PROTECTION OF INDUSTRIAL RADIOGRAPHERS THROUGH FACILITIES DESIGN

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INTRODUCTION

Because Industrial Radiographers are involved in more radiation accidents, receive more overexposures, and are cited for more serious items of non-compliance by governmental agencies than any other group in the nuclear field, their protection facilities must be designed foolproof and fail-safe.

The Boeing Company has long strived to meet this requirement by full radiation protection built into every industrial radiographic facility. This includes both enclosed shielded rooms and open field radiography. Facilities and equipment are designed to contain the hazard, with anything from a four foot concrete shielded room for an industrial radiographic accelerator to a piece of rope that isolates an Iridium-192 source during a field radiographic inspection on an aircraft.

X-ray units, accelerators, and radioactive materials are used in our radiographic inspection program on aircraft, missiles, and seacraft. We presently employ seventy-five Radiographers, operate ninety radiation sources, and take ten-thousand radiographic exposures per month.

ANALYSIS OF RADIATION HAZARD

When a Quality Control Group within the Company wants to use radiation to perform a quality control test, they determine the type and amount of radiation required to do the job. Once the source of radiation is determined, the Quality Control Group and Radiation Health Protection must agree upon where and how the source will be used. We must decide if the radiography can be done in a completely shielded room, a partly shielded area, or an open locality.

Protection facilities are designed to solve specific radiation problems. These problems are defined by analyzing the hazards to determine their impact upon the working and public environments. The hazard analysis considers the type and size of the radiation source to be used, the expected exposure levels, any interaction between employees and the sources, and worst possible consequences of employee error or equipment failure.

Industrial radiographic operations using the radiation source are reviewed to accurately establish: (1) The amount of time the Radiographer and other employees are exposed to radiation; (2) The intensity of the exposures; and (3) The areas of their bodies that are exposed. The possible exposure dose will help scope the facility and equipment design.

FACILITY AND EQUIPMENT DESIGN

When the analysis is complete and the degree of hazard is known for the operation, the necessary facilities and equipment can be designed to contain the hazard. At Boeing, we try to design out all the hazards associated with industrial radiographic inspections.

Our industrial radiographic operations are classified in three general categories: (1) Shielded Room operations; (2) Portable Self-contained

Protection Systems for use outside of a shielded room; and (3) Open Field Radiographic Inspections.

SHIELDED ROOMS: In a Shielded Room design, we place enough shielding in the walls, floor, and ceiling to keep the radiation exposure outside the shielded area to less than 10 mRem per week. We shield the room for the maximum kV and mA to be used, Curie amount to be used, the maximum work load, and how often the areas outside the room are occupied per week. We reduce the cost of shielding by limiting the number of Primary Beam walls. Shielded Rooms may be made of Lead so they can be moved if necessary. Steel supports are used to hold the Lead (1.3 x 1.3 meter) sheets in place. The sheet is bonded to 19 mm Plywood, and tack-welded with lead strip overlay. This type of room can be taken apart and moved to another location. In some cases, Concrete is chosen as the shielding medium. Large, keyed, solid concrete blocks are sometimes used in the design of high energy shielded rooms.

All entrances to the radiation area within the room are provided with Interlocks that shut down the radiation production when opened. The Interlocks are all of a fail-safe nature, and must be reactivated by both closing the door and resetting manually at the door. The interior of the exposure room is posted with a sign, "DO NOT OCCUPY AREA WHEN DOOR IS CLOSED". A Flashing Warning Light is placed outside of each entrance to the room, and also inside the room. The Warning Light on the outside illuminates a sign which reads, "RADIATION ON". This sign is actuated by the radiation. The Warning Light inside (preferably a Rotating Beacon) is activated twenty seconds prior to the production of radiation, and remains activated during irradiation.

An Audible Warning Device is also used inside each shielded area. This audible signal is activated twenty seconds prior to the production of radiation and remains on for thirty seconds after the exposure begins.

Signs warning "CAUTION——ENTRANCE TO A HIGH RADIATION AREA" are placed at the entrance to each shielded room to warn personnel of the hazard within the room. There is also a "HIGH RADIATION AREA" Sign within the room.

Emergency Power Cutoff Switches (Scram Buttons) are placed in each exposure room, and are easily identifiable because of the large red square painted on the wall behind it. A Sign is located above the switch which reads "IF ALARM SOUNDS, PUSH SWITCH AND EVACUATE ROOM IMMEDIATELY".

Also placed in each room is a Continuous Radiation Monitoring Device which gives off an audible signal when radiation is present. These are placed in the room as a secondary protection system to ensure that the Radiographer knows if the X-ray beam is on, or a radioactive source is exposed within the enclosure. A Portable Instrument is also carried in the room to ensure that a radiation source is shielded.

IN-PLACE SHIELDING: In-place Shielding Devices are designed for special field applications. This may be a small lead enclosure used in radiographing small parts, or a lead shielding fixture which allows the radiographing of an in-place hydraulic tube on an aircraft. The radiation exposure levels on the exterior of these devices do not exceed 2 mRem per hour at 30 cm from the shields. Where possible, the shields are fitted with safety equipment such as Interlocks and Flashing Lights. Signs, instructing Non-Occupationally Exposed Individuals to stay at least one meter from these devices, are posted in the area. The Interlocks ensure that the in-place shielding device is closed or fits tightly to the working surface, to eliminate leakage. A Flashing Light is activated when the radiation source is turned on or exposed. Both X-ray

units and radioactive material sources are utilized in the in-place shielding devices. By use of this type of equipment, radiographs can be taken on an aircraft in the assembly line without having to remove any of the nearby workers (a great cost savings for the company).

FIELD RADIOGRAPHIC INSPECTIONS: For Field Radiographic Inspections, posted barriers such as ropes, fences, and barricades are used to designate the hazard area. Distance from the source of radiation is used as our primary protection method. However, portable lead shields may also be used during field radiographies. Shields generally are 1.2 meter by 2.4 meter sheets of 9.5 millimeter or 12.7 millimeter Lead. Either may be used for Primary and Secondary radiation shields, depending upon the energy of the source. Use of shields cuts down the size of the hazard area and allows more employees to continue working near the radiographic operation.

In addition to the portable shields, we also use Lead Cones on the Gamma and X-ray beams to limit the field size. The Cones are fitted to the X-ray tube or on the exposure tube of the radioactive material device. Both Audible and Visible Warning Alarms are used at the radiographic site. Flashing Warning Lights are activated twenty seconds before radiation is present and all the time during the exposures. The Audible Alarm is activated by the radiation source. The barriers, signs, and warning devices are put in place by a Radiation Monitor from the Radiation Health Protection organization. Often, the Radiographer aids in this process; the two work as a team. During the actual radiographic exposure, both members of the team patrol the hazard area to ensure that no one enters.

FACILITY CERTIFICATION

The Facility and Equipment Certification Program plays an important part in the Boeing success of reducing its employee radiation exposures. Each radiation facility is certified to operate only under specific conditions. These certifications are written by the Radiation Health Protection organization, and the contents approved by the Operating Groups.

The Certification Form contains the conditions under which an X-ray, Gamma source, or Accelerator may operate in the facility. It specifies the maximum operating power range in kiloVolts (kV) and milliAmps (mA), or Curies for radioactive material, and the maximum time the equipment may be operated in a given week. It tells the Operator at which walls the radiation source can be pointed, what power levels can be used, and the minimum distance the source must be from the wall whenever it is activated. These conditions are specified for the four walls, the ceiling, the floor, and any door within the facility. All operations are re-certified annually.

EVALUATION OF THE FACILITY DESIGN

The effectiveness of a facility design must be evaluated during the initial start-up of the operation. The start-up survey is quite detailed in order to assure adequate containment of the hazards. The shield is verified, interlocks/lights/panic button checked, and protection systems reviewed in case of abnormal operations.

Long-term evaluation is through personnel dosimetry. Personnel dosimetry is worn by all personnel working in radiation areas. These include Film Badges, Pocket Dosimeters, and Thermoluminescent Dosimeters (TLD's) for special monitoring programs. The Radiographers are required to wear the Film Badge and Pocket Dosimeter at all times. TLD's are used in special programs to

determine if certain areas of the body are receiving more radiation than others.

Personnel working under field conditions are issued Personnel Audible Warning Devices which alarm when in a radiation field. Of course, each field radiography is monitored by a Representative of the Radiation Health Protection organization. Periodic (quarterly) Radiation Surveys are also conducted on radiation facilities. These surveys include monitoring of the shielding, safety devices, and radiation source. Reports of all surveys are maintained in our records for review by governmental agencies.

The results of the Boeing program have been excellent. Only one individual in twenty years of operation was exposed to one Rem in a year. The average exposures for one year are below 100 mRem.

The potential for high acute or even low chronic exposure to radiation has essentially been eliminated at The Boeing Company by designing out the radiation hazards.