# PART 1 - GENERAL

## X-RAY

1. **Purpose**

   A. The primary use of X-ray inspection (radiography) is to detect cracks and flaws in aircraft structure in areas not accessible for visual inspection. The radiographic techniques provided will detect broken structure, large cracks when there is a displacement of members, and small cracks when the geometry of the structure, material thickness and location of the X-ray generator in relation to the crack are ideal. X-ray inspection is not recommended as an exploratory technique for general use when visual inspection is practical.

   B. Radiographic inspection of bonded and composite structure is employed to determine the extent of visually detected damage and to aid in the assessment of bonded panel integrity. Such defects as crushed core and fractures associated with impact damage lend themselves to radiographic evaluation.

   C. Radiographic inspection of lightning strikes can add information on the extent of core damage in honeycomb structure.

   D. Subsurface conditions such as water in honeycomb and large fractures can also be detected by radiographic inspection. In addition, subsurface structural conditions which affect other NDI inspection such as ultrasonic bond tests can be determined radiographically. For example, the presence of a core splice or repair, potting compound, filler foam or excess adhesive can be shown by radiography.

   E. Usually when X-ray inspection is performed, it is because location and orientation of the suspected failure are known from previous experience. The Boeing Company conducts a comprehensive fatigue testing program in conjunction with the structural design of all Boeing airplanes. From this program and service experience, there has evolved a list of areas which should be inspected periodically by X-ray. These areas are listed in the Maintenance Planning Document for each model of airplane. The phrase "Adaptable to X-ray" has been inserted in these documents for items which:

      (1) Have defects which can be detected by X-ray.

      (2) Cannot be inspected visually without extensive disassembly.

      (3) Can be inspected more economically by use of X-ray than by other methods.

   F. Use the Maintenance Planning Documents in conjunction with the Nondestructive Testing Manual to perform a satisfactory inspection on the airplane.

2. **Description of Method**

   A. An X-ray radiographic inspection is performed by transmitting a beam of penetrating radiation through an object onto a photosensitive film. This beam is partially absorbed by the material through which it passes. Discontinuities and voids will cause a reduction in the total thickness of material resulting in less absorption and less reduction in the intensity of the X-ray beam. These varying beam intensities which strike the film form a latent image. The film is processed to form a visible image which is called a radiograph. The radiograph is then studied for the information sought.

B. Radiography does not always produce conclusive results. The results obtained from radiographic inspection are affected by the quality of the film, condition of the radiographic equipment and the location of the film and X-ray generator in relation to the defect orientation. Frequently other nondestructive test methods must be used in conjunction with radiography to make a final analysis of a defect. For example, when inspecting aircraft for corrosion, only serious corrosion pitting or flaking, on the order of 20 percent or greater, may show on the radiograph because of interfering items such as sealants, insulating materials, wires, tubing, etc. The radiographic indications must be examined with other test methods before a final analysis of the condition can be made. These methods are discussed in Parts 3 through 6.

C. Radiographic detection of water in honeycomb is dependent on the number of cells containing water, the volume of water per cell, the thickness of honeycomb core, and the orientation of X-ray beam to the honeycomb core. The radiographic appearance of adhesive build-up in honeycomb is similar to that of water and identification of small amounts of water in areas of adhesive build-up such as along the edge of a panel is not practical. Baseline radiographs should be established for comparison when inspecting for small amounts of water in honeycomb.

## 3. Equipment

**WARNING:** X-RAY EQUIPMENT TRANSMITS IONIZING RADIATION THAT CAN BE DANGEROUS. BEFORE YOU USE X-RAY EQUIPMENT, YOU MUST KNOW AND OBEY THE APPLICABLE HEALTH AND SAFETY PROCEDURES AND YOUR APPLICABLE LOCAL REGULATORY LIMITS.

A. X-ray Generators

(1) Basic X-ray equipment for inspection of aircraft structure should be portable with a generator tube having focal spot sizes as small as possible but not larger than 4 mm X 4 mm as specified by American Society for Testing Materials (ASTM) Specification 1165 or European Norm (EN) 12543.

(2) For metal structure, the generator tube should be capable of producing 160 kV with a 5 mA rating. Structures of composite material like graphite-epoxy having high strength-to-weight ratio, require low energy X-ray inspection. To satisfy these inspection requirements, generators producing a minimum of 20 kV and 3 mA, and having an inherent filtration of 1.0 mm beryllium equivalent or less are desirable.

B. X-ray Film

(1) Film classification in the United States of America is governed by ASTM E 1815.

(2) In addition to the ASTM film type, each inspection procedure will describe the type of film required, for example: "Any low speed fine grain high contrast film may be used."

(3) Automatic film processing is normally used for development technique. The developer solution temperature is set per manufacturer's instructions. When the film is processed by hand, the film manufacturer's recommended time and temperature are used.

C. Image Quality Indicators (IQI)

(1) When considered necessary, IQI's will be called out to confirm the sensitivity of the radiograph. Generally, procedures require better than 2 percent sensitivity and some may require better than 1 percent sensitivity.

(2) Wire penetrameters specified in ASTM E 747, EN462-1, or JIS Z 2306, are particularly suitable for aircraft structural X-ray as they are easy to position so they may be seen on the radiograph and they may be contoured to curved surfaces.

(3) Wire penetrameters should be placed on the area of radiographic interest, furthest from the film on the X-ray generator side of the structure. The 4 sets of ASTM wire penetrameters contain six wires each. See Figure 1.

(4) ASTM E 1025 plaque-type penetrameters can be used as an alternative to the wire type.

**NOTE:** When necessary, IQI's must be made of material that is almost the same as the structure to be radiographed.

(5) At this time, IQI's for use in radiographic inspection of composite structure are not available.

D. Lead Screens

(1) When lead screens are required, the recommended thickness will be given. If the procedure requires intensification without filtration of soft radiation provided by the lead screens, lead oxide film pack may be recommended.

(2) When using lead screens for intensification, it is important to ensure they are not scratched or disfigured and that the film is in direct contact with the lead.

(3) Lead screens serve two purposes, radiographic intensification and absorption of scatter X-rays. Lead screens used in the film cassette serve both purposes. Lead oxide film pack provides only radiographic intensification. Standard film packs provide no intensification or scatter radiation absorption. Both standard and lead oxide film packs may be used with external front and back screens for protection from scatter radiation.

E. Film Cassette - Standard cardboard holders may be used except with kilovoltages lower than 30 kV. For lower kilovoltage, holders may be fabricated from vinyl or mylar material, or from sealed paper envelopes.

F. Radiographic Contrast Media (Radiopaque Penetrant)

(1) The introduction of radiographic contrast media in the form of a radiopaque penetrant can enhance the radiographic detectability of delaminations, fiber fraying, and cracking in composite structure where such defects are open to the surface. Use of radiopaque penetrant can provide additional information on the extent of damage in cases of edge delamination, impact damage, and fastener hole damage.

(2) Several radiopaque penetrants have been evaluated for practicality. The results of this evaluation are given in Table 1. A solution of zinc iodide in methyl propyl ketone (MPK) has been found useful for enhancing the detectability of cracks and delaminations in graphite/epoxy composite structure; however, because its residue can cause subsequent part deterioration, MPK may only be used if the penetrant residue can be completely removed from the structure either by cleaning or during subsequent repair. It is therefore recommended that radiopaque penetrants be used only in the case of determining the extent of the damaged area in a part that will be repaired.

**NOTE:** Methyl Propyl Ketone (MPK) has replaced Methyl Ethyl Ketone (MEK) in this procedure because of local environmental regulations. For this procedure, MEK can be used as an alterative to MPK if permitted by your regulations.

(3) Preparation of Zinc Iodide/MPK Radiopaque Penetrant.

(a) Pour 100 ml of methyl propyl ketone (MPK) into a heat-resistant glass beaker.

(b) Measure 25 ml dry volume of zinc iodide crystals.

**WARNING:** USE CAUTION IN ADDING ZINC IODIDE TO METHYL PROPYL KETONE. SIGNIFICANT HEAT CAN BE GENERATED IN THE PROCESS OF DISSOLVING ZINC IODIDE IN MPK.

(c) Slowly add zinc iodide crystals to MPK while stirring the solvent.

(d) Store solution in dark glass container away from direct light.

**Table 1: Evaluation of Radiopaque Penetrant for Composite Structure**

| RADIOPAQUE PENETRANT | RESULTS |
|---|---|
| Zinc Iodide (ZnI2) dissolved in Methyl Propyl Ketone (MPK) | Short dwell time (5-10 minutes); relatively inexpensive *[1] |
| Zinc Iodide (ZnI2) dissolved in water, isopropyl alcohol | Nontoxic, long dwell time (approx 30 minutes) *[2] |
| Diiodobutane (DIB) | Very expensive; short shelf life, mildly toxic *[2] |
| Tetrabromoethane (TBE) | Highly toxic, carcinogenic, potent mutagen *[2] |

*[1] Zinc Iodide is deliquescent material at room temperature and will not evaporate from a defect or structure it has penetrated. Residue remaining on the part will be in a liquid form drawing moisture from the air and could cause part deterioration. Zinc Iodide is not recommended for use as a radiopaque penetrant if it is impossible to remove the residue either by flushing with solvent or by removal of contaminated material during repair.

*[2] This material is considered too impractical for use and hence has not been adequately evaluated for the effect of residue remaining in a repaired area on part integrity.

## 4. General Radiographic Practices

A. Density Measurements - Unless otherwise stated, the density measurements should be taken in the area of radiographic interest and be between 2 and 3.5 density for metallic and between 1.8 and 2.5 for nonmetallic composite structure.

B. Identification of Radiographs - Radiographs should be identified with the part and/or aircraft number, date, and inspection procedure when practical. The identification (usually lead letters or lead tape) and Image Quality Indicator should not be located in the area of radiographic interest as it could obscure a defect.

C. Film Cassette Location - Many structural X-rays have the inspection area adjoining a frame or stringer, so it is important that the film butts up close to the web. To achieve this, the film must be close to the critical edge of cassette. Fold and tape back excess cassette edge before positioning the film.

D. Technique Chart - X-ray generator characteristics vary from unit to unit. A technique chart showing exposure time required versus material thickness should be made for each unit to obtain maximum results with the least lost time. An example technique chart is shown in Figure 3.

E. Application of Radiopaque Penetrant to Nonmetallic Composites

**CAUTION:** RESIDUAL ZINC IODIDE/MPK COULD PREVENT A SATISFACTORY REPAIR IN COMPOSITE STRUCTURE. RADIOPAQUE PENETRANTS SHOULD ONLY BE USED IF ALL RESIDUE CAN BE REMOVED FOLLOWING INSPECTION OR DURING SUBSEQUENT REPAIR.

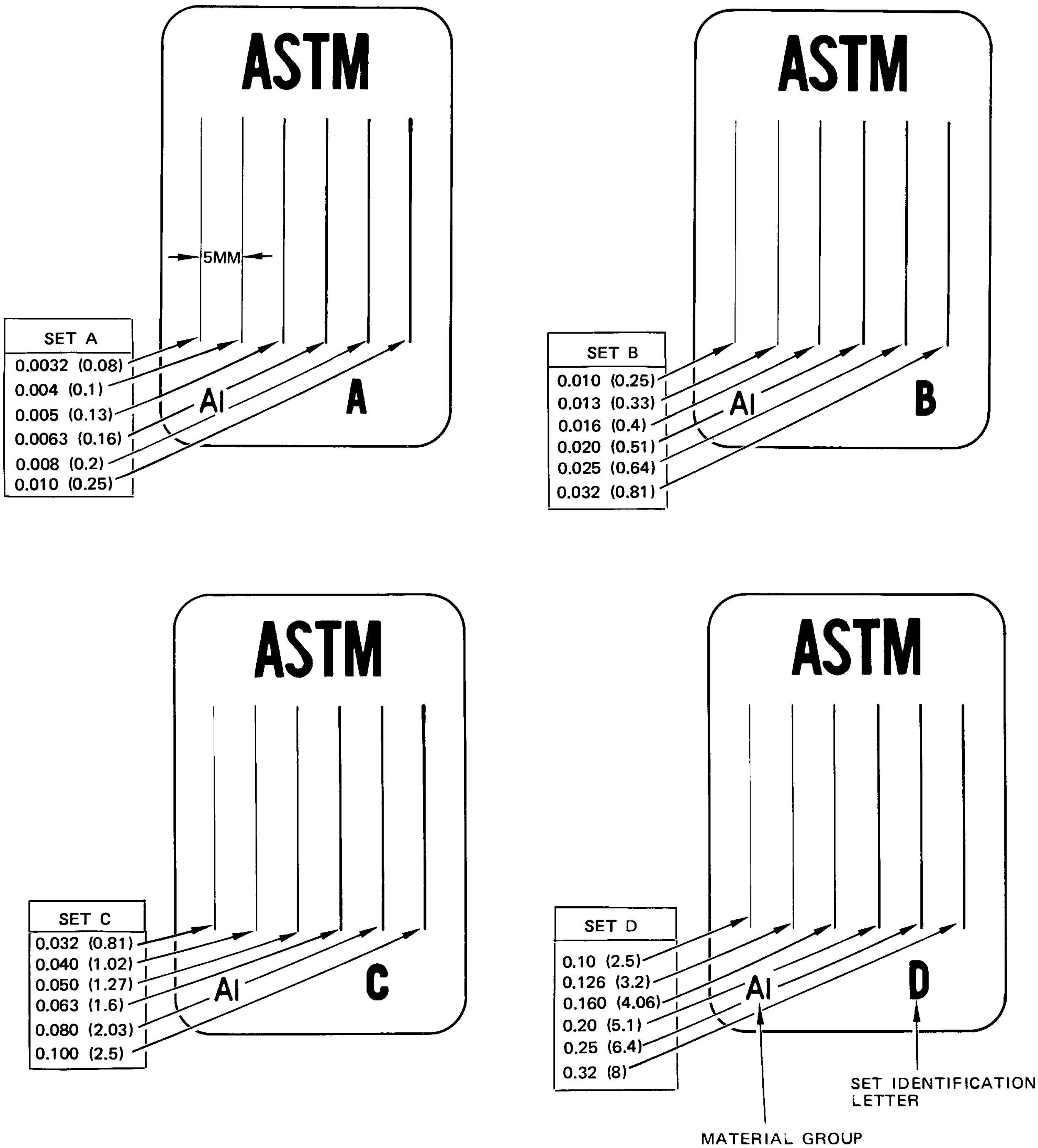
(1) Preclean inspection area surface with a cloth dampened with methyl propyl ketone (MPK) as required to remove foreign material.

(2) Apply penetrant to inspection area with a cotton swab.

(3) Allow penetrant to remain on surface for the required dwell time (5-10 minutes for zinc iodide/ MPK).

(4) Remove excess with an MPK-dampened cloth.

(5) Clean inspection area after radiographic exposure with an MPK-dampened cloth.




NOTES
ALL DIMENSIONS ARE IN INCHES, WITH MILLIMETERS IN PARENTHESIS

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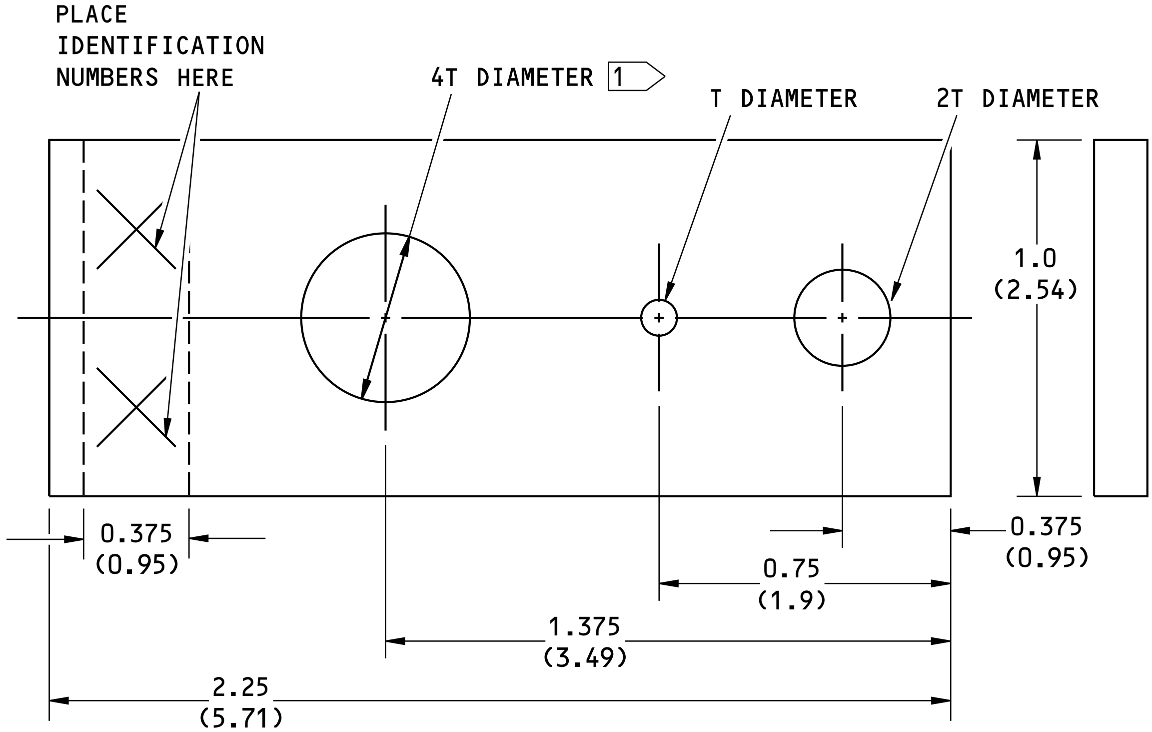
**ASTM Wire Penetrameters**
**Figure 1**




| INSPECTION LEVEL | I.Q.I. THICKNESS | MIN. HOLE DIAMETER | SENSITIVITY % |
|---|---|---|---|
| 2-1T | 2% OF SPECIMEN THICKNESS | 1T | 1.4 |
| 2-2T | 2% OF SPECIMEN THICKNESS | 2T | 2.0 |
| 1-2T | 1% OF SPECIMEN | 2T | 1.0 |

NOTES

- ALL DIMENSIONS ARE IN INCHES WITH CENTIMETERS IN PARENTHESES. FOR FURTHER INFORMATION REFER TO ASTM E 1025.
- PENETRAMETER THICKNESS IS BASED ON THE TOTAL THICKNESS OF MATERIAL BEING PENETRATED. FOR EXAMPLE, IF A ONE-INCH STACKUP IS BEING RADIOGRAPHED FOR A CRACK IN A 0.25-INCH THICK MEMBER, PENETRAMETER THICKNESS IS SELECTED ON THE BASIS OF THE ONE-INCH STACKUP.

1 REFERENCE ONLY, 4T DIAMETER IS NOT USED.

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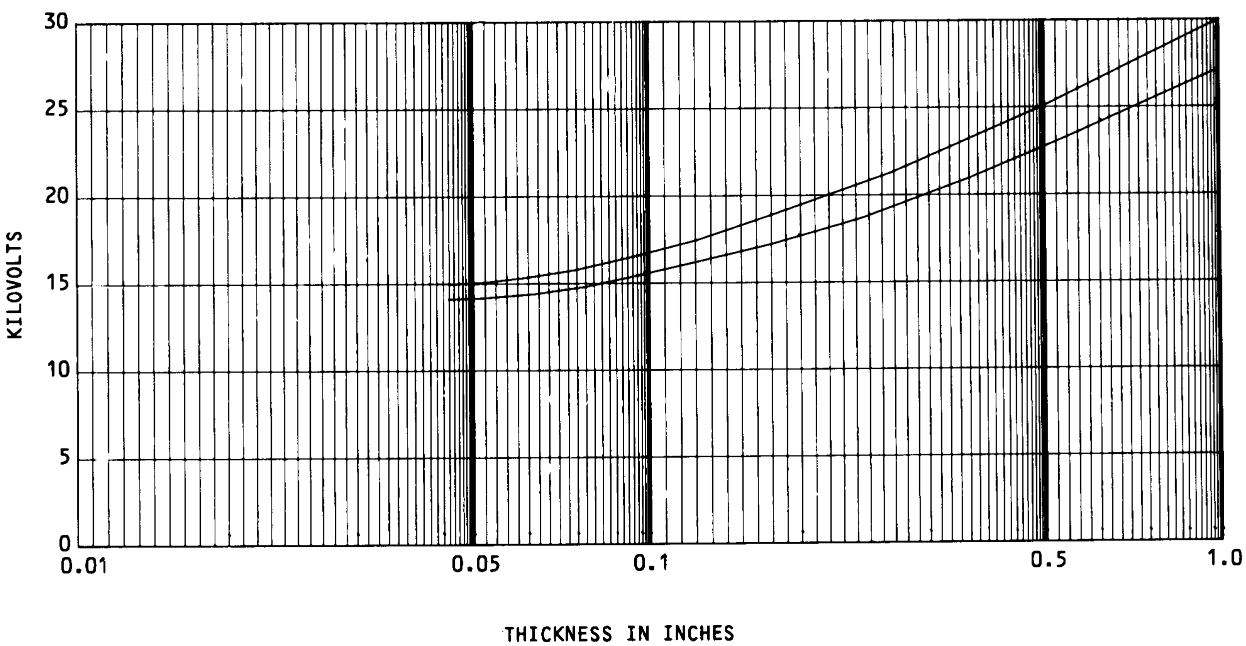
**Plaque - Type IQI'S**
**Figure 2**

TECHNIQUE CHART (EXAMPLE ONLY)

| | |
|---|---|
| INSTRUMENT | – PHILIPS 10–150 KV |
| FOCAL SPOT | – 0.4 MM |
| MATERIAL | – GRAPHITE/EPOXY LAMINATE |
| FILM | – ASTM CLASS II |
| PROCESSOR | – AUTOMATIC |
| SFD | – 36 INCHES (91.4 CM) |
| DENSITY | – 2.0 TO 2.5 |
| MILLIAMPERE MINUTES | – 8 MAM |

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**Example Technique Chart**
**Figure 3**