▣ PAPER ▣

PRACTICE SPECIFIC TRAINING FOR APPLICATION OF IONIZING RADIATION IN INDUSTRIES

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Industrial radiography practice is usually employed in public domain. Over the years there are several radiation accidents reported in this practice. The accidents often result in severe or fatal exposures to occupational workers and public. The number of radiation accidents is also significant when compared with other industrial accidents. This paper describes practice specific training as one of the measures to the improve radiation safety and reduce the accidents. The efforts by International Atomic Energy Agency (IAEA) to disseminate information and to improve the radiation safety status in industrial radiography are also discussed.

Key words: Industrial radiography, Radiation protection

1. INTRODUCTION

Radiation sources in different sealed and unsealed forms are used in a variety of applications in industries. Among these, main are industrial irradiators; industrial radiography; well-logging; luminizing; moisture, density, thickness and level gauging; tracer techniques and equipment for fluoroscopic and crystallographic analysis of materials. While the radiation sources employed in gamma irradiators are of very high strength, non-destructive testing using radiography techniques is predominant in industrial applications. Nuclear control systems or gauging systems use alpha, beta, gamma and neutron radiation sources for the measurements of level, thickness and density, determination of moisture content. In terms of the IAEA categorization of radiation sources [1], industrial irradiator and gamma radiography sources are classified as category I, nuclear gauging sources as category II and fixed gauges with low radioactivity as category III. UNSCEAR [2] periodically publishes data on occupational exposures of various categories of personnel. The mean exposure in industrial exposure is low, however, industrial radiographers, luminizers and well loggers generally record higher doses than the rest of the group. Getting into details of industrial radiography group, the radiation sources commonly used are ^{192}Ir, ^{75}Se, ^{60}Co and X-rays. The newer techniques like neutron radiography, computed tomography are also utilized. Neutron radiography is widely used in the aerospace industry for testing of turbine blades and other components of airplane engines, high-reliability of explosives, and to a lesser extent in other industry to identify problems during product development cycles.

Industrial radiography is a technique employed in public domain and there are accidents often reported in this practice. The accidents generally result in severe or fatal radiation exposure to occupationally exposed persons and public. The number of accidents is also significant as compared to the number of other industrial accidents. Industrial irradiator accidents have been equally severe resulting in fatalities of radiation workers, but over the years with improved facility design and effective radiation protection program, the number of accidents has drastically reduced. This paper describes practice specific training as a measure to improve the radiation safety and reduce such accidents.

2. MATERIALS AND METHODS

Selected accident histories are recounted;

i) A radiographer had a permit to carry out X ray radiography work on a pipeline at a gas compressor station. A barrier clearly identified the extent of the controlled area, and pre-exposure and exposure warning signals were given following the radiation protection requirements. After a number of exposures, the radiographer observed two men emerging at a distance along the pipeline. Enquiries revealed that the two men also had a permit to work, that they had been inspecting the pipeline internally and that they had crawled through

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Table 1. Suggested Content of Industrial Radiography Training for Various Categories of Personnel.

Topics	Radiographer*	Qualified Expert	Radiation Protection Officer	Senior Management	Regulator	Public
Industrial Radiography applications, and equipment	x	x	x		x	x
Control of radioactive sources (IAEA code of conduct and Categorisation of sources)	x	x	x	x	x	
International system of Radiological protection	x	x	x		x	
IAEA Basic Safety Standard		x	x	x	x	
Off site Radiography (in enclosure)	x	x	x			
On site Radiography	x	x	x			
Regulations		x			x	
Organizational responsibilities		x		x	x	
Radiation protection program	x	x	x		x	
Authorisation, and Inspection of industrial radiography users		x			x	
Safety assessment of industrial radiography sites		x			x	
Enforcement		x			x	
Security of radiation sources	x	x	x	x	x	
Type testing of radiography equipment (conformance to ISO standard)		x			x	
Individual monitoring	x	x	x		x	
Workplace monitoring	x	x	x		x	
Safe transport of radiography sources	x	x	x		x	
Occupational exposures in IR		x	x			
Accidents in IR	x	x	x	x	x	x
Public protection		x	x			
Emergency Preparedness & response to industrial radiography incidents	x	x	x	x		x
Duties and responsibilities	x	x	x	x	x	x
Training	x	x	x	x	x	awareness

* Radiographer need to have training in radiography techniques also.

the X ray beam twice while performing their inspections. Reconstruction of the incident revealed that the inspectors had each received an estimated dose of 0.2 mSv. The event was caused by a lack of coordination of the work to be performed on the site. This incident could have been prevented if the radiographer maintained the required control of the area. The radiographer could have obtained all the necessary cooperation and information from the site manager prior to the start of the operations, to avoid the unwarranted exposures during the radiography operation. The required controls (barriers and warning signals) at the access points to the controlled area were not adequate to avert the needless human exposures.

ii) A fatal radiation accident occurred in 1984 in which eight members of the public died from the consequence of an over-exposure due to a radiography source. An 1.11 TBq (30 Ci) ^{192}Ir source became disconnected from the drive cable and was not properly returned to its exposure device. Subsequently, the guide tube was disconnected from the exposure device and the source eventually dropped to the ground. A passer-by picked up the small metal cylinder and took it to his home. Although the exposure device was marked with the radiation symbol (trefoil), the source itself bore no markings. The source was treated lost from March to June 1984 and a total of eight persons, including the person who took the source home, members of his family and relatives, died. The clinical diagnosis confirmed lung hemorrhage. It was initially thought that the cause of death was poisoning. Only after the last death, it was suspected that the deaths might have been caused by radiation exposure. The cause of the accident was the disconnection of the source assembly became disconnected from the drive cable, which fell to the ground and remained at the worksite. It was possible to prevent the accidents and such overexposures if radiation surveys were duly performed to ensure that the source returned to the fully shielded position. The person who picked up the source was evidently unaware of the health hazard. The source did not bear any radiation warning symbol which might have prevented the person from picking up the source [3].

iii) In May 2000 a farmer from a small village found a source and took it home; where he lived with his wife, sister and four children. In the following weeks the source was handled by the family members and moved it to various locations in the home. His 9 year old son died in June 2000 and the death was reported to be due to marrow failure and inflammation caused by a viral or bacterial infection. Other family members were also found to be sick with skin lesions, bone marrow failure and gastrointestinal symptoms. Subsequently the farmer died following which an investigation was undertaken. High radiation levels were detected in the house and the source was recovered. The estimated dose varied from 4-8 Gy. This fatal accident could have been prevented if the farmer and his family had recognized the potential hazard [4].

The lessons learned from the accidental history leads to several facts; a) ineffective regulatory control or regulations, b) lack of effective radiation protection programme c) radiography equipment failure, d) inadequate training of management and radiographers, e) insufficient security during transport, storage resulting in theft, f) lack of awareness or failure to recognize a radiation source, g) inappropriate maintenance procedure, h) skipping test approval step, i) failure to monitor source after radiography procedure, j) deficiency of emergency plans and k) radiation monitors not functional.

A solution could be by implementing a robust regulatory programme and periodic equipment maintenance and `training'. The training could be defined as the acquisition of knowledge, skills and competencies. But the implementation could be with respect to target audience or with respect to the applications. In industrial radiography there is a spectrum of audience to be trained ranging from radiographers to managers. It is apparent that radiographers, their supervisors or qualified experts, radiation protection officers (RPO), and management need to be trained differently. Each category of person may require different levels of training and therefore a suggested syllabus is presented in Table 1. From Table 1, it is possible to select the appropriate topics for each target audience. The classroom training could be supplemented by 'on-the-job-training (OJT)'. Conventional training methods provide training to acquire knowledge and good understanding of the subject, but are unlikely to cover all practical aspects. OJT is a critical component of human resource development. To gain competence in an identified practice, special skills and practical knowledge are required which can be acquired through OJT. The IAEA Safety Report provides a complete guidance for OJT training for industrial radiographers. The recommendation includes learning objectives, syllabus and implementation [4].

The other priority group that needs to be instructed is the public at large. From the accident histories, it is evident that the inadvertent exposures did occur in the public domain. The key reason s are the failure to identify the source and lack of information about the radiation hazards. The public do not need to undergo a detailed training but a brief awareness session about radioactive sources is required. The selected cases quoted here confirm that the acquisition of source and exposing self and family members to high magnitude of radiation exposures were due to unawareness. There have been where the sources ended up with the scrap dealers and were disintegrated. This happened with radiotherapy source heads too. In this case the catastrophe and the wide spread of contamination is indescribable. To avoid such occurrences, it may be, essential if public are taught to identify a radiation symbol, to recognize a radiography source pencil, and stay away from the site where radiography is performed. At times, a radiation symbol may go unidentified, therefore, additional symbols or a warning note could be included to prevent any direct contact with the source. In a strong regulatory regime, it is not possible to find such orphan sources but for a forceful and meticulous safety and security system such an option is useful.

Several radiation protection plans and Member States services by the International Atomic Energy Agency are available. The IAEA special safety guide [5] recommends how industrial radiography work should be carried out within the framework of the Basic Safety Standard (BSS) and other IAEA safety standards. The guidance in this publication is aimed primarily at managers of operating organizations who are authorized to carry out industrial radiography work, radiographers, radiation protection officers and regulators. The guidance may also be of interest to designers and manufacturers of industrial radiography equipment and facilities. The Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR) established by IAEA is an international database being developed to provide a tool that can be used by end-users to improve the implementation of optimization in occupational radiation protection in particular targeted areas, including industrial radiography. For each participating NDT company, the database will contain anonymized data on individual industrial radiographers, including their occupational doses, radiographic workloads, level of NDT training, radiation protection training, sources used, percentage of site radiography, use of collimators and survey meters, and number of incidents. The metric for assessing optimization of radiation protection will be occupational dose per radiographic exposure. NDT facilities will be able to benchmark their own facility and individual radiographers' performances against global or regional data. The industrial radiography section of the database will also have a module devoted to incidents − accidents, near misses and deviations from normal − and will provide information, examples and analyses that should lead to reduction in the occurrence of incidents in industrial radiography [6].

3. CONCLUSION

Industrial radiography is inevitable and there may be alternate techniques available, but it is necessary to establish if they meet the objective. The occupational exposure from this industrial application are, however, well within the prescribed limits [2]. The number of monitored workers increased from 72,000 in 1975-1979 to 116,000 in 1980-1984 and 113,500 in 2002 which remained about the same thereafter. The average effective dose dropped from 2.6 to 2.0 mSv and further to 1.5 mSv. According to the dose distribution data, about 305 of the monitored workers received doses higher than 1 mSv and 15 of them received doses higher than 15 mSv. By following the radiation protection principle of As Low As Reasonably Achievable (ALARA), the effort is to further decrease the average individual doses [7], through training and effective radiation protection program. The disastrous accidents involving both the occupationally exposed persons and the members of public tilt the scale. This can be eliminated. One key step is to eradicate 'Orphan sources' and increase the public alertness. Governments or Technical service organizations with the responsibility of radiation safety should design tools to establish link with the members of public; through brochures, seminars or media announcements. The radiography companies should ensure that gamma radiography sources are kept under proper control from the time they are received, throughout their working life and until final return to the supplier after the use. This implies that the radioactive sources could be secured from theft or malicious acts.

The important lessons to remember at all times are;

a) Radiation protection rules are strictly adhered to

b) Abundant supervision of radiographers and radiography work exists

c) All categories of staff are adequately trained and retrained periodically

d) The members of public are well informed.

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