EXECUTIVE SUMMARY

Radioactive sources are being used worldwide for various peaceful purposes such as power generation and medical, industrial & research applications. Industrial radiography is an important nondestructive technique to detect the presence of any flaw or cracks in the industrial pressure vessels, boilers or piping transporting hydrocarbons. These pressure vessels and boilers are subject to extreme dangers of explosion as these are operated at high pressures. Hence, to reduce the associated risks of such explosions, radiography inspections are carried out during manufacturing of these vessels and at regular periodicity during operational life of the vessel. It may be noted that during radiography testing, the physical and chemical properties of the vessels do not change.

There are 554 industrial radiography institutions in India, which operate about 2700 radiography devices. Most of these radiography institutions are service providers. Industrial radiography is carried out using radioactive sources like Ir-192, Co-60, Se-75 etc. These radioactive sources continuously emit high energy gamma radiations. The ionizing gamma radiation has the capability to create mutations and damage to cells in the biological system. Therefore, potential exposure to radiation will result in biological hazards to the human body, such as skin injury and amputation of extremities. The nature of hazard depends on the quantity of exposure received and on several other parameters. In the severest case, very high exposure may cause death of the person also.

Radiography devices are specifically operated by a trained operator (or radiographer) using manual operation procedure, by rotating the handle of the

remote control unit provided in the device. For each operation/exposure the radioactive source moves out of the shielded position and when the operation/exposure time is completed, the source is retracted back into the device by rotating the control unit in the reverse direction. During such operations, there is a possibility of the source getting stuck in the projection sheath, leading to an accidental exposure to the operator and team members.

Several accidents have been reported in the practice of industrial radiography in India, and internationally too. Most of these accidents are due to equipment failure or operational errors. Among all the non-nuclear applications of radioactive sources, the probability of accidents is relatively higher in the area of industrial radiography practice. Out of the total unusual occurrences/accidents reported in industrial applications of radiation, industrial radiography practice contributes about 54% of the total accidents. However, from the device point of view, industrial radiography contributes only about 21% of the total devices used in industrial applications of radiation. Also, the number of excessive-exposure cases reported for industrial radiography are maximum among those reported for all the industrial applications of ionizing radiation. This necessitates the requirement of an in-depth analysis and risk assessment in the industrial radiography practice, aimed to enhance the radiation safety in this practice. Risk assessment is the starting step for risk management in any existing practice. The prospective risk assessment studies are well established and accepted for nuclear facilities. However, such studies for the non-nuclear applications of radiation sources are very limited.

Bearing this background, the present study was conducted for risk analysis and assessment in the industrial radiography practice in India, for both, the safety components i.e. design of the radiography devices and for operational safety. Both these aspects have been analyzed in detail to identify the areas which require interventions for improvement of overall radiation safety in the practice. Failure Modes and Effects Analysis (FMEA) methodology has been utilized for design based risk assessment of industrial radiography devices. While, Operational risk

assessment has been carried out using the Probabilistic Safety Assessment (PSA) methodology.

Following are the major contributions from the present research:

i. In-depth analysis of the radiography operations has been carried out in selected practical scenarios in industrial radiography practice.

ii. Risk assessment study has been carried out and probabilities for radiation-exposure, which exceeds the prescribed dose limits or may lead to the deterministic health effect to operating personnel, have been evaluated. Probabilities of other exposure categories also have been determined.

iii. Factors, which affect the radiation safety in the operation of radiography devices with their relative contributions have been identified to provide inputs to enhance the radiation safety.

iv. In-depth study of the existing design of radiography devices has been carried out and all possible component failure modes of radiography devices have been identified and analyzed by risk assessment process. Risk Priority Numbers (RPN) for these failures have been calculated and failures have been ranked based on their criticality.

v. Recommendations for interventions in the design and operational procedures of industrial gamma radiography equipment have been made in this work, to reduce the accidents probability and radiation hazards in industrial radiography practice in India.

The present research work involves incorporation of various expertise from the field of industrial radiography, such as radiological safety officers from operating organizations, manufacturers & suppliers of the radiography devices, maintenance

personnel, and radiation safety regulators. Data required for the analysis was generated through various channels, such as conducting two rounds of Delphi survey, field inspections of industrial radiography devices and several meetings with various stakeholders.

The Probabilistic safety assessment result shows that an industrial radiography operating personnel in India receives normal occupational-exposures in 89.68% and 93.1 % cases, for open field and enclosed radiography operations respectively. The abnormal radiation exposure received, which is termed as potential exposure, varies depending on several factors. Probabilities for the category of most severe potential exposure to ionizing radiation (PE-III), which may cause deterministic health effects like radiation injury (in some of the cases) have been calculated as 3.506E-04 and 1.293E-04, for the open field radiography and enclosed radiography operations respectively. The principle contributing factors for such potential exposures are the unsupervised operation of radiography devices by an untrained person and 'unuse' of radiation survey meters for radiation monitoring during these operations.

The present work through the Failure Modes and Effect Analysis based risk assessment for the existing design of the radiography devices identifies six failure modes of the exposure device, which have risk priority numbers in the range of 100 to 500, where corrective actions are required to be recommended. The analysis, also shows that the detection probability of these failures before an actual failure occurs is very low. These failures are the internal damage, to the source projection guide tube and to the control unit projection sheath. It is not possible for the operating institution to examine the inner condition of this sheath even while the severity of this failure can be high. The other important failures are the damages to crimping parts of the metallic source assembly.

The present research work concludes with the identification of the various factors which contribute to the potential exposure scenarios, along with their relative contributions. The present study also recognizes the areas where interventions are

required in the design and operational procedures in the industrial radiography practice, and important recommendations have been made here to reduce the overall risk in the practice.

Results of this study provide important and useful inputs for operating organizations and manufacturers of the radiography devices for enhancing radiation safety. The study also provides inputs for the radiation safety regulators, which will be helpful for framing the policies for the radiation safety of the occupational workers.
