ASPECTS RELATED TO THE TESTING OF SEALED RADIOACTIVE SOURCES

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ABSTRACT

Sealed radioactive sources are commonly used in a wide range of applications, such as: medical, industrial, agricultural and scientific research. The radioactive material is contained within the sealed source and the device allows the radiation to be used in a controlled way. Accidents can result if the control over a small fraction of those sources is lost.
Sealed nuclear sources fall under the category of special form radioactive material, therefore they must meet safety requirements during transport according to regulations.
Testing sealed radioactive sources is an important step in the conformity assessment process in order to obtain the design approval. In ICN Pitesti, the Reliability and Testing Laboratory is notified by CNCAN to perform tests on sealed radioactive sources.
This paper wants to present aspects of the verifying tests on sealed capsules for Iridium-192 sources in order to demonstrate the compliance with the regulatory requirements and the program of quality assurance of the tests performed.

Key words: sealed source, test, transport, quality assurance

Introduction

Radioactive sealed sources have been used since several years for a wide range of applications in a variety of shapes, sizes and radioactivity levels. In industry, they are widely used for non-destructive testing, radiation processing, “on-line” process control systems, online elemental analysis for raw materials, semi-formed and final product, mineral resources evaluation, food irradiation and smoke detection. One well-known example of such sources is ^{192}Ir sources for industrial radiography.

The miniature size of these sources and the high degree of uniformity in activity distribution needed technical challenges in the process production and development of quality control methodologies. Same aspect related to necessity of specially designed and remotely operated positioning systems for source assembling and sealing (welding) in a hot cell, offers another area of interest.

A sealed radioactive source is classified as “Law dispersible radioactive material“ in accordance with Specific Safety Requirements –SSR no.6:2012[1]. For use of radioactive sources is necessary to require the approval of National Competent Authority. An application for approval include: a description of the radioactive material (capsule and content), a statement of the design of capsule, a statement of the tests that have been carried out and their results, a specification of applicable management system, any proposed pre-shipment actions, etc.

This paper presents some aspects related to quality assurance in the production process of ^{192}Ir sealed sources for industrial radiography, as well as in the testing process of the welding sealed capsules in INR Pitesti.

The 192Ir sealed sources for industrial radiography

^{192}Ir is one of the most widely used sealed sources for radiography applications. Taking into account the relatively short half-life of the isotope (74 days), it is essential to organize the production of sources as close as possible to the client to avoid logistic problems.

The assembling and welding techniques of ^{192}Ir sealed sources for industrial applications were optimized. An active core of this kind of source is a set of irradiated iridium disks with a diameter of 0,5 to 3,5 mm and thickness of 0,2 to 0,5 mm (depending on required source activity and dimensions). The sources of radiotherapy made in INR are disks of 3 mm with a maxim activity of 4,440 TBq (120 Ci). The capsules made from stainless steel are sealed by TIG welding. This design provides a source classification C 43515 according to ISO 2919: 2012 [2].

Radioactive sources are manufactured in accordance with strict control methods. Stringent tests for leakage are an essential feature of radioactive source production. The methods adopted depend on the design and intended application source, and also on statutory requirements, and the standard method is ISO 2919:2012. A test report is delivered for each source or batch of sources.

The Quality Assurance System

In order to guarantee sustainable assurance of test results delivered to the approving authority as well as to applicants or customers, Reliability and Testing Laboratory, operates and maintains an effective quality management system designed to ensure that the applied test methods meet international accepted quality requirements.

This complete quality assurance plan encompasses both, quality assurance and quality control functions. Quality Assurance involves meeting programmatic requirements but on occasion requires the implementation of external checks on testing quality. These external checks include independent system audits, third party sample and analysis for accuracy and precision or comparison to calibration standards. Quality Assurance audits confirmed that operational and maintenance procedure and quality control are a series of frequent routine internal checks, such as system inspections, periodic calibrations, and routine maintenance.

The Quality Management System developed and implemented by INR's Reliability and Testing Laboratory is based on the international standards-ISO 9001:2008 [3] and ISO CEI 17025:2005 [4] and includes the processes necessary to achieve the organization's overall objectives that consist of:

- The description of the management system in the Quality Management Manual of Reliability and Testing Laboratory - MC LIF [5] ;
- Documents that describe the management system processes-system procedures;
- Detailed work control documents - technical procedures, instructions, checklists, process control cards and forms.

A significant part of Quality Management System involves documentation and the scheme of a documentation structure for a Quality Management System of INR's Reliability and Testing Laboratory is given in Figure 1.

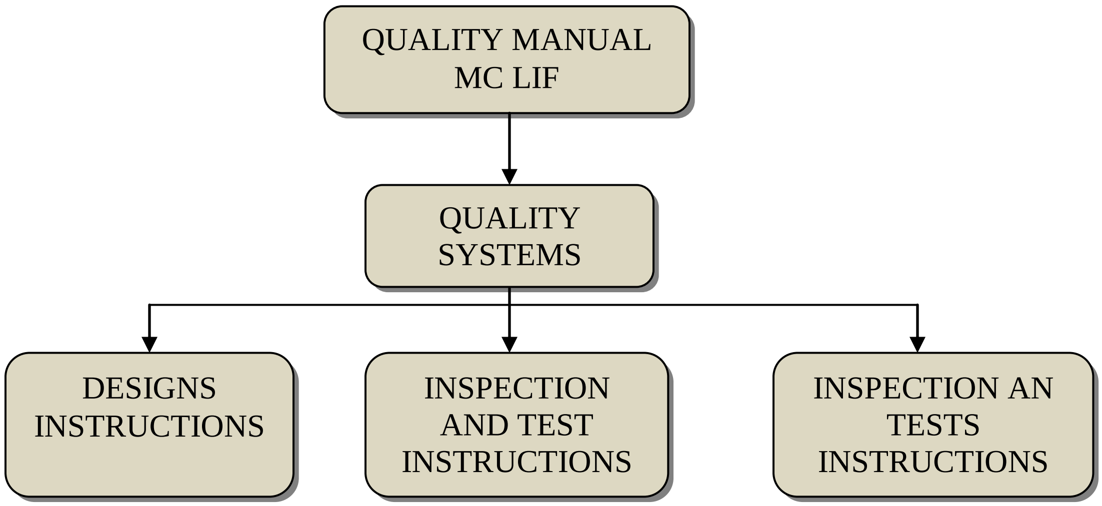

Fig.1. *The Quality Management System documentation structure.*

Following the implementation of Quality Management System the INR's Reliability and Testing Laboratory was notified by the National Commission for Nuclear Activities Control (CNCAN) through the NOTIFICATION no. LI 02/2015.

The Quality Management System implemented by the Reliability and Testing Laboratory is intended to assure that the sealed source testing are accomplished in a quality assured way, using appropriate equipment and calibrated instruments working within their recognized capabilities and within the limits of accuracy. Only by controlling all design-related activities in such a way, a manufacturer, user or certifying body have a reasonable assurance that the tested sealed sources complies with the designer's requirements.

The quality control programme is implemented for sealed sources manufacturing in INR. For manufacturing sources the supplies and materials have to pass inspection tests. They should have certificate for their identification. Sources must be hermetically sealed. Leakage tests should be provided in accordance with immersion method 5.1.1. (SR ISO 9978:1996)[6]. The measured activity of liquid where sources have been treated must not exceed 0,2 kBq.

Estimation of source (or simulated sealed source) leak tight and strength must be carried out according to the result of examination before and after carrying out tests. Not less than two sources of the type specified are to be subjected to each test. The programme of tests is developed according to ISO 2919:2012 [2]. When changing the design and the technology for manufacturing the source of the type specified which influence on its safe application as to purpose, new sources must be tested.

Experimental tests for welding capsules

The sealed radioactive sources must comply with the performance tests and general requirements in accordance with classification system established in International Standard ISO 2919:2012[2]. This standard provide a set of tests by which manufacturers of sealed radioactive sources can evaluate the safety of their products in use, and users of such sources can select types which are suitable for required application.

The tests fall into several groups including exposure to abnormally high and low temperatures and a variety of mechanical tests. Each test can be applied in several degrees of severity, the criteria of pass or fail depends on leaking contents of the sealed radioactive source.

The radioactive sources for industrial radiography must comply the following tests:
- temperature test;
- external pressure test;
- impact test;
- puncture test.

General requirements

All tests, except the temperature tests, were carried out at ambient temperature.
For each test, at least two test sources of the model type shall be subjected to the test, and shall pass the criteria as defined in ISO 2919:2012[2] point 7.1.5. "*Compliance with the tests was determined by the ability of the sealed source to maintain its leak tightness after each test has been performed. After each test the source shall be examined visually for loss of integrity and it shall also pass an appropriate leakage test carried out in accordance with SR ISO 9978[6]".*

The tests, for welding capsules for ^{192}Ir sealed source for industrial radiography, were performed on three capsules marked P1, P2 and P3 as shown in Fig.2.:

Fig.2. *The sealed welding sources*

External examination

External examination should be fulfilled by visual inspection giving particular attention to quality of welding joints (the plug and the capsule). Correspondence of dimensions of the assembled source with requirements to specifications is checked with the certified gauges ensuring measurement accuracy by drawings.

Puncture test

Puncture test was performed in accordance with ISO 2919[2] point 7.6. The 300g steel hammer (Figure no.3), with the pin rigidly fixed at the lower part, was dropped onto sealed source positioned on the hardened steel anvil. The hammer is dropped from the height of 1 m onto the top of sealed source by the means of the smooth vertical tube (Figure no.4). The pin is positioned to drop as close as possible to the welding joint.

Fig.3. *The steel hammer* **Fig.4.** *The device for the puncture test*

After the puncture test each source (Figure no 5) was examined visually for loss of integrity and a leakage test with helium was conducted to verify its leak tightness. All sources fulfil the criteria.

Fig.5. *The sources after the puncture test*

Impact test

Impact test was performed in accordance with ISO 2919[2] point 7.4. The impact hammer (Figure no.6) with the mass of 5 Kg was dropped onto sealed source positioned on the hardened steel anvil with the diameter of section of the flat striking surface of 25 mm (with its outer edge rounded to a radius of 3mm). The drop height, measured between the top of the sealed source, positioned on the anvil, and the face of the hammer in its position prior to release, was 1 m. The hammer is dropped from the height of 1 m onto the top of sealed source by the means of the smooth vertical tube (Figure no.7):

Fig.6. *The impact hammer*

Fig.7.*Vertical tube*

Fig.8. *The sources after the impact test*

After the impact test, each source (Figure no 8) was examined visually for loss of integrity and a leakage test with helium was conducted to verify its leak tightness. All sources fulfil the criteria.

Temperature test and thermal shock

The heating or cooling test of sealed capsules, are made in the climatic chambers with a test zone volume of at least five times the volume of the specimen.

The sealed capsules were cooled at -40°C for 20 min., then were exposed to temperature below the ambient. After this test, the sealed sources were tested at thermal shock as follow:
Sealed sources at ambient temperature were heated at +400°C and then were kept inside at that temperature for at least 1 h. After this time, the sources were subject to thermal shock by transferring them, within 15 s, to water at ambient temperature (about 20°C).

Details during temperature and thermal shock tests are shown in the figure no 9 and 10:

Fig .9. *The climatic chambers*

Fig.10. *The capsules after the temperature test*

After the temperature test and thermal shock, each source (Figure no 10) was examined visually for loss of integrity and a leakage test with helium was conducted to verify its leak tightness. All sources fulfil the criteria.

External pressure test

The test was carried out in a special chamber at 25 kPa pressure for two periods of 5 min each. Between these periods the pressure was returned at atmospheric pressure.

After the external pressure test, each source was examined visually for loss of integrity and a leakage test with helium was conducted to verify its leak tightness. All sources fulfil the criteria.

Conclusions

The adequate implementation of the Quality Management System applicable to testing activities will assure a greater safety for the testing of sealed radioactive sources. When a task is carried out in a quality assured manner the whole process employed by the company or organization involved will evolve systematically. Through the application of an appropriate QA data base record, safety and compliance of the sealed radioactive sources can be easily demonstrated to the third parties.

A consistently high quality and reliability of welding capsules tests, as an integral part of design approval procedure for radioactive sealed ^{192}Ir sources, can only be achieved if the quality requirements for manufacture and testing of prototypes and test models are clearly defined, if the requirements for the quality management system are specified and the quality control methods are documented accurately. Based on a quality assurance system, the test results can provide objective evidence for tested specimens or prototypes within the design source approval in order to demonstrate the compliance with safety requirements.

References

[1] International Atomic Energy Agency: Regulations for the safe transport of radioactive material" Safety requirements no. SSR no.6:2012, Vienna

[2] International Organization for Standardization ISO 2919:2012- Radiological protection. Sealed radioactive sources. General requirements and classification.

[3] International Organisation for Standardization: EN ISO 9001: 2008 Quality Management Systems-General requirements

[4] International Organisation for Standardization: EN/ISO/IEC 17025: 2005 General requirements for the competence of testing and calibration laboratories.

[5] Reliability and Testing Laboratory, INR Pitesti – Quality Manual MC LIF

[6] Romanian Organization for Standardization SR ISO 9978: 1996- Radiological protection. Sealed radioactive sources. Leakage test methods