CHAPTER 7

CONCLUSION AND FUTURE WORK

CHAPTER OVERVIEW

Malfunctioning or failure of radiography devices or operational failures may lead to accidents, and sometimes to serious ones. This chapter presents a summary of the research work carried out by us for design and operation based analysis and risk assessment of industrial radiography practice in India. Very limited studies have been carried out for prospective risk assessment in the non-nuclear radiation facilities including industrial radiography. The current design of the radiography devices have been evaluated thoroughly and risk assessment has been carried out by us using the Failure Modes and Effect Analysis (FMEA) method. This method identified all the possible failure modes of gamma radiography devices and ranked them based on the criticality, which was determined by calculating the 'risk priority numbers'. While the operational risk assessment has been carried out by us using the Probabilistic Safety Assessment (PSA) method, for which two different scenarios of open field radiography and enclosed radiography operations were considered in our analysis. In this an event tree was modelled to calculate the probability of potential exposure of ionizing radiation to the operating personnel. This study identifies the factors which contribute to the potential exposure scenarios, along with their relative contributions. Limitations of present research work have been outlined in this chapter. We have suggested recommendations for future work in this chapter for risk assessment of non-nuclear radiation facilities, especially for industrial radiography practice.

7.1 SUMMARY AND CONCLUSION

Industrial gamma radiography is an important Non-Destructive Testing method that is practised in several important industries to detect the presence of defects or flaws during the manufacturing processes or during operations of various metallic jobs used in industries like pressure vessels, boilers, piping etc.

Industrial radiography of these vessels is carried out using gamma radiation emitting sources, like Ir-192 and Co-60, which pose serious health hazards in case of any incidents/accidents. The mentioned radioactive sources are housed inside the devices called the Industrial Gamma Radiography Exposure Devices (IGRED), which provide shielding from the hazardous gamma radiation when not in use. Currently, about 2700 such devices are being operated in India by 554 service provider institutions. These devices are operated manually by the operators, by moving the radioactive sources "in" and "out" of the devices for exposing them for radiography. Several such exposures are repeated on each working day. A device failure or human error during an operation of these devices may lead to serious outcomes in terms of radiation exposure to the operating personnel. In the case of a severe accident, radiation exposure from such sources may cause permanent loss of limbs or similar other health hazard. Accidents have been reported in India, and internationally too, in industrial radiography practice that use gamma sources. This necessitates risk assessment in current industrial radiography practice followed in India. We have carried out design and operation based analysis and risk assessment of industrial radiography practice in India. The results from our study would be helpful for risk management in the radiography practice, by allowing for efficient allocation of the available resources to the identified risk prone areas. It may be noted that very limited number of studies have been published in the literature for prospective risk assessment in the industrial radiography practice.

Our present research work for risk assessment in the design and operation of industrial gamma radiography exposure devices has been carried out to identify the areas which require interventions or improvements to enhance the overall radiation safety in the industrial radiography practice in India.

We have carried out the risk assessment for the design aspects of the IGREDs by using the Failure Modes & Effect Analysis (FMEA) methodology. Our study identifies and analyses all the possible failures of the device at its basic component level. Results of FMEA are represented in terms of Risk Priority Numbers (RPN) of the failure. A higher value of RPN represents more critical failure and hence indicates higher risk involved. Our FMEA results show that none of the associated failure modes has RPN higher than 500, for whom urgent design corrections are required. This fact reflects that the existing design of IGREDs is robust and the probability of severe accidents is reasonably low. However, six of the failure modes of the exposure device have been found in our study to have RPNs in the range of 100 to 500, for which corrective actions need to be recommended. Although these failures are not very severe in nature, such failures cannot be ignored from the viewpoint of radiation safety. Our results show that the detection probability (D) of these failures, is very small. This tells that although the accident consequences from these failures may not be very severe it is difficult to identify the failure before an actual accident occurs. This fact contributes to increased risk priority numbers being assigned to these six failure modes.

These above mentioned failures are, internal damages to the source projection guide tube and to the control unit of the projection sheath. It is not possible for the operators to examine the inner condition of the sheath and also the severity of this failure, if occurred, would be high. The other important failures are, the damage to the crimping parts of the metallic radioactive source assembly. The damage to the crimping part does not happen in one shot. Once the damage starts, it would take significant time to manifest the failure. However, even then practically it is not possible to see or realize the damage until a complete failure occurs. Thus though the occurrence rate of this failure is low, but the severity of effects of this failure is very high, and hence, the risk priority number of the failure is high. We have recommended corrective actions like interventions in the design and adopting QA protocols to reduce the risk priority numbers of these failures, and hence, increase the radiation safety of the operating personnel. The other failures identified in our study have risk priority numbers less than 100, which keeps them in the acceptable category.

The role of radiation monitoring instruments is very crucial in industrial radiography operations. A radiological survey using these instrument is the only method to confirm safe retrieval of the radioactive source into the device. However, these instruments have various electronic components, which may fail during radiography operations. We have carried out reliability assessment against failure of these instruments (portable radiation survey meters and fixed zone monitors) by using the fault tree analysis method. We obtained failure rates of 2.253E-5 and 6.011E-3 per hour, for the portable survey meter and the fixed area monitor respectively, in our study. The corresponding probabilities for unavailability of these instruments when required, as calculated from the above mentioned failure rates are 1.126 E-6 and 1.001E-3, for the portable survey meter and the fixed area monitors respectively. Thus, the failure rates of portable radiation survey meters (RSM) is less than that of the fixed zone monitors. We recommend use of both of these mentioned instruments in the enclosed radiography operations, and insist that the use of RSM should not be neglected because of the presence of fixed area monitors in the enclosures.

In addition to the design aspects of the device, its operational aspects are also equally important for the safety assessment of the radiography practice. Accidents may occur during operations of even fail-proof devices, if the operational procedures are not correctly followed. Several accidents have been reported due to operational error or negligence of the operators [1]. We have carried out risk assessment for the operational aspect of IGREDs in India too, using the Probabilistic Safety Assessment (PSA) methodology. For this we have done Event trees modelling for industrial radiography practice for both, the open field and the enclosed radiography operations. The primary objective of this modelling was to obtain the probabilities of potential exposures to ionizing radiation for the operating personnel, and to identify the factors/events which contribute significantly to these potential exposure scenarios. Our present study also calculates the relative contribution of these identified factors/events. The data for our event tree modelling were generated by the expert elicitation method. For this, two rounds of Delphi survey were conducted among the radiological safety officers working in industrial radiography institutions of India.

In our study, the probabilities of the most severe category of potential exposure to ionizing radiation (PE-III), that may cause deterministic health effects (like radiation injury) have been calculated to be as 3.506E-04 and 1.293E-04 for open field radiography and enclosed radiography operations respectively. Our results clearly indicate that industrial radiography operations performed inside enclosures have reduced probability of potential exposures as compared to the radiography operations in open field. We have also calculated the probabilities of other categories of potential exposures and for the normal occupational exposures in our study. Our results show that an industrial gamma radiography personnel in India receives normal occupational exposures in 89.68% and 93.1 % cases in the open field and enclosed radiography respectively, whereas the total probability of all types of potential exposures has been estimated in our study as 9.0 % and 5.6% for open field and enclosed radiography operations respectively.

In our study we have found that the most important contributory factors which lead to the potential exposure or accidental scenarios are, the unsupervised operation of radiography devices by an untrained person (or trainee) and the occurrence of not using radiation survey meters for radiation monitoring during these operations. Thus, supervision of a trainee, when he attempts to operate the device is essential. The trainee should operate the device only under physical observation of a Radiological Safety Officer (RSO) or a certified radiographer. We recommend, based on the results of our study that on-site training of the trainee (or untrained person) about the safe operation of device and familiarization about the radiation survey instruments should be emphasized in the respective institutions.

We recommend, based on our results, that the operator adopt the practice of using radiation survey meters, especially before and after starting the exposure, a practice which is sometimes ignored due to overconfidence of the operators. Similarly, we analysed several failures in the radiography devices in our study, which occur due to inadequate knowledge and improper training of the operators about the operational procedures and the handling of the radiography devices. We believe that the RSO can play an important role in training the operating team members about the safety aspects, which would significantly reduce the probability of potential exposures. We have identified other contributing factors too and have accordingly made recommendations for risk management in the operation of the radiography devices.

As mentioned earlier in this thesis, limited number of studies for prospective risk assessment in the industrial radiography practice have been attempted previously. This present study of ours is useful, besides giving some very relevant and important results, in establishing the feasibility of application of risk assessment methodologies of FMEA and PSA, using Event Tree Analysis and Fault Tree Analysis, for industrial radiography practice. The present study is helpful in learning about the necessary interventions required for safe operations of the radiography devices, and hence, for risk management associated with both, the design and the operation based failures in industrial radiography practice in India. These recommendations should be implemented by the radiography institutions to enhance the overall safety in this practice.

We firmly believe that the results from our present study would provide important and useful inputs for enhancing safety to the organizations operating as well as manufacturing the IGREDs. The results from our present study also provides important inputs to radiation safety regulators, which would be helpful in framing the policies for radiation safety of the occupational workers in this practice.

7.2 LIMITATIONS OF THE STUDY

We considered a wide scope for our study on risk assessment in industrial radiography practice in India, and covered all the relevant aspects of the practice. We have analysed in detail the design based failures as well as the operational failures for our risk assessment study. However, the scope of this study is still limited to the radiography operations that use gamma–ray sources. The radiography equipment which uses X-ray for radiography is excluded from our present study. The design, the working principle and the operation of a X-ray based equipment are entirely different from that of the gamma-ray based equipment. Therefore, the risk assessment of X-ray based radiography practice requires another independent study. It may be noted that currently, the contribution of X-ray based devices is only about 10 % in the radiography operations in India.

The data used in this study have been generated for the Indian scenario, which may be specific to our country only. For example, the behaviour of the operator, the ambient atmosphere where the device is operated, the workload etc. may differ from country to country. Therefore, a few findings may differ for industrial radiography practice in other countries, especially the results related to the operational aspects of the practice.

7.3 SCOPE FOR FUTURE WORK

Our present study on risk assessment is exploratory in nature and no such work has been published in the literature for industrial radiography practice. The risk assessment in our study has been carried out using the FMEA and the PSA methodologies. There exists a lot of scope for future work in this field. In this regard, the following are some of the recommendations for future work:

I. Identification of initiating events for modelling of accident progression has always been a crucial task for risk assessment studies. In the present FMEA study, the possible failure modes have been found and ranked based on their criticality. Important and severe failure modes identified in this study can be utilized as initiating events for scenario development, to carry out further risk assessment studies in industrial radiography practice.

II. The ranking methodology used for conventional FMEA technique has a few reported disadvantages, like it is difficult for experts to convert the field data to the precise numerical value of occurrence (O), severity (S) and detection (D) rankings. The present FMEA study may be extended using a suitable methodology like fuzzy logic to convert the O, S and D rankings to precise and crisp values.

III. Limited studies have been carried out till date using probabilistic safety assessment for non-nuclear radiation facilities. This is mainly due to unavailability of data required for event tree and fault tree assessment. The present study has been carried out by using data generated by an expert elicitation method. The other mechanism can be developed to collect field data which are essential for such assessments over a period of time. The PSA studies for the scenarios presented in our work are recommended, while using the data collected by alternate sources/methods.

IV. The recommendations made through this study may be implemented in some of the selected industrial radiography institutions, and this study may be repeated after a specific observational period, to analyse the effectiveness of our recommendations to reduce the identified risks in the industrial radiography practice in India.

V. Risk analysis in industrial radiography practice may be carried out using alternative risk assessment methods. Such studies would be helpful for inter-comparison of the results. Further, the methodology used in our present study can also be applied for risk assessment in other areas of applications of radioisotopes, such as the nucleonic control systems, the gamma irradiation chambers, well logging practice etc., which are still unexplored for risk assessment studies.
