

**ACCIDENTS IN INDUSTRIAL RADIOGRAPHY AND LESSONS TO BE LEARNED - A REVIEW OF IAEA SAFETY REPORT.**

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**Abstract**

*This IAEA Safety Report Series publication is the result of a review of a large selection of accidents in industrial radiography which Regulatory Authorities, professional associations and scientific journals have reported. The review's objective was to draw lessons from the initiating events of the accidents, contributing factors and the consequences. A small, representative selection of accident descriptions is used to illustrate the primary causes of radiography accidents and a set of recommendations to prevent recurrence of such accidents or to mitigate the consequences of those that do occur is provided. By far the most common primary cause of over-exposure was "Failure to follow operational procedures" and specifically failure to perform radiation monitoring to locate the position of the source. The information in the Safety Report is intended for use by Regulatory Authorities, operating organizations, workers, manufacturers and client organizations having responsibilities for radiation protection and safety in industrial radiography.*

**1. Introduction**

The application of industrial radiography grew rapidly after the 1940s. Safety Standards vary and even though there has been significant improvement in the Regulatory Authority's radiation protection infrastructure in some IAEA Member States, overexposures and fatalities still occur. The dose rates that prevail close to a source or a device may be high enough to cause overexposure of extremities in a matter of seconds which may result in the loss of a limb. Whole body exposures resulting in a fatality are rare, but they have occurred when sources have been mishandled or have been in the possession of members of the public.

Industrial radiography accounts for approximately half of all reported accidents for the nuclear related industry, in both developed and developing countries. These accidents are primarily known to the small number of countries that have the regulatory infrastructure necessary to collect information and draw the benefits from the lessons learned. By studying the circumstances of each accident and the apparent deficiencies in safety, the regulatory system, the design and personnel performance, several measures can be identified which, if implemented, would improve safety performance in industrial radiography. There is a need to disseminate such knowledge gained and the lessons learned from these accidents, especially to those countries where the radiation safety infrastructure is weak or non-existent, so that others may benefit from the experience and implement the necessary changes in their regulatory, (licensing, inspection and enforcement ) procedures and operational radiation protection.

The International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (the BSS) establish basic requirements for protection against the risks associated with exposure to ionizing radiation and for the safety of radiation sources that may

deliver such exposure [1]. The BSS [Appendix IV.21], requires that, registrants and licensees shall be prepared to take any necessary action for responding to and correcting any reasonably foreseeable operating mishap or accident that could involve a source. On radiation emergency preparedness planning and response, the IAEA has issued several documents giving detailed guidance for responding to accidents with radiation sources [2-3] documents .

In order that all those involved in the manufacture, supply, use and regulatory control of radiation sources may learn lessons from accidents with an objective to reduce as far as possible the magnitude and likelihood of accidents, the BSS [IV.18-20] includes the following requirements;

“Registrants and licensees shall conduct formal investigations as specified by the Regulatory Authority if:

- a) a quantity or operating parameter related to protection or safety exceeds an investigation level or is outside the stipulated range of operating conditions; or
- b) any equipment failure, accident, error, mishap or other unusual event or circumstance occurs which has the potential for causing a quantity to exceed any relevant limit or operating restriction.

The investigation shall be conducted as soon as possible after the event and a written report produced on its cause, with a verification or determination of any doses received or committed and recommendations for preventing the recurrence of similar events.

A summary report of any formal investigation relating to events prescribed by the Regulatory Authority, including exposures greater than a dose limit, shall be communicated to the Regulatory Authority as soon as possible and to other parties as appropriate.”

The IAEA has investigated and published reports including lessons learned , of some accidents with radiation sources [4-8]. Guidance for the safe design, procedural control and operation of industrial radiography equipment is contained in the IAEA Safety Report Series on practical radiation safety [9-11].

## **2. Scope and structure of the safety report**

The Safety Report is the result of a review of a large selection of accidents in industrial radiography. The review's objective was to draw lessons from the initiating events of the accidents, contributing factors, the consequences and remedial actions taken. Section 2 contains an overview of scenarios of forty-three selected accidents, categorized by causes and analyzed for initiating and contributing causes. Lessons to be learned are discussed in Section 3. Section 4 gives a list of suggested preventive and remedial actions which if applied may prevent the recurrence of such accidents or mitigate the consequences of those that do occur. In the annexes, additional practical information is provided, i.e. such as details of basic training programme, and a glossary of terms.

### **2.1. Primary causes of reported accidents**

Despite advances in equipment design and improved safety systems, accidents continue to occur owing to many factors: primarily failures to adhere to procedures and occasionally inadequate regulatory control. Several of the more severe accidents illustrate the consequences of failure to establish adequate human, procedural and equipment controls. One or more factors may combine to cause an accident. These may include an initiating event and many contributory factors. Attempts have been made to categorize the accidents by the primary causes. These are:

- failure to follow operational procedures;
- inadequate training;
- inadequate regulatory control;
- inadequate maintenance;
- human error;
- equipment malfunction and defect;
- design flaw;
- wilful violation.

An accident description and measures to prevent or mitigate the consequences of similar accidents are given under each of the above categories for illustration.

## **2.2 Failure to follow operational procedures**

*Failure to follow operational procedures, including the requirements of a Regulatory Authority, is a primary or contributory cause in the majority of accidents. This problem is seen across the entire cross-section of workers, from the most senior and well trained, who may become complacent, to the less experienced and untrained.*

## **2.3 Inadequate training**

The second most common cause of reported accidents is inadequacy of training, which includes ineffective initial and refresher training programme. This also includes unqualified personnel such as radiographer assistants working without supervision.

## **2.4 Inadequate regulatory control**

A primary cause of accidents is inadequate regulatory control. This may be due to an ineffective Regulatory Authority or it may be that no radiation protection infrastructure has been established. Effective regulatory control by a system of authorizations is essential to establish standards for the possession, use and disposal of radioactive materials and the possession and use of X ray generating machines. These authorizations are intended to ensure that personnel are trained, that proper equipment in good working condition is used and that written procedures incorporating radiation protection and safety considerations are in place.

Where there is inadequate regulatory control, reporting procedures and data collection are commonly inadequate.

## **2.5 Inadequate maintenance**

Numerous events are caused by inadequate inspection and maintenance of radiographic, ancillary and safety equipment. Failure to meet the manufacturer's recommended level of maintenance may result in wear, damage and breakdown of essential components. An inspection of equipment prior to its use will detect unsafe conditions such as loose fittings and crushed guide tubes. These should be corrected prior to performing radiography.

## **2.6 Human error**

Even if equipment is operating properly and effective operating procedures are established, the safe operation of radiographic equipment relies heavily on the radiographers' judgement and response. The probability of human error increases during work under adverse and stressful conditions, such as of fatigue caused by night work, low light and high noise environments, production pressures and physical exertion. *The probability of human error may also increase with substance use, misuse or abuse.*

## **2.7 Equipment malfunction/defect**

Although manufacturing defects are not common, they do occasionally occur. In addition malfunctions can occur as a result of the conditions of use.

## **2.8. Design flaw**

Although design flaws are not common, they do occasionally occur. Design changes result from field experience and from ongoing development by the manufacturers, users and Regulatory Authorities.

## **2.9. Wilful violation**

Training, equipment design and implementation of effective operating procedures cannot stop an individual from deliberately violating safety procedures. The probability of these deliberate acts increases when working, under stressful conditions due to substance abuse, fatigue, economic factors, production pressures or physical exertion. Wilful violations are more likely to occur in operating organizations where there is no strong safety culture.

## **3. Conclusion**

A very important way of reducing potential exposures in the use of ionizing radiation is the prevention of accidents and mitigation of the consequences. To do this, it is necessary to feed back operating experience in both normal and abnormal situations. Accidents and incidents in the workplace must be formally investigated and documented. Others can then benefit from the lessons learned. The intended readership for this IAEA Safety Report include operators of industrial radiography equipment, management of operating organization, regulatory authority personnel, manufacturers of radiography equipment and clients of industrial radiography.

## **4. References**

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