RADIATION PROTECTION FOR INDUSTRIAL RADIOGRAPHY IN THE AEROSPACE INDUSTRY

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"Industrial Radiography" has been a dirty word to Health Physicists all over the world. This is true because the 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.

The Boeing Company employs eighty Radiographers, operates ninety radiation sources, and takes ten-thousand radiographic exposures per month. Our Radiographers average less than 100 milliRem Whole Body exposure per year. They have never been cited for a governmental non-compliance, nor have had any radiation accidents. X-ray units, Accelerators, and Radioactive Materials are used in our Radiographic Inspection Program on aircraft, missiles, and seacraft.

The major components of our Radiation Protection Program are: Hazard Analysis, Facility and Equipment Design, Program Administration, and Evaluation of the Protection System.

HAZARD ANALYSIS

A Hazard Analysis starts when a Quality Control Organization within the Company wants to use a source of radiation to perform radiography. Depending upon the thickness and density of material to be radiographed, the Operating Group will determine the type of radiation source required.

If a Radioisotope such as Cobalt 60, Iridium 192, Ytterbium 169, etc., is to be used, the strength of the source in Curies is determined. With this information, the External hazard is analyzed from the standpoint of energy and amount. The Internal hazard must be assessed from the method of encapsulation and the type of radioactive material.

When an X-Ray Unit is involved, we are given the type of tube they are going to use, such as a 360 degree emission or side emission tube, and the maximum kiloVolts (KV) and milliAmps (MA) capabilities of the unit. Similar information is also provided on Particle Accelerator operations.

Once the characteristics of the source are determined, we must agree upon where and how the source is to be used. If the source is going to be used in a shielded room near an unpopulated area, the shielding and protection requirements will be minimal. A stationary source in a populated area will require more shielding and a complete protection program. When a source is used in a shielded area, the main beam wall use factors, distance to people, and occupation factors are necessary information to determine the shielding requirements.

However, if the source is to be a portable unit and used mainly for field radiographic inspections, we then need to know

where and how often these unshielded sources will be used. The type of radiographs taken will dictate the maximum KV, MA, and "ON" time of a machine, or required "exposure" times for sources of radioactive materials. These parameters are considered when evaluating the size of a hazard or restricted areas.

The interaction of all employees and a source is analyzed at great length. This analysis covers both the Radiographer using the source, and the Employees working in and around the source location. The Radiographer and his Helpers are classified as "Occupationally Exposed Workers". The other Employees are classified as "Non-Occupationally Exposed Individuals", and can only receive one-tenth of the radiation exposure of an Occupationally Exposed Worker.

Operations conducted by the Radiographer using the source are reviewed to accurately establish: (1) The amount of time the Radiographer and other employees are exposed; (2) The intensity of the exposures; (3) The areas of their bodies that are exposed. The possible exposure dose will scope the Radiation Protection Program.

Having assessed the hazard associated with normal radiographic operations, we then consider the consequences if the equipment fails, or the Radiographer errs. If a human error or failure of the equipment can cause high External or Internal exposure, then every possible protective device is used to eliminate the hazard.

FACILITY AND EQUIPMENT DESIGN

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

In a Shielded Room design, we place enough shielding in the walls, floors, and ceilings to keep the radiation exposure outside the shielded area to less than 10 mR per week. We shield the room according to the maximum KV and MA, work load, use, and occupational factors associated with the area. We reduce the cost of shielding by limiting the walls at which the Primary Beam may be directed.

All entrances to the radiation area within the room are provided with Interlocks that shut down the x-ray production when opened. The Interlocks are all of a fail-safe nature, and must be re-activated by both closing the door and re-setting manually. 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 says, "Radiation On". 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. "Caution—High Radiation Area" Signs are

placed at the entrance to each shielded room to warn personnel of the hazard 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 says, "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. These continuous warning devices do not replace the Portable Survey Instruments which are used by the Radiographer upon entrance to the room.

Before any of the shielded rooms are put into service, a complete radiation survey is performed of all occupied areas adjacent to the walls, ceilings, and floors of the room. Each safety device is checked out to make sure that it is operational and fulfills its requirements. If they all check out, the room and radiation source are certified by the Radiation Health Protection Organization as safe to operate. This certification will be discussed later, in the "ADMINISTRATIVE" section.

In-place shielding devices are also designed for special applications. This may be a small lead box used in radiographing small parts, or a shielding fixture which allows the radiographing of an in-place hydraulic tube on an aircraft. The radiation exposure levels do not exceed 2.0 mRem/hr at 30 cm from the shields. Where possible, these shields are fitted with safety equipment such as Interlocks, Flashing Lights, etc. Signs, instructing Non-Occupationally Exposed Individuals to stay approximately one meter from these devices, are posted near the equipment. The Interlocks ensure that the in-place shielding device is closed or fits tightly to the working surface, to eliminate leakage. The Flashing Light is activated when the radiation source is turned on or exposed. Both X-ray units 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.

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 are also used during field radiographies. Shields are generally 1.2 meters by 2.4 meters Sheets of 9.5 millimeters and 12.7 millimeters Lead, to accommodate the high energy sources. They both may be used for Primary and Secondary radiation, 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 nearby 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 of radiation. The Cones are fitted to the x-ray tube or on the exposure tube of the radioactive material device. Both Audible and Visual 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 actual radiographic exposures, both members of the team patrol the hazard area to ensure continuous evacuation of Non-Occupational personnel.

PROGRAM ADMINISTRATION

After the facilities and equipment have been designed and obtained, the Administrative functions are called upon to provide the rest of the Radiation Protection Program. The general policy of The Boeing Company is to make each Operational Supervisor responsible for the health and safety of his employees. The Radiation Health Protection Organization serves them in an advisory capacity. If the Radiation Health Protection Organization did operate as an enforcement group, they would have to be present during all industrial radiographic inspections, even the ones conducted in a shielded room. This is impractical, and very costly! Also, the employee who works in a hazardous area must be willing to accept some of the responsibility for his own protection. We have also determined that the workers and the supervision of Operating Groups tend to accept advice much more willingly than to comply with commands or ultimatums.

There is one exception to this policy. If an operation is conducted in a manner that could cause a serious radiation hazard, the Radiation Health Protection Organization has the power to stop the operation. Because of the high risk involved in a field radiographic inspection, a Radiation Monitor from the Radiation Health Protection Organization is always present to aid in the evaluation of the hazard.

Our command media plays a very important part in the administrative portion of the Radiation Protection Program. The Radiation Health Protection Organization reviews or writes all Administrative, Operating, and Emergency Procedures which involve the use of radiation for industrial radiography.

The Administrative Procedures establish the Radiation Protection Program, and give general rules and requirements.

The Operating Procedures are written for specific industrial radiographic operations, and tell the Radiographer in a step-by-step method how he should perform his work. Operating Procedures also assign protection responsibilities to the Radiographic Group as well as the Radiation Health Protection Organization.

Emergency Procedures are written to cover every type of industrial radiography operation, and document the possible hazards with the necessary controls. Responsibilities are assigned to the Operating Group as well as other Emergency Organizations, such as Fire, Plant Security, Maintenance, Occupational Medicine, and the Radiation Health Protection Organization.

The backbone of the whole Radiation Protection Program is the education and training provided for the Radiographers, Radiation Health Protection personnel, Management, and Emergency Groups.

At Boeing, every Radiographer and Radiation Health Protection

employee is required to take a 24-hour Radiation Protection Course prior to working in a radiation area. These Courses are taught by the Radiation Health Protection Organization, and help to cement relations between the two groups. Subjects such as Basic Radiation Physics, Biological Effects of Radiation, Methods of Controlling Radiation Hazards, Operating Procedures, Emergency Procedures, Legal Requirements, and Recent Radiation Accidents are covered in the Radiation Protection Course. A written examination is given at the end of the Course, and the students are required to pass with at least a 75 percent score. Refresher Courses are required for all Radiographers and their Helpers. On-the-job training is also an on-going part of the training program.

An Equipment Certification Program plays an important part in the Boeing success of reducing its employee exposures. Each source of radiation 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. The write-up includes the name of the piece of equipment, the identification number, the location where the equipment may be used or stored, the organization who owns the equipment, and personnel who are approved to operate the equipment. 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 he can point the radiation source, what power levels he can use, and the minimum distance the source must be from the wall whenever it is activated. These conditions are spelled out for the four walls, the ceiling, the floor, and any door within the enclosure.

A list of operating limitations is also included in the Certification. Such things as "This equipment can only be operated by a trained and authorized Radiographer", "All Safety Devices must be in working order", "A Safety Device Checklist shall be completed prior to each day's operation", "Any operation not complying with the limitations on the certification must be monitored by the Radiation Health Protection Organization", "Radiation Health Protection personnel must be contacted prior to any field radiographic inspection using this radiation device", and "A copy of all Administrative and Operating Procedures must be posted along with this certification" are some of the limitations placed on operations.

All operations are certified annually. Quarterly inspections ensure a continued safe operation. The certification form is reviewed by each Operator. When the Radiographers have read and understand the limitations placed on the operation of a particular radiation source, they sign a Form confirming they have reviewed and understand the document.

EVALUATION OF THE PROTECTION SYSTEM

After the Administrative Program has been set up and the Industrial Radiography Protection Program is underway, the Radiation Protection Program is evaluated through Physical Examinations, Personnel Dosimetry, and Radiation Area Surveys.

Normally, Physical Examinations are given to employees prior to working in a restricted area, on an annual basis, and when the employee terminates his work with radiation. If real or potential overexposures are suspected, special physical examinations are administered.

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. TLD's are placed on the head, hands, legs, and other body surfaces to determine localized doses.

If there is any possibility of internal deposition of radioactive material, a Bio-Assay is done on each Radiographer involved. The Film Badge Program is on a monthly basis, with Pocket Dosimeters being issued and read on a daily basis. Film Badges are purchased from, and processed by, a disinterested third party. This ensures that The Boeing Company will not under-read a film badge in case of an overexposure. Each film badge that reads over 100 mRem in a period of a month is investigated, and a letter of explanation is required from the person receiving the exposure.

Personnel working under field conditions are issued Personnel Audible Warning Devices, which alarm when in a radiation field. Of course, each field radiography (as explained earlier) is monitored by a Representative of the Radiation Health Protection Organization.

Periodic (quarterly) Radiation Surveys are also conducted on shielded installations. 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 1 Rem in a year. The average exposures for one year are below 100 mRem.

Boeing's Industrial Radiographic Program has never been cited for items of non-compliance by any governmental agency. This includes the United States Nuclear Regulatory Commission and the Washington State Radiation Control Agency. The potential for high acute or even low chronic exposure to radiation has essentially been eliminated at The Boeing Company, and the term "Industrial Radiography" is not looked upon as a dirty word by any of the Health Physicists or Radiation Health Protection people associated with this Program.