PART 1 - GENERAL

X-RAY

1. Introduction

A. X-ray inspection (radiography) is primarily used 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. 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. Radiographic inspection of lightning strikes can add information on the extent of core damage in honeycomb structure. 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 inspections 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. Usually when an 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 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.

B. 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. 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, in the order of 20 percent or greater, may show on the radiograph because of interfering items such as sealant, 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. Radiographic detection of water in honeycomb is dependent on the number of cells containing water, the volume of water per cell, the thickness of the honeycomb core, and the orientation of the 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.

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

2. Equipment

WARNING: X-RAY EQUIPMENT GIVES OFF IONIZING RADIATION THAT CAN BE DANGEROUS. PERSONS THAT USE X-RAY EQUIPMENT MUST REFER TO THE APPROVED ORGANIZATIONS FOR THE SAFE OPERATIONS OF THE FACILITIES AND EQUIPMENT.

A. Before you use ionizing radiation equipment, make sure you have the necessary personal protection equipment with you and that you use all proper safety precautions. Follow all the requirements for the safety of personnel and the protection of property specified in the National Institute of Standards and Testing (NIST) Handbook 114, NCRP Reports 33 and 91. Use the applicable government or your company publications, if you are not in the United States of America. Do not exceed the personal radiation exposure limits set by the applicable city, state, or national codes.

B. X-Ray Generators 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 exceeding 2 mm x 2 mm for inspecting metal structure and 1.5 mm x 1.5 mm for inspecting nonmetallic composite structure. With the increasing need to position x-ray tubes in tight locations, the use of end anode side emission tubes is recommended. For metal structure the generator tube should be capable of producing 160 kv with a 5-milliamp rating. For bonded and composite nonmetallic structure the generator tube should be capable of producing a minimum of 20 kv and 3 milliamp, and have an inherent filtration of 1.0 mm beryillium equivalent or less.

C. X-Ray Film

(1) Film classification in the United States of America is governed by the American Society for Testing Materials Specification ASTM E94 as specified in Table 1:

Table 1 X-RAY FILM CLASSIFICATION

X-RAY FILM CLASSIFICATION			
FILM TYPE	**SPEED**	**CONTRAST**	**GRAIN SIZE**
1	Low	Very High	Very Low
2	Medium	High	Low
3	High	Medium	High

NOTE: There are other classifications, not included in the above chart, which are not generally used on aircraft structure.

(2) In addition to the ASTM film class, each inspection procedure will describe the type of film acceptable, 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.

D. 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 could require better than 1 percent sensitivity.

(2) ASTM wire penetrameters, either ASTM E 747 80 or the DIN type 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 (Figure 1). The DIN type IQI has 7 wires in each set with a total of 3 sets, covering the range from 0.004 to 0.126 inch.

(4) The ASTM plaque-type penetrameter may be used as an alternative to the wire type IQI covering a range from 0.005 to 0.150 inch (Figure 2).

NOTE: IQI's must be made of similar material to the structure being radiographed.

(5) At this time, IQI's for use in radiographic inspection of composite structure are not available. For optimum sensitivity in the radiography of composite structure it is recommended that x-ray inspections be performed using a source to film distance greater than 48 inches, a kilovoltage of less than 25 kv, and ASTM Class 2 film.

E. 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 packs provide 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.

F. Film Cassette

(1) 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.

G. 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 2. A solution of zinc iodide in methyl propyl ketone 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, it 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 alternative to MPK if permitted by your regulations.

Table 2 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.

(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.

3. 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

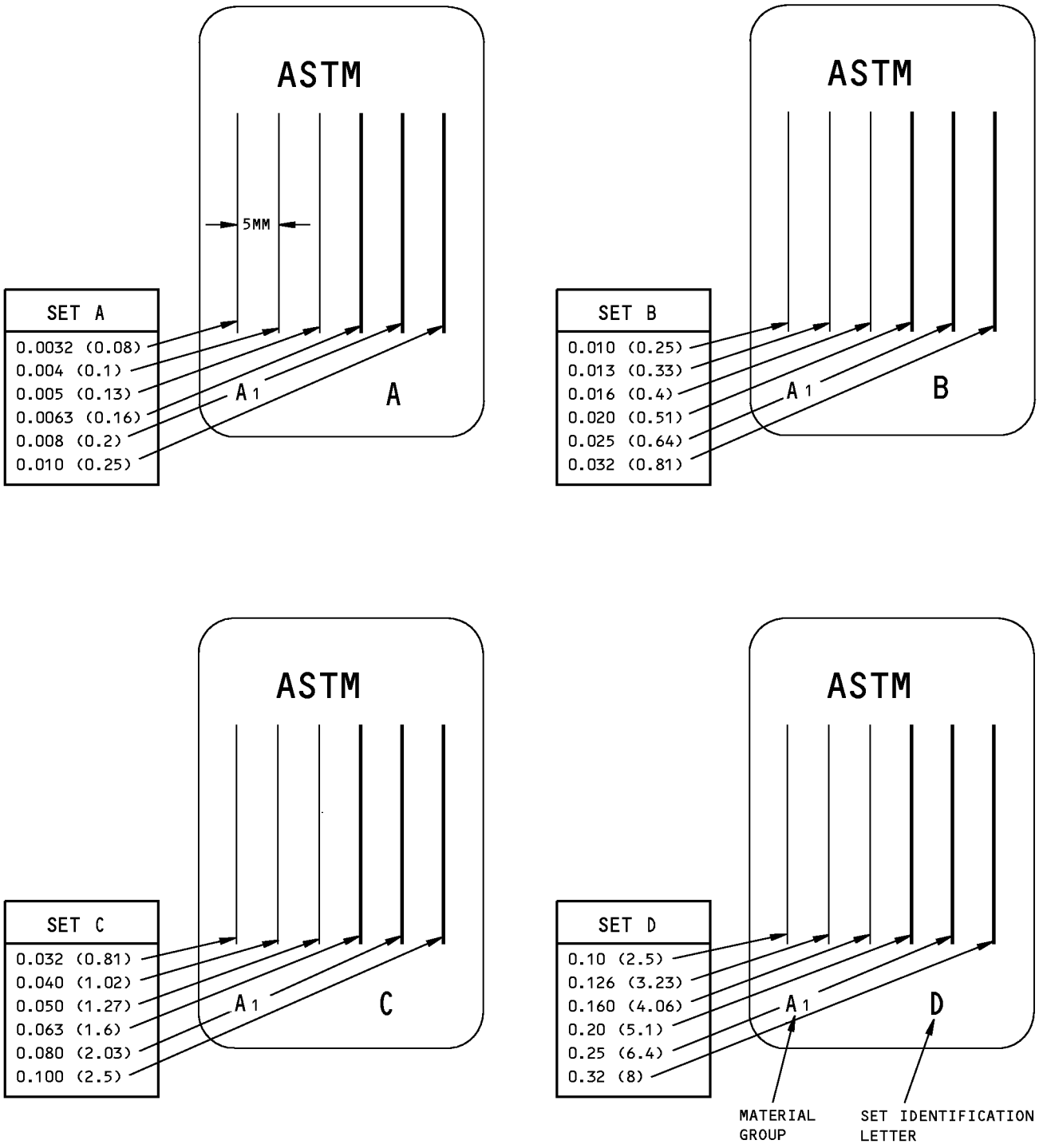
(1) Preclean inspection area surface with a cloth dampened with methyl propyl ketone (MPK) as required to remove foreign material.

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

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

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

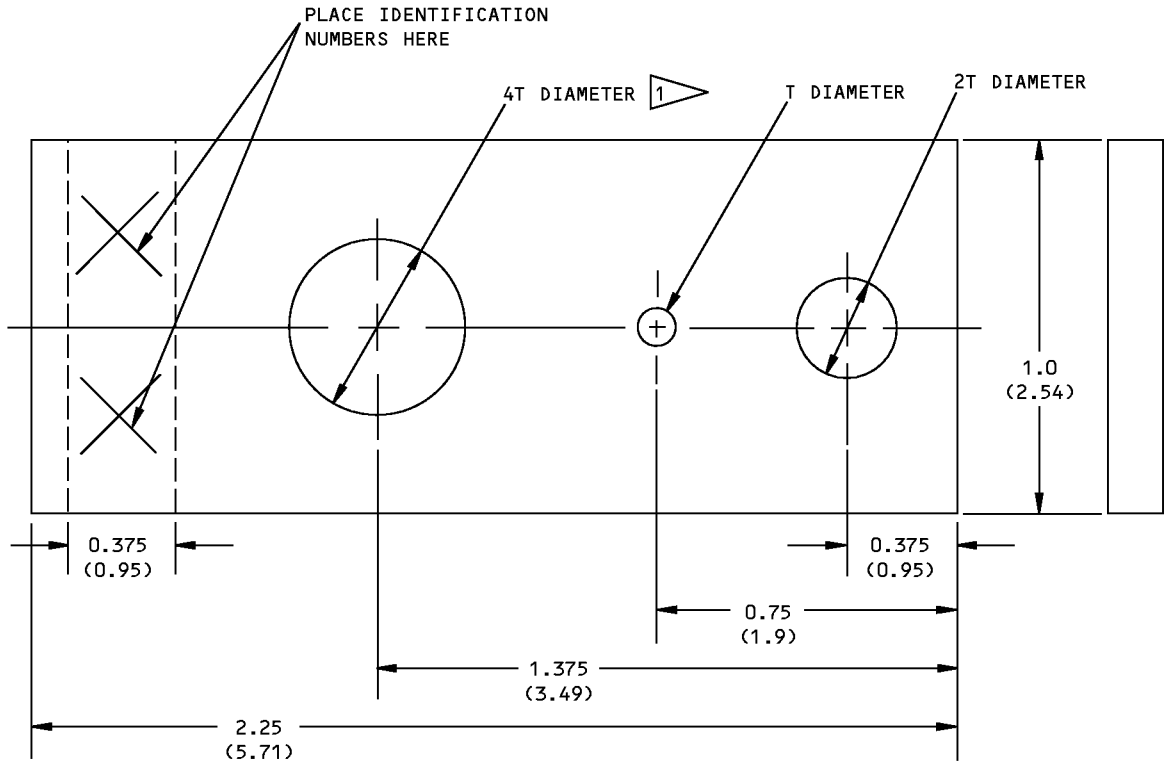
(5) Clean inspection area after radiographic exposure with an MPK- dampened cloth.



NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS IN PARENTHESIS)

ASTM Wire Penetrameters
Figure 1



INSPECTION LEVEL	IQI 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

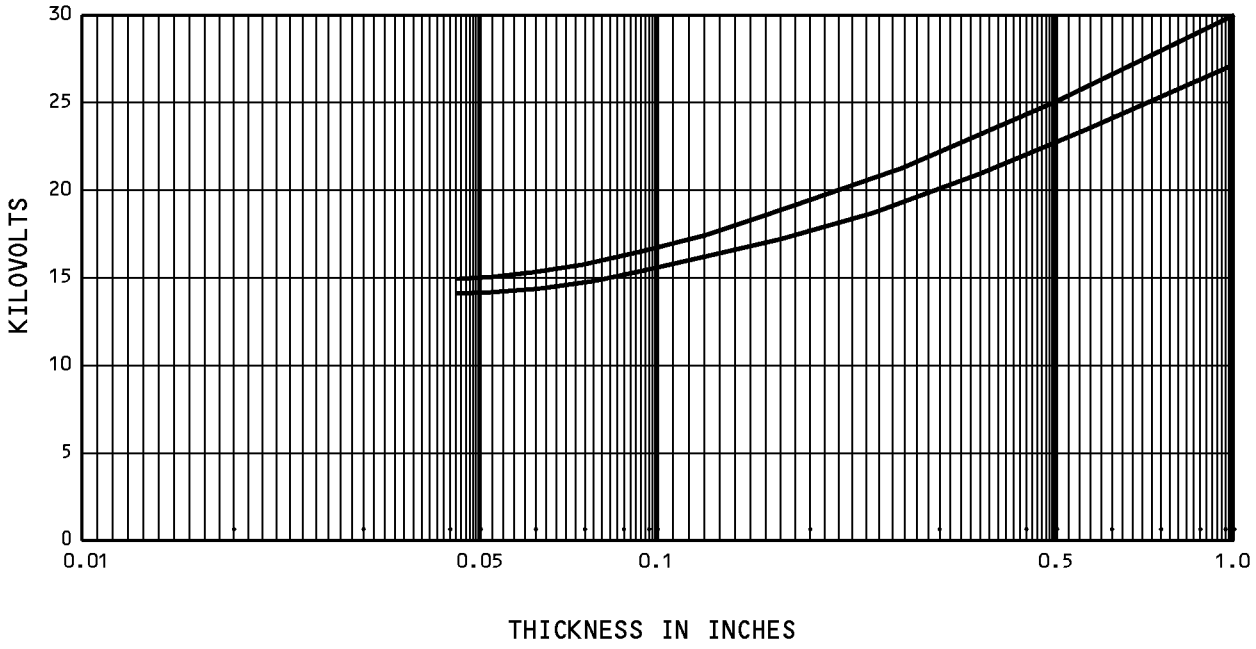
- ALL DIMENSIONS ARE IN INCHES (CENTIMETERS IN PARENTHESES). FOR FURTHER INFORMATION, REFER TO ASTM E142-77,
- PENETRAMETER THICKNESS IS BASED ON THE TOTAL THICKNESS OF MATERIAL BEING PENETRATED. FOR EXAMPLE, IF A 1-INCH STACKUP IS BEING RADIOGRAPHED FOR A CRACK IN A 0.25-INCH THICK MEMBER, PENETRAMETER THICKNESS IS SELECTED ON THE BASIS OF THE 1-INCH STACKUP.

1 REFERENCE ONLY, 4T DIAMETER IS NOT USED.

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 2
PROCESSOR	- AUTOMATIC
SFD	- 36 INCHES (91.4 CM)
DENSITY	- 2.0 TO 2.5
MILLIAMPERE MINUTES	- 8 MAM



Example Technique Chart
Figure 3