Chapter 2. RADIOGRAPHIC INSPECTION

10. GENERAL. Radiographic inspection of the structure is recommended if the suspected structural area may be hidden or not easily accessible. This type of inspection is not recommended as an exploratory technique for general inspection. In most instances when radiographic techniques are used, the suspected location and orientation of the failure will be known from previous experience. Information available should provide inspectors with the necessary setup and exposure data for shooting most of the areas of the aircraft. These instructions should provide good radiographic views based upon the best orientation to detect a failure.

11. AIRCRAFT PREPARATION. Due to the hazardous nature of radiographic radiation, it is necessary to isolate the aircraft and to keep unauthorized personnel at a safe distance. The aircraft may be defueled and properly marked with warning signs or roped off. In most instances no disassembly of the aircraft will be required; however, X-ray tube leveling will be required. The individual inspection requirements will generally dictate the configuration and attitude of the aircraft.

12. RADIOGRAPHIC EQUIPMENT. For all inspection requirements of this section, the basic radiographic equipment must be portable. Consequently, any approved portable equipment is acceptable provided it is calibrated and the rating is compatible with the inspection requirements. The requirements for associated items of equipment such as "geiger" counters, penetrometers, lead screens, dark room equipment, etc., will be found in MIL–STD–453.

13. INSPECTION TECHNIQUE. Each individual inspection required should provide radiation source and film orientation, also exposure requirements and setup geometry. In all instances, the recommended setup has proven the best orientation and exposure to detect damage in the most critical area. While every attempt has been made to provide the best inspection setup possible, additional setups or orientation should be considered if aircraft modifications or film interpretation warrant such action.

14. PRINCIPLES OF RADIOGRAPHY.

a. General. X-rays and gamma rays are radiations which have the ability to penetrate material opaque to visible light. These radiations on passage through material are absorbed to varying degrees which is dependent on the density and atomic number of the material. This phenomenon of absorption is used to render information that is recorded on a film. The following are general definitions:

(1) Gamma rays. Electromagnetic radiation of high-frequency waves (or short wave length) emitted by the nucleus of an atom during a nuclear reaction. Gamma rays are not deflected by electric or magnetic fields. They are identical in nature and properties to X-rays. Source will depreciate in intensity with time and thus exposure time must be recalculated periodically.

(2) X-rays. A form of radiant energy resulting from the bombardment of a suitable target by electrons produced in a vacuum by the application of high voltages.

b. Concepts. X-rays and gamma rays because of their unusual ability to penetrate material and disclose discontinuities have been applied to the industrial radiography inspection of castings, welds, metal fabrications, and nonmetallic products. Radiography has proven a successful maintenance tool with which to implement maintenance programs for inspection of aircraft.

(1) The three major steps concerned in radiography inspection are:

(a) Exposure of the material to X- or gamma radiation including preparation for exposure.

(b) Processing of the film.

(c) Interpretation of the radiograph.

c. ***Production of X-radiation.***

(1) **General.** X-radiation is produced when some forms of matter is struck by a rapidly moving, negatively charged particle called an electron. This condition can be produced by the following basic requirements:

(a) Source of electrons. If the appropriate material is heated sufficiently, some of the electrons will become agitated and boil off or escape from the material and surround it in the form of a cloud.

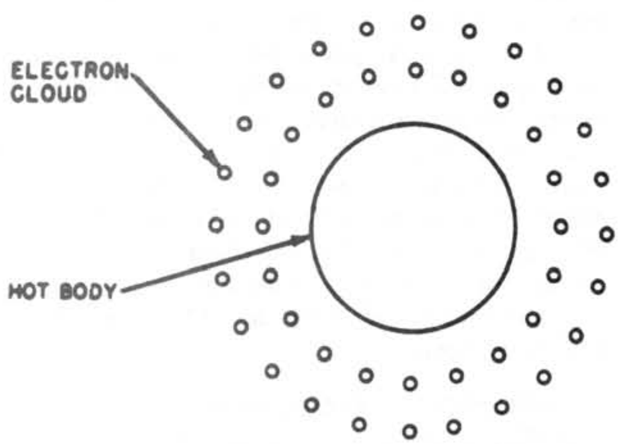

FIGURE 1.—Electron cloud around hot body.

(b) Directing and accelerating electrons. Unless some force pulls the cloud of electrons away, it will return to the emitting material. Movement of the electrons is essential and is brought about by the repelling and attracting forces inherent in electrical charges. A strong like charge is used to move the electrons which must be conducted in a vacuum (tube) to avoid collision with air molecules and resultant loss of energy.

(c) Bombardment. It is necessary that the moving electrons strike some substance. When electrons bombard the target, certain atomic disturbances occur within the target material releasing radiation known as X-rays.

d. ***Production of gamma radiation.***

(1) **Natural sources.** Radioactivity which is a phenomenon of spontaneous atomic disintegration is a property displayed by atoms of certain materials. The lack of stability of the atomic structure of the material probably causes the disintegration. The energy is released due to the unbalanced condition, in the form of gamma rays and is spontaneous.

(2) **Artificial sources.** Certain elements can be made radioactive by bombardment in an atomic pile. These elements are changed structurally and are known as isotopes of the original element. Among the common isotopes currently used in industry are those derived from elements Cobalt, Cesium, Iridium, and Thulium, and are referred to as Cobalt 60, Cesium 137, Iridium 192, and Thulium 170. The numerical designation indicates the weight of one atom of the particular radioisotope and differentiates from other isotopes of the same element or the parent element itself.

e. ***Radiation intensity.*** Quantity or number of rays available during a specific period of time must be determined. This is important since the time required to make a radiographic exposure is directly related to the radiation intensity. X-ray intensity is directly proportional to the tube current and is, in general, a function of the voltage raised to a power greater than 2.5. Gamma ray intensity is radiation emission as measured over a period of time at a fixed distance.

f. ***Effect of radiation on film.*** Film is basically a cellulose material with a photosensitive emulsion on both sides. A change occurs in the emulsion when exposed to X-rays or gamma rays since it is sensitive to certain wave lengths of electromagnetic radiation.

g. ***Film characteristics.*** There are many diverse applications in industrial radiography. To produce the optimum radiograph, there are several factors to consider in each application. The following headings encompass important areas of information on film characteristics of which the radiographer should have knowledge:

(1) Film density.

(2) Exposure.

(3) Film characteristic curves.

(4) Film speed.

(5) Technique charts.

(6) Radiographic screens—

(a) Lead foil screens.

(b) Fluorescent screens.

(c) Cassettes and film holder.

(7) Film processing and control.

(8) Film defects.

15. SAFETY.

a. ***Personnel safety*** is one of the most important considerations in the use of X-ray equipment. Radiation from X-ray units and radioisotope sources is destructive to living tissue, so adequate protective methods and detection devices must be used. Since the detrimental effects of excessive exposure are not immediately apparent, personnel frequently exposed to X-rays should have periodic blood counts and physical examinations.

b. ***The National Bureau of Standards*** has issued a number of handbooks on the subject of protection against radiation. These books can be obtained from the United States Department of Commerce.

c. ***While the exposure is in process,*** the operators and all personnel in the immediate vicinity must be protected.

d. ***Three general types*** of radiation monitoring devices are in general use.

(1) **One type** consists of a small, pencil-like ionization chamber which is given an electrostatic charge at the beginning of each day's work. As it is subjected to penetrating radiation, it discharges proportionately to the amount of radiation received. By inserting this chamber into an electrometer, the amount of radiation received between the time of charge and the time of reading can be determined.

(2) **The second** and most commonly used radiation monitoring device is the film badge, consisting of a holder, a filter, and special X-ray film. These film badges are distributed to the radiographic operator, assistants, and all persons who may be in the vicinity of an exposure area. After one or two weeks of exposure, the film is processed and the resultant density of the negative is read by means of a densitometer. By comparing the density of the film with a master guide, the radiation received by the badge wearer can be determined.

(3) **A third type** of radiation monitor uses either a large ionization chamber or geiger, proportional or scintillation counters in conjunction with an electronic rate meter. This type of instrument reads the radiation intensity being received at a given location at the time the instrument is in operation and is independent of time. These devices are useful for posting the areas of radiation hazard and for determining the safe distance from the exposure area at which the operators and personnel must remain.

e. ***The assets and liabilities*** of radiographic techniques are well established. It is important to show how some of the liabilities associated with radiographic techniques provided the stimulus for the development of new nondestructive techniques. Foremost among these liabilities is safety. Safety considerations require areas which must be shielded. There are, however, technical liabilities such as insensitivity and, in fact, ineffectiveness of radiographic techniques for many of today's needs. All of these liabilities and others not noted were sufficient to initiate the search for new and more efficient nondestructive evaluation tools.

16. INTERPRETING RADIOGRAPHIC FILM.

Interpretation of radiographic films must be attempted only by qualified radiographic personnel. However, the qualified radiographic film reader must be aware of the necessity of the need for maximum film interpretation due to increased structural complexity and the differing failure characteristics of new materials. Further, the radiographic reader must possess a knowledge of the aircraft and engine structure.

a. ***The most important phase of radiography*** is the interpretation of the exposed film. The effort of the whole radiographic process is centered in this phase. Defects or flaws which are overlooked, not understood or improperly diagnosed can jeopardize the reliability of the material. A particular danger is the false sense of security imparted by inspection approval based on improper interpretation. At first impression, radiographic interpretation may seem simple but a closer analysis of the problem soon dispels this impression. This subject is too varied and complex and cannot be covered adequately in this Advisory Circular.

b. *Description of radiographic process.* The penetrating radiation passes through the object and produces an invisible image on the film. The processing of the film provides a radiograph or shadow picture of the object. More radiation passes through the object where the section is thin, and as a result, the corresponding area on the film is darker. The radiograph is read by comparing with the known design of the object and observing either the similarities or differences. (See Figure 2, diagram showing fundamental elements of radiographic exposure.)

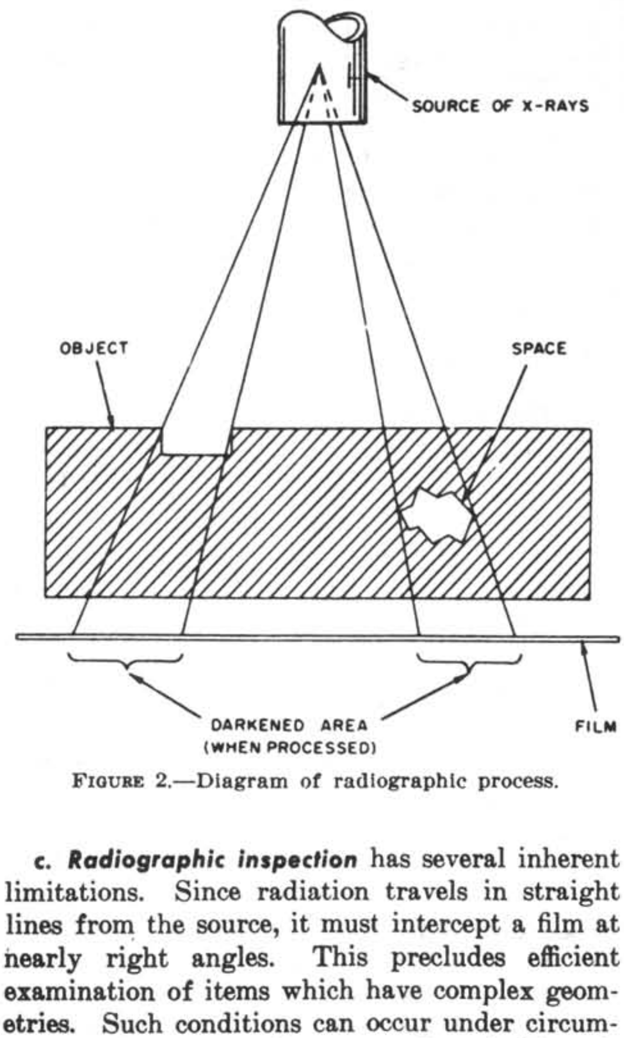

FIGURE 2.—Diagram of radiographic process.

c. *Radiographic inspection* has several inherent limitations. Since radiation travels in straight lines from the source, it must intercept a film at nearly right angles. This precludes efficient examination of items which have complex geometries. Such conditions can occur under circumstances wherein the film cannot be suitably oriented, or if suitably oriented, will be subject to the adverse effects of scattered radiation or image distortion.

(1) The information in a radiograph or plate is obtained by density differences brought about by differential absorption of the radiation. These density differences, must be oriented almost parallel to the direction in which the radiation is traveling. Discontinuities such as laminar-type flaws, will often be undetected because they do not present a sufficient density differential to the radiation. This limitation is countered to some extent since the orientation of fractures can be approximately predicted and the setup oriented accordingly.

(2) The nature of laminations precludes their ready detection, and radiographic inspection is seldom used to locate this type of flaw. Penetrating radiation is absorbed in direct proportion to the thickness of material. As material thickness is increased, the time required to obtain sufficient information on the film also increases.

(3) For a given energy (penetrating power) of X- or gamma radiation, there exists a thickness beyond which radiography is not feasible. Radiographic equipment of higher energy potential could be obtained; however, costs would increase markedly because of the barriers required to protect personnel from the harmful effects of the radiation as well as the basic cost of larger equipment.

d. *Characteristics of X-ray and gamma ray.*

(1) X-ray and gamma ray are forms of electromagnetic radiation as are visible light, infrared waves, radio waves, and cosmic waves. The wave length, lambda (λ), of an electromagnetic radiation is expressed in units of length to suit the length of the waves, in meters (m.), centimeters (cm.), millimeters (mm.), microns ($1\mu = 1/1{,}000$ mm.), in millimicrons ($1 m\mu = 1/1{,}000\ \mu$); or again for X-rays in angstrom units ($1A° = 1/10\ m\mu = 10^{-8}$ cm.), and also for X-ray and gamma ray in X units ($1X = 1/1{,}000\ A°$). Figure 3 shows position of X-ray and gamma rays in the electromagnetic spectrum.

(2) Short wave lengths are the distinguishing characteristics of X-rays and gamma rays. Penetrating power, or energy, is dependent upon the