A Study of dose Distribution and Radiation Protection in Industrial Radiography in Ireland

L. Currivan, J. T. Duffy, D. Spain and D. Pollard
Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Clonskeagh Road, Dublin 14, Ireland. E-mail: rpii@rpii.ie

Abstract
This study was undertaken to review occupational radiation safety in industrial radiography undertaken on site and at fixed facilities in Ireland. Industrial radiography has already been identified as the work practice which gives rise to the highest occupational doses in Ireland. In this paper the distribution of doses to industrial radiographers is analysed and an evaluation of operational procedures employed is presented. The regulatory infrastructure in Ireland is described and experience from regulatory inspections and recent incidents is discussed.

Compliance with national regulations and license conditions is audited by the regulatory authority during inspections of site and fixed radiography facilities. In the course of inspections many aspects of radiation safety are audited including: operational controls, demarcation of controlled area, dose rate at the barrier, availability of survey meter and dosimeters, training in emergency procedures and compliance with IAEA transportation regulations.

Based on personnel monitoring results, from 1996 to 2002, radiography staff involved in routine operations received wholebody doses ranging from 0.1 to 9.4 mSv/year. One worker received a dose of 36 mSv in 1998 as a result of an accidental overexposure, as compared with the 20 mSv annual limit for exposed workers. Analysis of the data shows that the majority of industrial radiographers, approximately 91%, receive less than 1mSv/y. Approximately 5% receive greater than 2mSv.

Introduction
This study has been conducted by the Radiological Protection Institute of Ireland (RPII) to review the radiation safety practices at fixed and site radiography facilities and to examine the dose distribution to the workers involved [1]. The RPII is the national organization with regulatory, monitoring and advisory responsibilities in matters pertaining to ionizing radiation. The role of the RPII is, through its Regulatory Service, to implement a system of licensing and inspection so as to ensure that the risks associated with ionizing radiation are kept to a minimum. In addition to its regulatory function the RPII also provides an approved dosimetry service for assessing doses from occupational exposure to ionizing radiation.

Industrial radiography is an important tool for non-destructive testing (NDT). Applications include weld inspection on oil and gas pipelines, detection of flaws in aircraft components and power plants as well as in chemical and petrochemical production sites. Where practicable, radiography is expected to be undertaken in dedicated facilities in which effective engineering controls, safety and warning systems are installed. However, this is not always possible and radiography carried out in situ is known as site radiography. Site radiography is one of the few occasions that large radiation sources are used in areas, which can be accessed by others and where effective engineering controls are not always practical and so where there is significant reliance on safe working practices to ensure protection of workers and the public. Possibly for this reason, a significant number of industrial radiography incidents have been reported worldwide, in which persons affected were not only those directly connected with the activity but also members of the population involved by chance [2]. Figure 1 and 2 illustrates assembled radiographic equipment for both fixed and site radiography.
Regulatory Infrastructure

The RPII is the national competent authority for control of the use, custody and transportation of sources of ionizing radiation. The RPII was established under the Radiological Protection Act, 1991[3], which establishes the legal basis for radiation protection in Ireland. The Radiological Protection Act, 1991 (Ionising Radiation) Order, 2000 [4], hereafter referred to as the Ionizing Radiation Order, implements into Irish Law the provisions of Council Directive 96/29/Euratom laying down the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation [5]. Users of radioactive sources must also comply with regulations covering transport and shipping as set out in Council Regulation (Euratom) No. 1493/93 of 1993 [6] and the relevant national transport regulations as set out in Statutory Instruments No. 6 and No. 492 of 2001 [7,8].

The Ionizing Radiation Order requires that defined practices involving the use, custody, or transportation of sources of ionizing radiation may only be carried out in accordance with a license issued by the RPII unless certain conditions for exemption are met. The RPII issues licenses covering a broad range of applications, with 18 licenses (representing approximately 1.5% of the total) issued to NDT undertakings involved in fixed and site radiography. These undertakings predominantly use directional x-ray, panoramic x-ray, iridium-192 with one company using selenium-75 sources. Apart from the typical industrial applications of NDT, one of the licensees is a museum and uses an industrial x-ray unit for examination of paintings and artefacts in a dedicated facility.
In Ireland, industrial radiographers are considered to be exposed workers as they are liable to exceed 1mSv per year in the course of their work. Undertakings are required to classify as a Category A worker an exposed worker who is liable to receive an effective dose greater than 6 mSv in a period of 12 months. All other exposed workers are categorised as category B. Currently all industrial radiographers operating in Ireland are classified by their employer as Category B workers. However, in practice many undertakings afford these workers the same level of protection as if they were Category A.

Applications for a new licence and/or licence renewal must include radiation safety procedures and a risk assessment as appropriate. The risk assessment is designed to identify the hazards, the severity of the risks and the control measures needed to reduce the risks from exposure to ionizing radiation. These documents must address all issues associated with the practice including where relevant, the safe transport of radioactive material. The RPII Regulatory Service has compiled guidance notes for use by licensees to assist in the completion of radiation safety procedures [9] and a risk assessment [10].

A licence issued for the custody, use and transportation of radioactive material includes a range of licence conditions, with which the user is legally obliged to comply [11]. General conditions relate to administrative items, design of radiological installations, dosimetry reporting levels, acquisition of sources, operational controls, maintenance, quality control, return or other disposal of sources, special precautions for disused licensed items, transportation and record keeping.

In addition to the above, the licence conditions for holders of industrial radiography licenses will include the following specific operational controls:

1. Radiography may only be undertaken by those radiographers listed in the licence, or by assistant radiographers provided that they are under the direct supervision of one of the listed radiographers.
2. A radiographer shall be at all times in attendance while site radiography is being carried out. That area where the dose rate exceeds 0.0025 mSv/h shall be suitably demarcated unless it can be shown that annual doses to non-occupationally exposed persons will not exceed the levels specified in the licence.
3. During radiography, a survey meter must be used to check that dose rates in all directions are demarcated as specified above. The survey meter must also be used to confirm that a radioactive source has been returned to its container.
4. (i) All radiographers and assistant radiographers shall be provided with, and during radiography operations shall wear, a direct reading pocket dosimeter. Such dosimeters shall be checked, at intervals not to exceed one year, for correct response to radiation. Acceptable dosimeters shall read within 30% of the true radiation dose. A record shall be kept of all such checks.
   (ii) Pocket dosimeters, when worn, shall be read and doses recorded daily. If a dosimeter is discharged beyond its range, that person’s personal dosimeter shall be sent for immediate processing. The person concerned shall not be permitted to be directly involved in work involving radiation until the magnitude of the possible exposure has been evaluated and its implications assessed.

**Training Requirements for industrial radiographers in Ireland**

In Ireland undertakings are legally obliged to inform exposed workers in relation to health risks involved in their work and to ensure that sufficient and appropriate training in the field of radiation protection is provided for workers and apprentices. Radiography staff are listed
on a schedule attached to the RPII licence and are required to have current certificates for radiographic testing and radiation safety. These can be obtained from the Irish Institute of Welding and Engineering Inspection (IIWEI) scheme for the certification of NDT personnel known as Certification of Inspection Personnel (CIP). This scheme is similar to the scheme approved by the British Institute of NDT, known as Personnel Certification Non-destructive scheme (PCN). The American Society for Non-destructive Testing (ASNT) scheme is also recognised. Staff from the Radiological Protection Institute of Ireland contribute to the NDT radiation safety courses organised by the IIWEI.

**RPII Inspection Programme**

The inspection programme is designed to monitor compliance with regulations and to ensure that risks to workers and the public are kept to a minimum. In as far as practicable those licensees where the greatest radiological risks exist are inspected most frequently. Inspections are safety-focused and where practical, sources were inspected while in use, in keeping with the recommendation of the IAEA Peer Review Mission in November 2000 [12]. Standard inspection audit forms are used as a guide for the inspector and a summary report is issued following an inspection. This report directs the licensee to carry out any necessary corrective actions arising from the inspection within a specified timeframe. Compliance with licence conditions and operational controls is audited during inspections of site and fixed radiography facilities. Licences are currently issued for a 12 month period and inspections are undertaken approximately every 12 to 18 months.

**Personnel Monitoring**

Occupational doses presented in this study are based thermoluminescent dosimetry carried out using dosimeters by supplied by the RPII Dosimetry Service. The TLD results are evaluated and compared with annual dose limits for workers, which are set by the Ionizing Radiation Order. The annual wholebody dose limit in Ireland is 20 mSv for adult workers and 1 mSv for members of the public.

**Results and Discussions**

**Inspection findings**

The experience of inspections has shown that in general undertakings in Ireland involved in the practice of industrial radiography implement good work practices. Radiographic facilities are designed and constructed to ensure maximum safety and have suitable interlocks, warning lights and signs. With the increased health and safety culture adopted by Irish industry in recent years, the level of safety awareness of industrial radiographers has improved. The presence of safety statements, mission statements, personal protective equipment, permits to work, health and safety audits are now the norm.

Where items requiring attention are identified during inspections it has been found that these are dealt with in a timely manner. Items typically identified, many of which are administrative in nature, include failure to:

- have up to date radiation safety procedures and risk assessment,
- inform the local authority fire officer of the presence and location of radioactive sources,
- complete the relevant shipping declaration form as outlined in Council Regulation (Euratom) No. 1493/93 of 1993,
- carry out a radiation survey of fixed radiographic installations, x-ray bays etc. on a regular basis,
- inform the RPII Regulatory Service of changes to inventory and radiography personnel,
f) ensure that radiation monitoring equipment is in calibration,
g) wear direct reading pocket dosimeters or electronic dosimeters,
h) store TLDs in low radiation background area when not in use,
i) provide adequate policing of barriers around work areas.

_Dose Distribution - Routine Operations_

In site radiography, the working conditions are such that some routine exposure is expected. Radiographers receive most of their exposure in the execution of the step by step procedure of industrial radiography in particular when they get close to the gamma-emitting radioactive source in its shielded or unshielded position.

The results of the TLD based personnel monitoring for routine conditions are presented in Figure 3. It should be noted that Figure 3 does not include data for accidental overexposures. Between 1996 and 2002 the estimated measurable whole body doses to industrial radiography staff in routine conditions range from 0.1 to 9.4 mSv/year. It can be noted that the highest annual exposure received as a result of routine operations over the period is below the annual limit of 20mSv. Approximately 75% of the doses recorded were below the minimum reporting level of 0.1mSv. Analysis of the data shows that the majority of industrial radiographers, approximately 91%, receive less than 1mSv/y. The average annual effective dose to measurably exposed workers in industrial radiography in Ireland during the period 1996 to 2002 was 1.2 mSv. The most recently available comparable worldwide data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is 3.2 mSv/year for the period 1990 to 1994 [13]. The average exposure to industrial radiographers in Ireland during this period was 1.58 mSv/year.

It is the policy of the RPII Dosimetry Service to write to employers if any recorded dose exceeds 2 mSv for a 16 week period. The employer is informed immediately of the dose and is requested to investigate incident and to report the outcome of such investigation to the RPII Regulatory Service. The number of such notifications issued during 1999, 2000, 2001 and 2002 were respectively 14, 26, 9 and 19. It is found that, in the main, these exposures were due to prolonged working with radiation sources or mistakes by operators. It is considered that this system of rapid notification is an important measure, which contributes towards keeping exposures low.
Dose Distribution - Unusual Occurrences

Worldwide industrial radiography accounts for approximately 50% of all reported radiation incidents [14]. A number of reasons for this high incident rate are commonly reported including:

- Failure to follow operational procedures (the most common of these where staff do not adhere to their radiation safety procedures),
- Inadequate training of the staff involved,
- Inadequate maintenance, equipment malfunction or defects resulting in equipment failure,
- Human error, often due to workload, inadequate time schedule or inhospitable work conditions,
- Inadequate regulatory control,
- Damage to equipment due to an accident.

Seven incidents involving licensed industrial radiography undertakings have been reported to the RPII Regulatory Service since 1992. The data show that these were mainly caused by loss of licensed items, breach of controlled areas, lack of warning signs on vehicles and equipment failure.

The most significant incident occurred in March 1998 when an industrial radiographer received a wholebody dose of 36mSv [15]. The accidental exposure occurred when the guide-tube, through which the radiographic source travels between its shielded container and the structure being radiographed, was distorted preventing the source from returning to its container. The radiographer involved in the retrieval of the source used a mobile ‘cherry picker’ type lift to manoeuvre himself close enough to repair the damage. The lift malfunctioned leaving the radiographer stranded close to the source. It took a number of minutes to get the lift to work again and during this time the radiographer received the dose.

Conclusions and Recommendations

- This work supports earlier studies which show that on average industrial radiographers in Ireland receive higher occupational exposure than other workers and as a group receive approximately twice the annual average wholebody dose of the next most exposed group [1]. Close monitoring and control of these workers is, therefore, warranted.
- Improved safety culture adopted by Irish industry generally in recent years has been reflected in improved standards in industrial radiography. While a number of items
requiring attention by licensees have been identified during inspections the majority are administrative in nature and of no radiological significance.

- It is important that licence conditions are periodically reviewed taking into account experience from inspections and reported incidents so as to ensure that they continue to protect exposed workers as well as members of the public adequately.
- Hiring and maintaining a well-trained workforce and encouraging good work practice should ensure the protection of exposed workers and members of the public from exposure to ionizing radiation above dose limits.

References


[6] Council Regulation (Euratom) No. 1493/93 of 8 June 1993 on Shipments of Radioactive Sources between Member States


