PREFERRED
RELIABILITY
PRACTICES

# RADIOGRAPHIC TESTING OF AEROSPACE MATERIALS

**Practice:**

Radiographic testing can be used as a nondestructive method for detecting internal defects in thick and complex shapes in metallic and nonmetallic materials, structures, and assemblies.

**Benefit:**

Unlike most other nondestructive testing methods, radiographic testing provides a permanent visual record of the defects for possible future use. It can also be used to determine crack growth for use in fracture mechanics to determine critical flaw size in a particular component.

**Programs That Certified Usage:**

Saturn I, IB & V Vehicles, Space Shuttle External Tank (ET), Space Shuttle Solid Rocket Booster (SRB), Space Shuttle Main Engine (SSME), and many other MSFC projects.

**Center to Contact for More Information:**

Marshall Space Flight Center (MSFC)

**Implementation:**

Radiography is an effective method of nondestructively detecting internal flaws in materials and structures. The radiation source emits energy that travels in straight lines and penetrates the test piece. As the radiation energy passes through the test piece, an image, is received on the recording medium opposite the x-ray source. This image is used to evaluate the condition of the part being tested. Film is most frequently used as the recording medium for the image, but there are other techniques that may be used such as fluoroscopic screens, and digitized systems coupled with video monitors. The three basic elements are: 1) a radiation source, 2) the test piece being evaluated, and 3) a recording medium are combined to produce a radiograph as shown schematically in Figure 1.

An x-ray is radiation produced from a manmade x-ray tube. Table 1 compares the penetration range of high energy x-ray sources with conventional x-rays. Radiographic film is classified according to speed, contrast, and graininess as depicted in ANSI/ASTM E94.

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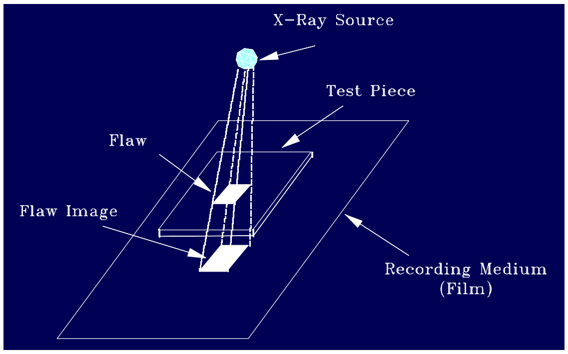


**Figure 1. Layout for Flaw Inspection**

**Table 1. Comparison of Penetration Range of Conventional X-Ray Tube vs High Energy Source**

| Maximum Accelerating Potential | Penetration Range in Inches of Steel |
|---|---|
| X-Ray Tube | |
| 150 kV (kilovolts) | up to 5/8 |
| 25-kV | up to 1 1/2 |
| 400kV | up to 2 1/2 |
| 1000kV | 1/4 to 3 1/2 |
| High Energy Source | |
| 2.0 million electron volts (MeV) | 1/4 to 10 |
| 4.0 MeV | 1 to 12 |

Table 2 lists the ASTM film type, relative speed of the film type. Manufacturer-furnished x-ray film exposure charts show the relationships between thickness, kilovolts and exposure time, but only apply to a specific set of conditions. The manufacturer's furnished charts are only accurate to within ±10 percent, since no two x-ray machines are identical.

Radiographics constitutes a health hazard that requires special radiation training for personnel concerned with its use. Also, adequate safety devices should be built into the x-ray facility including those listed below:

- Safety interlock switches
- Keylock system
- Radiation monitoring device
- Warning system
- Adequate facility shielding.

At least one qualified operator plus a Radiation Protection Supervisor or designated alternate must be present at all times during any x-ray operation. The personnel requiring access to the x-ray area must be monitored to ensure that no one absorbs excessive amounts of radiation. The normal means for monitoring radiation is by wearing pocket dosimeters and film badges. The dosimeter is read and recorded daily and usually the film badge is developed and read at least quarterly. Both devices are compared and should check within 20 percent of each other. The allowable dose of radiation is 1 1/4 Roentgen equivalent man (rem) per quarter year. For added

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safety, each time the x-ray area is entered a survey meter should be used to ensure that the area is safe to enter.

**Table 2. Film Description and Applications**

| ASTM Type | Relative Speed at 200kV | Description | Suggested Applications |
|---|---|---|---|
| Special | 9 | Very slow speed, very high contrast, finest grain size | Electronic components, finest detail at low kV's on thin light metals, plastic, tubing, and other low absorbers. |
| 1 | 30 | Slow speed, very high contrast, very fine grain size | Radiography of thin to medium thick metals, at low to medium kV's, thicker light metals and thin sections of heavy metals. |
| 1 | 50 | Intermediate speed, very high contrast, extra fine grain | At higher kV's - castings, welds, and other assemblies |
| 2 | 100 | Medium speed, high contrast, fine grain size | Radiography of medium thick to thick light metals, and medium thick sections of heavy metals. Most suitable for isotope, supervoltage, and betatron radiography |
| 3 | 170 | Fast speed, medium contrast, coarse grain size. | Radiography of medium thick sections of heavy metals or other materials at isotope, supervoltage, or betatron energies. Large castings and weldments. |

Interpretation of radiographs requires highly trained and qualified technicians who must (a) define the quality of the radiographic image, which requires a critical analysis of the radiographic procedure and the image developing procedure; (b) analyze the image to determine the nature and extent of any abnormal condition in the test piece; (c) evaluate the test piece by comparing interpreted information with standards or specifications; and (d) report inspection results accurately and clearly. The major advantages and disadvantages of radiographic testing are listed in Table 3.

## Technical Rationale:

Radiographic testing has been used successfully at MSFC for years to identify and characterize cracks, voids, inclusions, porosity, lack of weld penetration, lack of fusion in welds, and many other types of defects. Radiographic testing is an accurate and reliable nondestructive testing method for determining defects and flaws internal to materials, structure, and assemblies. It is also used to detect defects and flaws in both metallic and nonmetallic materials.

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**Table 3. Advantages and Disadvantages of Radiographic Testing**

| Advantages | Disadvantages |
|---|---|
| Provides visual image<br>Provides permanent records<br>Inspects complex shapes<br>Inspects both metallics and nonmetallics<br>Inspects for internal flaws in materials<br>Inspects thick materials<br>Provides real-time viewing (via fluorescent screens & electronic means) | Requires access to sides[(1)]<br>Cracks must be nearly parallel to x-ray beam<br>Expensive in time, labor, & facilities<br>Delay of results<br>Delamination undetectable<br>Health hazard<br>____________________<br>(1) Can be overcome by back-scattering radiography |

## Impact of Nonpractice:

Failure to detect defects and flaws internal to materials could result in failure of components and possible loss of mission and life.

## Related Practices:

Ultrasonic Testing of Aerospace Materials:  PT-TE-1422
Eddy Current Testing of Aerospace Materials: PT-TE-1421

## References:

1. MIL-HDBK-728/5:  "Military Handbook: Radiographic Inspection," December 1985.
2. MIL-STD-410E:  "Nondestructive Testing Personnel Qualification and Certification," Military Standard, January 1991.
3. MM 1860.2D:  "Radiation Safety Manual," NASA, Marshall Space Flight Center, Marshall Space Flight Center, AL  35812, December 1991.
4. MM 1700.4C:  "Safety and Environmental Health Standards," NASA, Marshall Space Flight Center, Marshall Space Flight Center, AL, December 1983.
5. Metals Handbook, Volume 17:  "Nondestructive Inspection and Quality Control," pp. 295-357, ASM International, Metals Park, OH, 1989.
6. MIL-STD-453C:  "Radiographic Inspection," Military Standard, December 1984.