Controlling the risk due to the use of gamma sources for NDT
First feedback from the deployment of replacement NDT Techniques

Etienne MARTIN (COFREND, France)
Content

- **The context**

- **Status of the deployment**
  - Definition of good practices
    - Responsibilities
    - Maintenance Policy: Reasons for the use of RT
    - Implementation
      - Analysis of the different Phases of a job,
      - Analysis of Influent factors
  - Alternative methods
    - Justification of the use of Gamma radiography
    - Collaborative Projects

- **Difficulties in deployment**
  - Physical principle / Acceptance criteria

- **International Benchmark**

- **Conclusion**
The context

- In France, two regulatory bodies rule over the activities using gamma ray sources
  - Public Health
  - Nuclear Safety
- Due to unacceptable accidents, in 2005, the French Nuclear Safety Authority decided to work with industrial companies using gamma radiography on two topics related to this field:
  - Development and optimization of best practices during radiographic inspection,
  - Identification of replacement methods to radiographic testing

The project was coordinated by COFREND (French Confederation for Non-Destructive Testing)
A working group including COFREND and the French Society for Radioprotection (SFRP) organised 9 workshops on:

- Regulatory framework
- Responsibilities
- Radiographic testing
- Feedback from experience
- Equipment
- Dosimetry
- Training
- Guide for risk assessment
- Self assessment Guide
## Best Practices (2/7)

### Responsibilities

<table>
<thead>
<tr>
<th>WHO?</th>
<th>FOR WHAT?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Utility, Customer,</strong></td>
<td>- Precise identification of objectives and working conditions upon the</td>
</tr>
<tr>
<td><strong>Project superintendent</strong></td>
<td>drafting of the specification</td>
</tr>
<tr>
<td><strong>Vendors - Intervening</strong></td>
<td>- Identification of the elements to be specified in order to control the</td>
</tr>
<tr>
<td>company (I.E) in</td>
<td>intervention when reviewing the proposal.</td>
</tr>
<tr>
<td>radiography.</td>
<td>- Acceptance or identification of reservations to be raised upon order</td>
</tr>
<tr>
<td></td>
<td>review</td>
</tr>
<tr>
<td></td>
<td>- Nominative identification of the persons responsible for the contract</td>
</tr>
<tr>
<td></td>
<td>and the work done by each entity</td>
</tr>
<tr>
<td></td>
<td>- Elaboration of the prevention plan</td>
</tr>
<tr>
<td></td>
<td>- Feedback</td>
</tr>
</tbody>
</table>
Question 1 : Why use RT ?

- To conform to local or international codes and standards, with their acceptance criteria, for the production of components
- Gamma-ray sources are easy to use: easy access to Plant areas, no need for external power source
- The historical NDT performed on the pre-service inspection is still in use: easy to compare radiograms between different inspections
- Radiography is often the most effective NDT, depending on the purpose of the inspection.
Question 2: Why not start by considering the purpose of the inspection, as part of a maintenance policy?

- NDT is only part of the global maintenance strategy of the Plant Owner.
- To date, EDF is the only Utility operating nuclear power plants, involving a total of 58 reactors: a significant amount of feedback from operation.
- EDF has built a huge program in addition to justifications aiming to:
  - Reduce the amount of NDT on the main primary and secondary systems, for the next 10 years.
  - Reduce the number of radiographic exposures carried out in the nuclear island, using surface examination techniques or changing the material of some components.
## Implementation: the phases of a job

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Performance of the job</th>
<th>Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of the site organisation</td>
<td>Take the camera out of the source storage</td>
<td></td>
</tr>
<tr>
<td>Work file</td>
<td>Transportation on site</td>
<td></td>
</tr>
<tr>
<td>Area plan</td>
<td>Localization of the component and location of the welding</td>
<td></td>
</tr>
<tr>
<td>Work permit</td>
<td>Information of the workers, supervision of the area</td>
<td></td>
</tr>
<tr>
<td>Dose prediction</td>
<td>Beaconing of the area</td>
<td></td>
</tr>
<tr>
<td>Link with other activities (insulation, scaffolding, brushing, shielding, drain circuits …)</td>
<td>Film installation</td>
<td></td>
</tr>
<tr>
<td>Checking of the area</td>
<td>Taking into account of the physical environment: temperature, lighting, dose rate and accessibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calculation of the exposure time and test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiography</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitoring of dosimetry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Removing ……..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dosimetry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ALARA</td>
<td></td>
</tr>
</tbody>
</table>
## Implementation: factors influencing vigilance

<table>
<thead>
<tr>
<th>Individual</th>
<th>Organisational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night work (sleep)</td>
<td>Intrusions</td>
</tr>
<tr>
<td>Routine</td>
<td>Lack of information</td>
</tr>
<tr>
<td>Tiredness</td>
<td>Waiting time</td>
</tr>
<tr>
<td>Painful</td>
<td>Loneliness</td>
</tr>
<tr>
<td>Interruptions</td>
<td>Time constraints</td>
</tr>
<tr>
<td></td>
<td>Pressure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment failure</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Incidents</td>
<td>Dose rate</td>
</tr>
<tr>
<td>Interruptions</td>
<td>Contamination</td>
</tr>
<tr>
<td></td>
<td>Light, noise</td>
</tr>
</tbody>
</table>
NDT using gamma rays include activities which require permanent vigilance in order to:

- Make sure of the quality of work;
- Manage the various risks including the risk of exposure to ionizing radiations;
- Fight against falls of attention which depend on the forms of tiredness, the work conditions, the difficulties of access, in certain cases on night work, etc;
- Manage temporary pressure (audits, monitoring,…);
- Manage the coercion aiming to avoid exposing other professionals,
- Manage the coactivity in the work environment (presence of hazardous substances.)
The Output: best practices

- French workgroups, overseen by COFREND, have recommended best practices for the different actors in RT.

- Hardware used in industrial radiography:
  - using a different gamma source container adapted to Selenium75,
  - systematic use of collimator or equivalent attenuator
  - systematic use of the mark out “Sentinelle”® (Carmelec Cie) or other light and sound signals

- Set-up a guide to operators for self-evaluation, taking into account the human factor and the conditions of work of the personnel involved in radiography.
In addition to the guidance in the use of best practices for RT, several projects were focussed on the investigation of replacement methods:

- **COFREND** analysed the purpose of an inspection and proposed guidelines enabling to replace gamma radiography or, if need be, to justify its use.

- Collaborative projects were launched that covered a wider field of investigation as they included the evaluation of advanced techniques.
Technical report on the Justification of the replacement of gamma radiography by another method.

- Based on an enquiry made over 55 companies
- Covering operations carried out with Ir192 and Co60 sources on piping, steel structures (welds and base metal)
- Centred on the technical aspects of the inspections (regardless of costs, dosimetry, and training of operators)
- Deliberately general to be adaptable to every industrial sector, on a case by case study.
Development of the following items is recommended:

- **Objectives of the inspection**
  - Stage, codes, extent, requirements in detection, sizing, localisation

- **Parameters of the zone to be inspected**
  - Manufacturing mode, material, geometry, surface condition

- **Parameters of the inspection environment**
  - Accessibility, inspection conditions

- **Parameters of the flaw**
  - Dimensions, type, orientation, localisation, features, nature
Collaborative projects (1/2)

Collaborative projects have been launched since 2005 with special interest in advanced technologies. They explored tracks that could be relevant to the problem.

These projects were:

- **ALTER-X (ALTERnative –X)**, led by the French Welding Institute.
- **MANUREVA (Multi Actors Numerics Radiographic EVAluation)**, an R&D collaborative study grouping four industrial end-users (DCNS, IS Industry, STX France SA and EDF) and a classification society (Bureau Veritas).
- Project associating AREVA NP – NETEC and EDF-CEIDRE
- Working group representing the pressure vessel equipment profession and composed of COFREND, AFIAP (French association of Engineers dealing with pressure equipment), SNCT, CETIM and Institut de Soudure.
The objectives of the projects were:

- to identify credible alternatives to industrial radiography using Ir 192
- to decrease significantly operational dosimetry of inspection personnel

The key steps of the projects were as follows:

- Use state-of-the-art non-destructive testing techniques, specifically applicable to welds, and identify their advantages / disadvantages and limitations
- Reach a consensus of the participants at the end of the embodiment of the prior art on the selection of the techniques to be experimented
ALTER-X

- Evaluate the applicability of the most promising techniques
  - TOFD,
  - Phased Array UT
  - Computed radiography (imaging plates) with X ray tubes and Se 75 source.
  - Advanced electromagnetic and ultrasonic techniques

- Set tasks for the various testing techniques used

- Define applicable areas and limitations of these techniques as a function of the geometrical characteristics of the component to be inspected: diameter, thickness…..

- Develop recommendations for the most promising general NDT techniques and propose them to the reference participants
MANUREVA

The objectives:

- to identify Computed Radiography (CR) inspection systems using imaging plates (IP) that meet end-users specific needs and to evaluate their performance.
- to limit the environmental and human impact of industrial radiography by taking advantage of the recent advances in digital Phosphor Plate detectors:
  - no chemical development constraints (effluent treatment)
  - flexibility of implementation (real-time scanning, digital exchange).
AREVA - EDF

In the continuation of a study by AREVA in 2006, the objectives of the joint project were:

- to establish performance limits of CR against EN 14784 specifications and R-CCM code image quality indicator (IQI) requirements
  - The performance has been evaluated for steel with a thickness range of 20 to 60 mm using a Ir 192 gamma source.
- To demonstrate the current status of achievable image quality in CR.
  - Image quality has been assessed in terms of EN 462 and ASTM (E 747, E 1742) IQI.
- The results have been scored considering the ISO DIS 17636-2, R-CCM 2007, and ASME V-2010. This also permitted comparison between the different standard requirements.
The document produced is in the form of a technical book, and aims to answer the following question:

“How practically, at manufacturing or mounting stage, industrials can substitute new testing methods or techniques to Iridium radiography?”

It complements the COFREND document (Justification of Gamma radiography), in which a step by step questionnaire enables the user to specify the inspection objectives and to assess the possibility to implement alternative techniques.

The technical book synthesises the writers’ knowledge and practice, with the objective to address the needs of various industrial actors.

A methodology is thus proposed to help in making the decision to use an alternative technique to RT.
Difficulties in deployment

UT has great potential to be used in lieu of RT, but History shows that the combined use of RT for fabrication exams followed by the use of UT for pre-service and in service exams underlines the difficulties to follow some defects because we don’t use the same physical phenomena.

Due to the physical principle of UT and RT, the performances of these two methods cannot be the same, even though they are active in the volume of the component.

<table>
<thead>
<tr>
<th>Radiography testing</th>
<th>Ultrasonic testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction of a high energy electromagnetic wave with the atoms of the structure under test.</td>
<td>Interaction of acoustic waves with discontinuities in the material.</td>
</tr>
</tbody>
</table>
Acceptance criteria ↔ Inspection situation.

- Equipment is manufactured in accordance with workmanship codes.
- Acceptance criteria are related to manufacturing.
- Once the component has been put into operation, inspections aim to assess its fitness for purpose.
- Inspection methods are qualified in regard of detection and characterisation performances.

For in service inspection, this is a revolution because the requirements of the Plant Owner have to define the objectives of the inspection with the different parameters of the defect, zone to be inspected and the environment and not a NDT System to implement.

At the end, we will have to get acceptance criteria based on fitness for service and not on workmanship standards.
International Benchmark

Acceptance criteria / physical principles

Studies carried out worldwide have reached comparable conclusions:

- Replacement of RT by UT is feasible in several cases.

- YET:
  - An assessment of UT capabilities needs to be carried out.
  - UT acceptance criteria must be adapted to the case of fitness for service.
  - Acceptance criteria for fabrication type flaws
    - Cannot use RT acceptance criteria due to differing physics of methods
    - Applying acceptance criteria may reject acceptable flaws causing unnecessary repairs
Conclusions

Reducing the risks linked to gamma radiography in NDT has several aspects:

- The adequacy of the use of radiography to an inspection situation must be justified.
- Protection against radiation is a social and human problem which can be solved by a generalisation of best practices:
  - Definition of responsibilities
  - Use of optimised equipment
  - Optimised risk assessment
- Reduction of the number of exposures is related to an optimisation of in-service inspections.
Conclusions (cont.)

Uncertainties remain

- The work done has to be perpetuated
  - Sustainability depends on each one involved in the process
  - Change the habits of the Utilities - Customers
  - Define an objective of inspection and not an NDT System to implement

- The regulatory framework has to encompass actual inspection situations
  - Gaps in codes and standards should be filled-in to include UT

- Economic motivations have sometimes more weight than the risk attached to ionising rays. Would a more stringent regulation foster the development of alternative solutions?
THANK YOU FOR YOUR ATTENTION