HERCA

HEADS OF THE EUROPEAN RADIOLOGICAL PROTECTION COMPETENT AUTHORITIES

HERCA Working group on Research and Industrial Sources and Practices

-

Feasibility of replacing radiography using radiation sources with less hazardous X-ray or non-ionising techniques

Information Paper

June 2021

This document has been approved by the Board of HERCA in October 2021

Authors: **WGRISP**

Title: **Feasibility of replacing radiography using radiation sources with less hazardous X-ray or non-ionising techniques**

Index

Information Paper on the feasibility of replacing radiography using radiation sources with less hazardous non-ionising techniques

Introduction

Several different techniques utilising ionising radiation can be used for industrial radiography. The most common ones involve the use of X-ray equipment or gamma sources including Ir-192, Se-75 and to a lesser extent Co-60. Both X-ray equipment and gamma sources can be used in a shielded enclosure or on site and their use in this regard depends mainly on the nature and geometry of the component to be tested. Different techniques have their advantages and disadvantages compared to others. For example, X-ray equipment is safer than an equipment using sources, but it cannot be used at some remote areas or other places where there is no electricity supply available. For some radiography techniques, sufficiently high radiation energy is necessary for obtaining sufficient penetration through the imaged object. Therefore, it may not be possible to replace a technique utilising a high energy radiation source with a less hazardous technique.

The use of different techniques may vary significantly between different countries within Europe depending on the type of industries where industrial radiography using ionising radiation sources is required. For example, some countries utilise radiography mostly in engineering works while some other may use it mainly in the oil and gas industry. The choice of techniques depends on several factors such as image type and quality preferences, radiation safety and security considerations, requirements of testing standards, practical requirements such the availability of a power supply in remote location(s) economical aspects and customary habits.

The security of radioactive sources has raised increasing concerns throughout the world during recent years. Unauthorized access to and use of radioactive sources could cause significant risks to people and the society. Some countries have already strengthened regulatory requirements regarding dangerous radioactive sources including industrial radiography sources, and many countries are in the phase of establishing such requirements. Implementation of appropriate security measures may be challenging, especially for mobile gamma equipment. In addition, mobile gamma equipment has been subject to several accidents reported world widely leading to significant radiation exposures of workers and others. One possible way to address these safety and security concerns would be to replace gamma radiography sources with X-ray equipment where this is possible.

Purpose of the questionnaire

The purpose of the questionnaire was to gather information from stakeholders from each participating country such as industrial radiography companies, regulators, manufacturers/suppliers, training providers and professional bodies representing the interests of the NDT sector. The questionnaire sought to gather information on the following:

- the different types of industrial radiography techniques used, i.e. gamma and/or X-ray in shielded enclosures and/or on-site.
- industry types where industrial radiography is carried out
- reasons for using gamma radiography techniques
- can gamma radiography techniques be replaced by X-ray and if not, what are the reasons for this
- can non-ionising radiation techniques replace techniques using ionising radiation and if not, what are the reasons for this

It is the intention to use this information as a background for further discussion with HERCA on possibly of replacing some gamma radiography techniques with X-ray equipment and furthermore to replace the use of ionising radiation sources with non-ionising techniques.

Stakeholder responses

Members of the HERCA Research and Industrial Sources and Practices working group sent this questionnaire to a number of various stakeholders in their respective countries. Responses were received from industrial radiography companies, manufacturers, professional associations, and training organisations. A total of 210 responses were received from 12 countries. The majority of the responses came from industrial radiography companies (approximately 90%) and hence the overall results of this survey should be viewed in this context.

Types of technique used

The most commonly used industrial radiography radiation type used was X-ray (50%) followed by Ir-192 (34%) and Se-75 (11%). A greater proportion of radiography work using X-ray and Ir-192 sources took place in shielded enclosures, however it should be noted that almost 50% of respondents indicated that X-ray and Ir-192 were used in both shielded enclosures and on-site. Se-75 is used to a much lesser extent than X-rays and Ir-192 and it is used more frequently for site radiography. As expected the use of Co-60 for industrial radiography is not very common.

Most common industry types utilising industrial radiography

Industrial radiography is carried out in a wide range of industries types including aerospace, oil and gas, engineering, energy sector, pharmaceutical and shipping. A number of responses did not state the industry but rather that industrial radiography was used for industrial maintenance/quality purposes. The most common industry sector utilising industrial radiography is “engineering”. This sector included areas such as general engineering, construction, component manufacturing, pressure vessel and storage tank manufacturing. The use of X-ray equipment in both shielded enclosures and on-site featured strongly in this sector as did on-site gamma radiography.

A significant proportion of the responses came from the oil and gas sector. The use of X-ray equipment and gamma sources were extensively used in this sector however, in many cases the technique (on-site or shielded enclosure) was not specified. The use of X-ray techniques was more prevalent in the shipping sector, however in many cases the question did not differentiate between site radiography and radiography in shielded enclosures. The use of X-rays was most common in the aerospace sector, whereas the pharmaceutical sector most frequently used gamma sources on-site.

Reasons for using Gamma Sources

The main reasons for using gamma sources instead of X-ray equipment for industrial radiography are given in Table 1 below. The ease of handling and flexibility of use (28% of responses) followed by no requirement for an electricity power supply (19% of responses) were the two most common reasons why gamma sources were preferred to X-ray equipment and these were the most common reasons given for almost all industry types. Some situations require the use of gamma sources due to their suitability for testing thicker and more complex welds and components (12% of responses). The use of gamma sources is preferable where space restrictions or accessibility to the component to be radiographed is limited and therefore may pose difficulties for using X-ray equipment. It is interesting to note that requirements of relevant standards and codes (2% of responses) and customer requirements (< 1% of responses) were not cited as significant reasons for using gamma sources instead of X-ray equipment.

Reasons for using gamma sources	**% of Responses**
Easier to operate and handle;	28
Power supply not required	19
More penetrating for greater thicknesses of component	12
Space restrictions/flexibility/accessibility	11
Used for physical and technical operation reasons	9

Table 1: Main reasons for using gamma sources for industrial radiography instead of X-ray equipment.

Physical or technical obstacles preventing the use of X-ray equipment instead of gamma sources

The physical and technical obstacles that prevent or hinder the use of X-ray equipment instead of gamma sources (Table 2) are broadly similar to the reasons given for using gamma sources in the first instance as detailed in the previous section of this document. The biggest concerns expressed by far with replacing sources with X-ray equipment are accessibility to components or areas to be radiographed (18 % of responses) followed by the bulky nature of X-ray equipment (16% of responses). X-ray equipment needs a power supply to operate (13% of responses) and this certainly hinders its suitability for use in remote locations. Other limitations such as the thickness of material that can be tested using X-ray equipment and radiographing items with complex geometries are common reasons why it may not be

possible to replace gamma sources with X-ray equipment. Image quality is also an issue and this may be linked to issues previously mentioned such as limitation on thickness and complex geometries. Image quality issues were of particular concern in the oil and gas industry. It is worth noting that issues such as cost, customer requirements and technical standards requiring the use of gamma sources did not feature prominently.

Physical/technical obstacles	% of responses
Accessibility of areas to be radiographed	18
Size and weight of equipment	16
Need Power supply	13
Limitation on thickness/geometries of material that can be radiographed	13
X-ray does not give the desired results (quality issues)	9

Table 2: Main physical and technical obstacles that would prevent the use of X-ray equipment instead of gamma sources.

Advantages and disadvantages if gamma sources are replaced by X-ray equipment

The main advantages cited in replacing gamma sources with X-ray equipment include greater radiation safety/less incidents and accidents (20% of responses), an improvement in image quality (16% of responses) and no inherent transport or security related issues (15 and 10 % of responses respectively). The absence of transport regulations featured prominently in the engineering, and oil and gas sectors, whereas the reduction in security related issues was the main reason given in the industrial maintenance/quality sector. Other notable advantages include a smaller regulatory burden, no sources to lose or source changeovers required and it is easier to deal with emergencies and incidents.

Regarding the disadvantages of replacing gamma sources with X-ray equipment, 24% of responses cited concerns that it may not be technically feasible to carry out certain tests arising from the thickness of material, geometry issues etc., followed by 19% of responses noting concerns with accessibility and the bulky nature of X-ray equipment. As expected the need for an electrical power supply for using X-ray equipment at remote locations was an issue noted by 13% of responses.

Additional Factors in replacing gamma sources with X-ray equipment

The questionnaire also sought views on any additional factors that should be considered in replacing gamma sources with X-ray equipment. Much of the issues highlighted were similar to those given in the previous sections. However, items of note include the additional expense/frequency of repairs with X-ray units, technical challenges for site radiography and the requirements for technical standards which may specify the use of gamma sources .

Other additional factors	**% of responses**
Not possible to perform all exposures with X-ray (inherent safety of plants etc will diminish)	26
Ease of Use	16
Technical standards may require gamma sources	13
Site radiography using X-ray equipment is rare and technically challenging	12
Maintenance/repairs (expense/frequency)	9

Table 3: Main additional factors that should be considered in replacing gamma sources with X-ray equipment.

Main reasons for using ionising radiation vs non-ionising radiation techniques

One of the most common reasons given for using ionising radiation techniques is that non-ionising radiation techniques do not give the desired results due to issues with the detection of some defects or some defects not being detected (18% of responses). In addition, there are some tests, for example, onstream radiography which cannot be replaced by non-ionising techniques. In addition, there is an expectation from customers for ionising radiation techniques to be used (18% of responses) and hence there may be a reluctance for some customers to accept the results from techniques that do not use ionising radiation. Many standards also specify the use of ionising radiation techniques and these would have to be changed before consideration could be given to using non-ionising techniques. Other factors favouring using ionising radiation techniques include lower costs, increased frequency of inspections, radiograph/image is available following the test and results that are easier to interpret.

Reason for using ionising radiation instead of non-ionising techniques	**% of responses**
Non-ionizing methods do not give desired results (poor detection of defects or defects not detected)	18
Customer Requirements/acceptance by the client	18
Industry requirements (standards/codes require ionising radiation tests)	12
Practical difficulties in using non-ionising techniques	8
Best technique for voluminous imperfections	7

Table 4: Main reasons given for using ionising radiation instead of non-ionising radiation techniques.

The most common physical or technical obstacles encountered from changing from ionising to non-ionising techniques are issues such as having appropriate tests for certain thicknesses of materials (ultrasound techniques cannot be used for materials less than 8 mm in thickness), difficulties in accessing components with complex geometries and certain material types such as composites and coarse-grained materials (42% of responses). Another significant technical obstacle is that codes and design/technical standards specify radiography using ionising radiation techniques which in effect rules out the use of non-ionising techniques. (23% of responses). Other issues to note for non-ionising radiation techniques include, increased cost, tests in general, are more difficult to carry out and the results of tests are more difficult to interpret.

Advantages and disadvantages of using non-ionising techniques

The most common advantages cited for using non-ionising radiation techniques were increase in safety of operators and members of the public as there is no radiation safety/protection issues (36% of responses). Security issues with ionising radiation sources is also a concern and these are eliminated by using non-ionising radiation techniques (11% of responses). The use of ionising radiation sources tends to be very bureaucratic from a licensing/inspection/transportation perspective and changing to non-ionising techniques would eliminate these requirements. This would also eliminate the need for radiological risk assessments and radiation safety procedures. In addition, the requirement to carryout radiography outside normal work hours would no longer apply. This is an important consideration for site radiography leading to much greater flexibility for both the client and the radiography company for planning and executing work.

Advantages	**% of responses**
No radiation doses	19
Increased safety	15
Less of a security risk	11
Less rules/ procedures/training for operators	10
No licensing/inspection requirements	7
No restrictions on when radiography could take place	7

Table 5: Main advantages of using non-ionising radiation techniques.

The main disadvantages associated with non-ionising techniques are technical/physical issues such as test limitations and the non-availability of specific test while this was an issue for all industry sectors, and particularly so for the engineering, and oil and gas sectors. The costs associated with non-ionising techniques in terms of equipment, inspection time and training was also a significant disadvantage with replacing ionising radiation techniques with non-ionising ones. To a lesser extent, standards which specify the use of ionising radiation techniques could act as a barrier for switching to non-ionising techniques. It is interesting to note that the availability of trained staff to carry out non-ionising radiation techniques where traditionally ionising radiation is used was cited as an additional factor which should be considered in this regard.

Disadvantages	% of responses
Cannot perform test or testing limitations	29
Cost of test and/or equipment	12
Inspection time would increase (cost issues)	11
Flaws in objects not detected (internal defects may not be detected)	10
Standards require tests with ionising radiation	6
Operator training Costs	6

Table 6: Main disadvantages of using non-ionising radiation techniques.

Main Findings

While each working group member distributed the questionnaire to relevant stakeholders in the respective country, the group with the highest representation by far was industrial radiography companies with approximately 90% of completed questionnaires coming from this sector. The conclusions summarized below are thus mainly the view of this sector of the industry, not the ones of their clients or the regulatory bodies.

This survey found that there was almost a 50:50 split in the use of X-ray equipment and radioactive sources for industrial radiography. Ir-192 was the most common source type used followed by Se-75 and Co-60 to a much lesser extent. X-ray equipment and Ir-192 sources were used more frequently in shielded enclosures, however a significant number of respondents cited the use of X-ray equipment and Ir-192 in both shielded enclosures and on-site.

The most common industry types represented in the survey was “engineering” sector followed by oil and gas, industrial maintenance/quality, shipping and aerospace.

One of the main questions that this survey sought to answer was whether it is possible to replace the use of gamma sources with X-ray equipment for industrial radiography. The results of the survey are clear in that replacing gamma sources with X-ray equipment would bring technical and logistical challenges. Many respondents noted that the use of X-ray equipment in remote locations with an available power supply would be impossible. X-ray equipment is also very bulky and not easy to handle and would therefore not be suitable for on-site use. The use of gamma radiography equipment is more suitable where space is limited and the accessibility to or the geometry of the component to be radiographed is complex. It was also noted that the use of gamma sources is required for thicker material making the use of X-ray equipment not technically feasible in certain situations. Standards and Codes may also require the use of gamma radiation sources and this was cited as a particular issue for the oils and gas industry. The cost implications of replacing gamma sources with X-ray equipment was also noted. There would be significant start-up costs in the purchase of X-ray equipment. Typically, a gamma radiation exposure device and source would cost approximately €15,000 to purchase compared to approximately €40,000 for a X-ray set. The main advantages cited in changing from gamma sources to X-ray devices are an increase in radiation safety, less significant incidents/accidents, lesser security concerns and no transport regulations to be concerned with However, it does appear that, in the view of the industrial radiography professionals surveyed, the technical and logistical challenges posed by

changing from gamma sources to X-ray devices outweigh advantages gained in switching to X-ray devices.

The second part of the survey considered the possibility of replacing conventional radiography techniques using radiation sources with less hazardous non-ionising techniques such as ultrasonic testing. Poor rates of defect detection, customer requirements and expectations, and standards/codes requiring ionising radiation tests were cited by approximately 50% of respondents as barriers that would make it difficult in switching from ionising radiation to non-ionising radiation techniques. In addition, 42% of respondents stated that certain physical and technical obstacles such as the thickness of material (ultrasonic testing cannot be used on material that is less than 8 mm in thickness) and certain material types such as composites and coarse-grained materials, could pose significant challenges for the use of non-ionising techniques.

The advantages of replacing ionising radiation with non-ionising techniques are well known and relate mainly to the absence of the ionising radiation hazard such as no radiation dose, increased safety, no security threat, no licensing or other regulatory requirements and no restrictions on when radiography can take place.

It is clear however that technical or/and logistical obstacles need to be overcome before consideration can be given to replacing ionising radiation with non-ionising techniques or gamma sources with X-ray equipment and, in certain situations, it may not be possible to use non-ionising radiation techniques or X-ray equipment. In addition, customer requirements/expectations would have to be managed for them to be more receptive to the use of X-ray equipment or non-ionising techniques and standards would need to be changed to cater for the use of X-ray equipment or non-ionising radiation techniques.