The Role of X-ray Inspection in Counterfeit Electronic Component Detection.

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Abstract

X-ray inspection has become a part of counterfeit component detection and covered in SAE Standard AS6081. The standard highlights the importance of low levels of radiation to prevent damage and real-time x-ray compliance of MIL Std 883.

Introduction

It is now accepted that x-ray inspection is among the different inspection methods in use to detect the presence of counterfeit electronic components.
The problem that arises is that the formation and interpretation of the x-ray image is not truly understood by the user and leads to many false identifications.
For example, voltage settings either too high or too low will obscure the contrast details of the x-ray image. As a rule, it is important to understand the x-ray image and the factors that contribute to it. It is important, as well, to understand the physical construction of the component being inspected; just as a radiologist must know the human anatomy, in order to interpret the two dimensional shadow projection of a three dimensional object.

The x-ray shadow

The x-ray image is basically a shadow image of the object, projecting a two-dimensional representation of shape, opacity and thickness. Many different three-dimensional configurations can project similar two-dimensional shadows (Fig. 1). Using the light/shadow analogy, it can be seen that the relative position of components within the object will affect the size and appearance of the x-ray shadow (Fig. 2).
Characteristically, the shadow is distorted by *geometric magnification,* which causes details of the object closer to the x-ray source to be magnified to a greater degree than details further from the source. The magnification of the x-ray image can be calculated as the ratio of the distance from the x-ray source to the shadow plane divided by the distance from the source to the object (Fig 3).
As long as the object has a finite thickness, the x-ray image cannot have true dimensional accuracy. It can also be seen in Fig. 2 that, as the object becomes magnified, it loses edge sharpness. This is the “penumbra effect,” which results from the finite size of the x-ray source (Fig. 4).

X-ray imaging modalities

For viewing, the x-ray “shadow” can either be exposed to a photographic film or be converted to a video image. Different devices are used to convert the x-ray image to a video or fluoroscopic image. Thomas Edison invented the first fluoroscope in 1896 when he discovered that Calcium Tungstate acted as a *scintillator* and fluoresced when exposed to x-rays. It was his intention to use x-ray excited fluorescence as the basis of a light source until the technician working on it, Clarence Dally, developed terminal cancer. The technology has since progressed somewhat.
Today, the two basic fluoroscopic modalities can be described as static imaging and dynamic imaging. Both depend on a scintillator to convert the x-ray image to a light image. The flat panel imager is basically a scintillator coated onto a CCD array that produces static fluoroscopic images (Fig. 5); that is to say, a series of still x-ray images.
Dynamic, or real-time, fluoroscopy produces x-ray movies. Dynamic imaging fluoroscopes employ a scintillator coupled to an image intensifying device that amplifies the light image and presents it to a video camera for display (Fig. 6).
The image intensifying device can be a “demagnifying” type as shown in Fig. 6 or a “non-demagnifying” type.

Magnification Fluoroscopy employs fine particle, high resolution scintillators coupled to “non-demagnifying” intensifiers that produce high resolution fluoroscopic images at relatively low radiation dose levels. These fluoroscopic images can then be magnified optically for video display. Other imaging modalities include Computerized Radiography, wherein the x-ray image is stored on a “storage phosphor” and read out with a laser; CT or computerized tomography, wherein the image is mathematically reconstructed from many measurements of the transmission value of a pencil beam of x-rays.

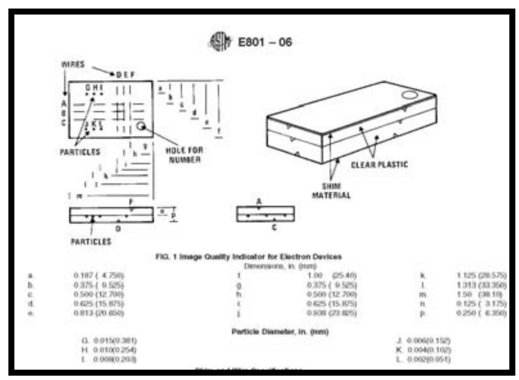
Implementation of x-ray inspection in conformity with DoD requirements.

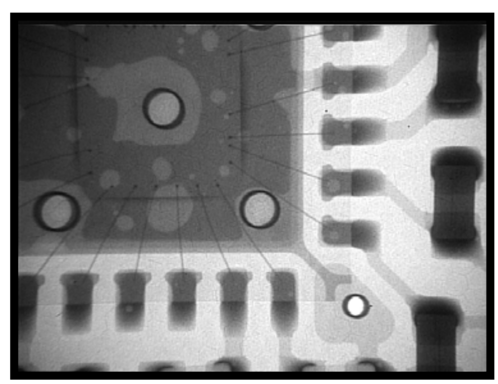
Although x-ray inspection is recognized as one of the tools for determining authenticity of an electronic component, it has not been acknowledged in any of the present Component Authenticity Programs or standards that for military applications, the Department of Defense has very specific image resolution requirements for the x-ray inspection of “Microcircuits”. These requirements are spelled out in MIL-STD-883H (26February2010) and MIL-STD-750-2 (3 January 2012) with reference to ASTM E801 and ASTM E1000.

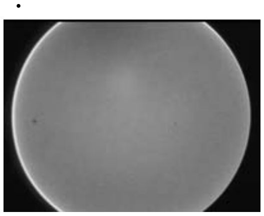
Although these standards were originally written for “radiography” mode, that is, film based x-ray imaging; these standards also have provisions for “radioscopy” meaning real-time or fluoroscopic imaging. Most of the commercial x-ray inspection systems that are presently being promoted for this application are real-time but many do not comply with these MIL-STD requirements.

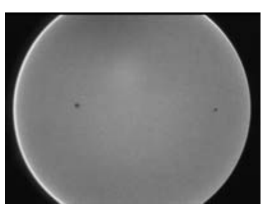
The basic tenant of these requirements is that a radiographic “image quality standard” as prescribed in ASTM E801, be recorded at the start and end of the x-ray inspection of each lot of electronic components.

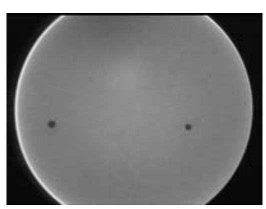
The “ IQS” image must demonstrate that the smallest detail of the component such as wires, wire bonds, die attachment voids, etc. are detectable with the x-ray system being used.

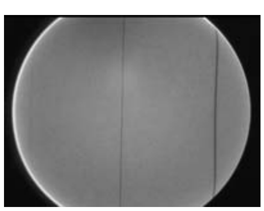


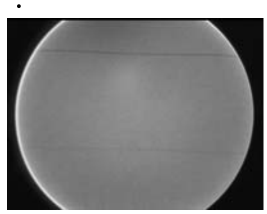


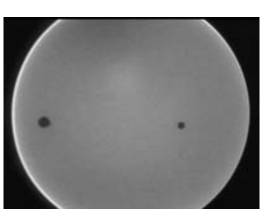












Radiation levels employed in x-ray inspection.

The question is asked; Would the level of ionizing radiation being employed in the inspection of an electronic component cause some damage to the device? To address this question we have to look at relative levels of radiation.
There are a number of units that are used to express dose levels; for this discussion we will use the milliRem (mRem). For the inspection of a medical device, the dose rate could be between 200 to 1000 mRem per minute.

Data from "Doses from Medical Radiation Sources"

The Health Physics Society.

Diagnostic Procedure	Does Level (mRem)
Chest x-ray	3
Limbs or joints	6
Mamogram	13
Coronary Angiogram	460-1500
Non-Diagnostic	
Flying in a plane in daylight at 30,000 feet	0.5 mRem/hr.

A great deal of study has been performed by NASA on the potential for radiation damage to vulnerable electronic components in space. The relatively vulnerable Si MOS Linear IC products might show damage at approximately 400,000 mRem and will likely degrade or fail beyond 1 million mRem
It is important to understand the radiation levels being used to inspect the component both to prevent component damage and to provide operator safety.