

5. FATIGUE FAILURE CONTROL. Fatigue failure problems may be controlled by employing adequate maintenance inspection programs and techniques. Obviously, the objective is to detect an incipient fatigue failure before it occurs so that the structure can be repaired or replaced. Thus, the inspection approach to the problem has several advantages:

a. It can decrease the incidence of fatigue failures.

b. It increases the operational reliability of the structure and equipment.

c. It allows a better utilization of the structure by extending actual service life until shortly before an incipient failure instead of retiring a structure at some earlier predetermined time, which, in many cases, would represent only a fraction of the structure's available useful life.

d. On the other hand, any inspection program consumes time, costs money, depending on the method used, and, may involve rather complex and expensive equipment. There are also some limitations and some complicating factors associated with each inspection method.

6. MAINTENANCE INSPECTIONS REQUIREMENTS. It is the maintenance people, once the aircraft is in operation, who detect and repair any such fatigue damage. Further, maintenance has the added responsibility of not creating any points of stress concentration during any repair or modification.

a. The prevention of fatigue failure in the structure by inspection depends on the ability of the inspection method(s) to detect an incipient fatigue failure.

b. The inspection of a structure should yield a positive identification of the fatigue damage that has already incurred and that would eventually lead to failure.

c. These inspection methods should be of a nondestructive type so that they would not do any damage to the items being inspected and would not affect their fatigue life. Various available nondestructive testing (NDT) methods for detecting fatigue damage are covered in Appendix 4.

NONDESTRUCTIVE TESTING

1. PREVENTIVE MAINTENANCE. Simply stated nondestructive testing (NDT) is generally preventive maintenance. This includes utilization of such maintenance tools as Xray, ultrasonic, magnetic particles, eddy current, and dye penetrant.

   a. Maintenance Inspection. NDT permits maintenance inspection without removing components from aircraft or tearing down complex assemblies. Defects in various aircraft systems which would escape detection through normal visual inspection will be identified by NDT.

   b. Training Required. Special NDT training is desirable to make sure that the technician is capable of operating the equipment and interpreting the results. Also, many states require that an Xray technician have an approved certificate for use of Xray in industrial applications. This is to minimize improper use with attendant health hazard of Xray equipment.

2. METHODS AND APPROACHES FOR DAMAGE DETECTION. Information on the application of NDT methods for the detection of fatigue damage is scattered through literature on metal fatigue and literature on NDT. Few publications deal with this problem specifically. Some publications are limited to laboratory investigations, and the NDT application is conducted under controlled laboratory conditions. Such investigations contribute considerably to available knowledge and provide new or improved NDT methods for field use. However, there is a great difference between what can be done in the laboratory and what can be used in practical applications under field service conditions.

3. NDT METHOD IN FIELD AND SERVICE USE. Most of the NDT methods that are used under field and service conditions are those capable of detecting fatigue cracks of various sizes. These methods are described in books on the subject of nondestructive testing and other publications such as reports, technical papers, and magazine articles. The NDT methods most commonly used in the field and service for fatigue crack detection follow.

4. VISUAL INSPECTION. Visual inspection is the oldest, simplest, cheapest, and most widely used of all NDT methods. The basic principal used in visual inspection is to illuminate the object and examine the surface with the eye.

   a. The surface should be adequately cleaned before being inspected. Visual inspection for detection of fatigue cracks can be improved by aids such as mirrors, lenses, microscopes, periscopes, and telescopes. These devices compensate for limitations of the human eye. Boroscopes permit direct visual inspection of the interior of hollow tubes, chambers, and other internal surfaces.

b. The capability of visual inspection to detect a fatigue crack depends on many factors such as the size and location of the crack, the illumination used, optical aids employed, and skill of the inspector. It is often difficult to detect even a relatively large fatigue crack that is located, for example, at the corner of a groove or that coincides with a machining mark. There are, of course, also limitations on the size of cracks that can be detected by visual inspection, depending on optical aids employed.

5. LIQUID PENETRANT. The liquid penetrant is one of the oldest methods of nondestructive testing and is capable of detecting cracks that may be impossible to find with the most careful visual inspection because either they are too small or because they are difficult to detect due to their location. The principle involves applying to the part surface a liquid penetrant having a low-surface tension and low viscosity. When used on a clean surface that the liquid will wet, the liquid is drawn into the cracks by capillary action. The presence of the liquid in the cracks is revealed when, after wiping the excess liquid from the surface, a developer is applied that acts like a blotter and draws the liquid out.

a. There are two types of liquid penetrants in general use. One contains a dye which usually gives a good color contrast against the selected developer; the other contains dissolved fluorescent material, which makes it readily visible when viewed under a "black" (ultraviolet) light.

b. Liquid penetrant inspection is inexpensive and readily applicable to field use. The surface must be cleaned before inspection and also afterwards to remove the developer.

6. MAGNETIC METHODS. Magnetic inspections are used to detect surface or near surface discontinuities in ferromagnetic materials, and they are well suited for the detection of fatigue cracks.

a. The principle employed here is that once a magnetic field is induced in a material, any cracks and flaws that are present, will perturb or distort that magnetic field. These methods are most sensitive when the crack orientation and the magnetic field direction are perpendicular to each other. When they are parallel, the crack will not be detected.

b. The magnetic particle method is the most frequently used. It consists of three basic steps:

(1) Establishment of the magnetic field in the part to be inspected.

(2) Application of magnetic particles to the surfaces of the part.

(3) Visual examination of the surfaces for indications of fatigue cracks. These indications are provided by the particles being attracted to the locations of the cracks (or other defects) due to local variations in the magnetic field that are produced.

c. Two classes of magnetic particles are available. The wet method particles use a liquid vehicle; the dry method particles are borne by air. These particles are usually:

(1) Colored to give contrast with the surface being inspected, or

(2) Coated with fluorescent material to make them readily visible under black light. Parts inspected by magnetic particle methods must be cleaned.

7. RADIOGRAPHY. Radiography is a method of nondestructive testing which uses Xray, gamma, beta, or neutron radiation. It is based on the ability of these radioactive sources to penetrate materials. The intensity of the penetrating radioactivity is modified by passage through materials and by defects in the material. These intensity changes are recorded on film as areas of varying density (or darkness) which permits distinguishing flaws and cracks. Obviously, maximum sensitivity occurs when the cracks are oriented such that its longest dimension is parallel to the direction of radiation.

a. Xray radiography has two main advantages; (1) versatility, and (2) sensitivity. The Xray energy source can be easily adjusted for variations in thickness. It is also adaptable to fluoroscopy and television systems.

b. The advantages of gamma radiography are; (1) portability , and (2) a relative low cost. Portability comes from the fact that the source is small. This permits its effective use in the field particularly in remote areas. One of the difficulties with the gamma radioactive source is that the source cannot be varied or turned off so that safety precautions must be observed at all times. (Xray constitutes a health hazard only during operation of the Xray equipment).

c. Conventional radiography is firmly established and reasonably easy to understand. One of the original drawbacks was the long time involved in the developing and processing of film. This has been overcome by modern automatic film processing techniques.

d. Interpretation of the processed film is the most important phase of radiography. Adequate tools such as a film illuminator lens and good working conditions should be available to assist the interpreter in detecting cracks in the part displayed on the film.

8. ULTRASONICS. Ultrasonc methods have received wide acceptance in the aviation industry and are particularly useful for determining the integrity of a member of a structure. Basically, sound energy above the audible range is transmitted into a part, and a signal is received and and analyzed. The ultrasonic wave is transmitted and received through transducers, which are placed upon the part to be inspected. The transducer must be properly coupled to the part and is the most critical aspect of the inspection. Good coupling can be achieved by using liquids at the transducer part interface.

a. The ultrasonic wave (or beam) may be evaluated in terms of either through transmission or reflection. The receiving transducer may be a separate unit (through transmission) or it may be the same transducer that sent the signal (reflection and resonance). For crack detection, the reflection technique is most commonly used. It permits the determination of the location of the crack wherever it might be within the part and only one transducer on one side of the part is needed. When ultrasonic wave (pulse) is sent into the part, a discontinuity e.g. a crack, in its path on which it impinges will both absorb and reflect energy. A defect can be recognized by the relative time for return of the reflected energy to the transducer.

b. The ultrasonic methods now available are rapid, economical, sensitive, and can have good accuracy for determining crack extent and position. Equipment is light and portable so that on-site inspections are possible. There are conditions which can limit the usefulness of ultrasonic inspections. These include unfavorable part geometry (such as complexity, contour, and size) orientation of the cracks, and misleading responses which may occasionally be obtained. Also, ultrasonic inspection, as presently practiced, depends upon experience, skill, and judgment of the inspector. He must interpret the crack size and location by the indirect evidence presented by the electronic equipment (oscilloscope). He must be able to distinguish between significant signals and spurious ones.

9. EDDY CURRENT. The eddy current method is a comparatively recent nondestructive testing technique. It is being frequently used for nonmagnetic materials. (When used for magnetic materials, it requires more complex systems). The principle involved is simple. A coil that is carrying a high-frequency alternating current is brought near an electrical conductor and eddy currents are generated in the conductor. The eddy (or induced) current create a magnetic field. Flaws, cracks, etc., cause resistance changes within the part. This affects the induced currents, and thus, the magnetic field produced by them. Detection and measurement of the magnetic field form the basis of the nondestructive testing.

a. Two types of coils are in common use. One is a circumferential coil through which a part passes. The second is called a probe coil which is placed on the surface of the part to be inspected. Each type coil can be made in a number of designs, depending on the application.

b. Eddy current instruments have various degrees of versatility. Many are portable. Once proven for a specific application, the inspection process is very rapid. Eddy current methods have been used very successfully for fatigue crack detection. However, eddy current methods are sensitive to many variables that influence the results obtained. Also, signals obtained are sometimes of a comparative nature, and reference standards are needed for interpretation.

10. REFERENCE PUBLICATIONS.

a. Advisory Circular 20-61, Nondestructive Testing Techniques for Aircraft.

b. Advisory Circular 65-9, Airframe and Powerplant Mechanics, General Handbook.

c. Advisory Circular 43.13-1, Acceptable Methods, Techniques, or Practices - Aircraft Inspection and Repair.

d. Defense Metals Information Center (DMIC) Report, S-25, dated 1 June 1968, Current Problems and Prevention of Fatigue.

e. Advisory Circular 20-9, Personal Aircraft Inspection Handbook.

f. Advisory Circular 20-50, Ultrasonic Nondestructive Testing.