# Considerations in the Leakage Test on Sealed Radioactive Sources

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**Abstract.** The radiation emitted by sealed radioactive sources (SRS) is used in several fields as medicine, industry and research. The SRS may be defined as a quantity of radioactive material sealed within non-radioactive material, or closely bounded to a non-radioactive surface, which the confining barrier is intended to prevent leakage or escape of the radioactive material under normal handling conditions and also under foreseeable mishaps. International recommendations state that SRS should be regularly inspected and tested as part of its safety assessment. In normal use, the SRS may be subject to vibration, shocks, corrosion, heat and other adverse conditions, so recurrent leakage tests performed during its working life are important to ensure that the SRS maintain its integrity. In some countries there are statutory regulations that specify the period between recurrent tests depending on the SRS design and its type of application.

From 2005 up to 2007, IPEN - CNEN/SP performed 659 leakage tests on SRS for industries, hospitals and industrial radiography services. The applied leakage test methods and their approval criteria followed an international standard. In Brazil, the regulations specify the period between recurrent leakage tests only for some types of industrial radiography SRS. Because of that, it was observed that some SRS of the same type and in similar working environment, but from different licensees, had diverse frequency of leakage test depending on their quality assurance programs or approved procedures.

In this work, suggestions are made for the preparation of a regulatory guide, which could provide guidelines or advices on some aspects as exemptions, frequency and record keeping of leakage tests on SRS. A regulatory guide could facilitate the implementation of leakage test and its enforcement by the regulatory authority, encouraging licensees to effectively perform those tests.

***KEYWORDS: Sealed radioactive source; leakage test; recurrent test.***

## 1. Introduction

Assessments related to protection and safety measures for ionizing radiation sources shall be made in the different stages of a practice, including manufacture, assembly, operation and maintenance, among others, in order to identify the ways in which normal and potential exposures could happen, taking into account events directly involving the radiation sources and their associated equipment, as well as effects of external events on those ones [1].

The manufacturers of radiation sources and equipments containing those sources are responsible for assuring that their products can be used in a safe way for the stated purpose. The products should have intrinsic safety margins capable to withstand reasonable degrees of wear and predictable abuses in their use or storage. The manufacturers should supply specifications of the radiation sources, advising about any limitation of their products and they should also specify a recommended working life for the radiation sources. This time should be much smaller than the safe life of the construction. The use beyond the recommended working life might be acceptable provided more frequent and more stringent tests implemented to identify any deterioration before any hazard develops [2].

A sealed radioactive source (SRS) may be defined as an amount of radioactive material permanently sealed in a capsule or between layers of inactive material, or firmly fixed to a inactive surface, or closely bonded in solid form, intended to prevent leakage, escape or dispersion of radioactive material under normal conditions of use and handling, as well as in small predictable occurrences during its use or storage, manufactured for the purpose of utilizing the emitted ionizing radiation [3, 4].

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The owners or users of radiation sources are responsible for their safety and security. A defense in depth system shall be applied to the radiation source, appropriate for the magnitude of the involved potential exposures [1]. The SRS and the device that contains it should be subject to periodic maintenances and testing to assure that they continue to meet the initial specifications. The tests would include leakage test of SRS, inspection and test of the source displacement mechanisms and shutters and checking the operation of warning systems. The frequency of these tests and controls should be based on experience and on the advice from the manufacturer or supplier [2].

The radioactive contamination presents risks for health and it also can interfere in radiometric measurement data, besides compromising the good quality of products. To prevent the radioactive contamination risks caused by the confinement loss during the storage or use of SRS, it should be performed periodic leakage tests in order to detect dispersion of radioactive material with the appropriate urgency. Cautions should be taken to protect the people from undue exposures while performing those tests, as the use of tweezers for manipulation and mirrors for visualization of the SRS.

These recurrent leakage tests are not necessarily the same as those carried out in the quality controls during the SRS manufacture. Indeed, in many cases, the tests carried out during the SRS manufacturing cannot be applied in recurrent inspections, either for the impossibility of removing SRS from the site, or by the safety conditions for handling the source, although, in some cases, the test methods used during the SRS production are recommended [5].

It is advisable, previously to the leakage test, to carry out a visual inspection in order to detect wear and tear or mechanical defects on the SRS. If any abnormality is observed, the type and magnitude of the deterioration must be precisely registered, in order to establish a stricter control of the source. Depending on the magnitude of abnormality, the SRS can be removed from service or the frequency of tests and controls can be increased.

The recurrent leakage test method to be used in each case depends on the radionuclide, the source activity, the thickness and nature of the inactive material used to manufacture the source, and also the way the source is housed in the equipment or device. For the easiness of execution, compared to other methods, and for having an appropriate sensibility for most applications of SRS, the wipe test, also known as smear test, is the most used. For some types of SRS, immersion methods are also used, however, in smaller scale and, for gaseous radionuclides, gaseous emanation methods are employed.

Between the years 2005 and 2007 IPEN-CNEN/SP accomplished 659 leakage tests in SRS at the request of industries, hospitals and industrial radiography services. For 122 of these tests the immersion in boiling liquid method was used and in the remaining 537 SRS the applied method was the dry wipe test. In this work some aspects of these tests are discussed and the preparation of a regulatory guide with advices and recommendations for the accomplishment of leakage tests in SRS is suggested.

## 2. Leakage Test Methods Used

### 2.1 Dry Wipe Test

In this type of leakage test viscose rayon wipes were used. The wipes had 80 $g/m^2$ grammage and 50 mm diameter. Whenever possible, all the SRS external surface was rubbed with the wipe and, later, the activity in the sample was measured.

When the access to the entire surface of the source was not possible, for example, when SRS could only be tested inside of the equipment shielding in which it was installed, then only the accessible surface of the source was sampled.

Once the direct access to the source surface was not possible or not desirable, for instance, because of unjustified radiation exposure of the persons carrying out the test, or in the case of alpha emitters sources having thin window, the wipes were carried out on the accessible part nearest to the source, where it was more feasible that the radioactive contamination might occur, as in source holders, shutters, source displacement mechanisms or along any joints or external movable parts of the equipment.

In those cases in which several surfaces of the same equipment were sampled, different wipes were used for each surface. In all the situations the wipes were identified and kept apart until the determination of its activity.

Whenever necessary, devices as tweezers and claws were used to carry out the sample collection. Only one face of each smear was used to carry out the wipe test to reduce the possible effects of self-absorption of beta or alpha radiations.

Soon after the sample collection, a screening monitoring was carried out on the wipe in order to verify if there was a level of radioactive contamination already measurable with a thin window Geiger-Müller detector. In positive case, safety measures would immediately be taken with the source that presented the radioactive leak.

When the owners or users of the SRS or a third part carried out the sample collection, a kit with the wipes to be used had been supplied. The kit also contained written instructions with step-by-step procedures for sampling the wipes in a safe way, as well as a standard form to be filled with the SRS data and a term of responsibility to be signed by the person who carried out the sampling.

To determine the activity present on the SRS surface a conservative 10% transfer factor from the surface to the smear was adopted, considering that there may be differences on the size and conditions of sampled areas, the pressure applied to the smear or even the radioactive material composition.

If the activity of leakage determined by the dry wipe method was less than 0.2 kBq, then the SRS was considered leak free [5].

### 2.2 Immersion in Boiling Liquid Test

This method was applied to $^{241}$Am SRS used in nuclear gauges. The nuclear gauges were brought to IPEN-CNEN/SP and the sources were removed from the equipments in a glove-box exclusively used for this purpose.

After removed from the equipment the SRS was submitted to the dry wipe test, as described above. If radioactive leak was not verified, the source was also submitted to the immersion in boiling liquid test.

In this method, the SRS was immersed in deionized water, that does not attack the external surface of the source, in a stainless steel container, and the water was boiled for 10 minutes. Then the source was allowed to cool to room temperature and rinsed with deionized water. The source was immersed in the same water of the previous cycle, and it was again boiled for 10 minutes. That process was repeated once again and the activity in the water was determined.

The activity in the water was measured by filtering it through a 0.3 μṃ paper filter, then the filter was dried at room temperature and its activity was measured in a sample counter. If the activity of leakage determined by the immersion in boiling liquid test was less than 0,2 kBq, then the SRS was considered leak free [5].

### 2.3 Sample Measurement

The activities in the wipes and filters were measured using Ludlum scalers model 2929, with sample counters model 43-10-1, properly calibrated by the laboratory of calibration of instruments of IPEN-CNEN/SP, which is accredited by the national nuclear regulatory authority. The calibrations were carried out for the geometry of the samples and for the type and energy of the radiations emitted by the radionuclides of interest. The sample counters used are sensible to alpha, beta and electromagnetic ionizing radiations, with different channels for beta-gamma and total alpha counting.

Background counting was made with a clean wipe in the sample holder. Background counting was performed before and after each group of samples. The counting time was determined so that the minimum detectable activity [6], for each radionuclide of interest, was inferior to 20 Bq, which corresponds to 10% of the approval criteria.

Each sample was counted twice and, in the case of several samples of the same SRS, the activities found in each sample were summed, so that the final result reflects the total transferable activity present in the SRS. The statistical deviations were propagated to obtain the final result.

### 2.4 Records

The sampling records are kept in standard forms. The form contains the sampler's data and signature, the SRS owner or user's data, the sitting of the equipment containing the SRS, the manufacturer and model of the equipment containing the SRS, the SRS data, the description of the sampled surfaces, the identification of each wipe and the date of sampling.

The sample measurement records are also kept in another standard form. This form contains the measurer's data, the SRS owner or user's data, the SRS data, the sample counter data, including the identification of its certificate of calibration, the date of the measurements and the background and sample counting's in both beta-gamma and total alpha channels.

The spreadsheet used to estimate the activities from the sample counting's is also kept. This spreadsheet contains the SRS owner or user's data, the SRS data, the date of sampling, the date of measurements, the sample counter data, including the identification of its certificate of calibration and the counting efficiencies, the background and sample counting's in both beta-gamma and total alpha channels, the minimum detectable activity, the activity in each sample and the total activity estimated for each SRS.

A certificate containing the conclusion of the leakage test is sent to the SRS owner or user in printed form and an electronic copy of the certificate, is also kept filed. This certificate contains the SRS owner or user's data, the SRS data, the chosen method for monitoring, the sampler's data, the date of sampling, the date of measurements, the sample counter data, including the identification of its certificate of calibration, the minimum detectable activity, the activity in each sample, the total activity and the conclusion of the leakage test stating if the total activity found is larger, or not, than the approval criteria.

The measured wipes and filters are also kept. They are maintained properly segregated and identified, in case of need of new measurements.

## 3. Discussion

### 3.1 Leakage Test Exemption

The activities of SRS can vary from some few becquerels to tens of petabecquerels. The radiological risks presented by this diversity of sources are so distinct that makes useful to determine certain values of activity below which the application of all the possible parameters of radiological control for a SRS would not be optimized. The concepts of accountable SRS [7, 8] or source inventory limits [9], based on different premises, are examples of activity values that could be adopted to define the obligation of leak testing SRS.

In Brazil, the activity values for exemption of practices are defined, but there is no regulation about the concept of accountable SRS or source inventory limits, so the decision of carrying out the leakage test in a given SRS is result of an optimization exercise that not always is considered appropriate by the national nuclear regulatory authority. Although there are studies that do not consider necessary to inventory or to carry out leakage test in SRS containing very small activities [9], there is no consensus or a regulatory position that defines which activity values would be those.

There are other factors that could lead to not be required the completion of leakage test in a given SRS [10, 11], as the short half-life time of the content, or the reactive qualities of the content, as in the case of some radioactive noble gases. A clear definition of the criteria that could exempt a SRS of being leak tested would be very useful.

### 3.2 Leakage Test Frequency

International recommendations establish generically that the frequencies of tests and controls related to the safety of radiation sources should be based on the user's experience and on the manufacturer or supplier's advices [2]. In spite of these recommendations, there are rare SRS manufacturers or suppliers that recommend leakage test intervals for their products. The most common is that they just inform the recommended working life time. On the other hand, the intrinsic safety margins adopted in the SRS manufacturing, and the diversity of possible applications for a given SRS, lead to the users, individually, have little experience with flaws in that type of device, therefore there is a difficulty of establishing an optimized frequency for the recurrent leakage tests.

The difficulty in determining an optimal frequency for leakage tests results that similar SRS, in also similar use conditions, may have very different leakage test frequencies, depending basically on the quality warranty programs of the users or on their approved procedures.

The definition by the national nuclear regulatory authority of minimum frequencies for leakage tests on SRS not only would help the users to establish an appropriated monitoring program, but it could also facilitate the surveillance of radiological controls applied by the users to their radiation sources and thus it could improve the public's confidence in the polices of control of radioactive sources in the country.

The definition of these minimum frequencies could be dependent on the type of SRS application, as in some countries [12], or it could be a single, but more restrictive frequency [7]. Though more often tests result in higher costs in the implantation of the monitoring program, in general, the costs of a leakage test can be relatively low, especially if the sampling is carried out by the user. The user should also have in mind that the costs of an eventual operation of decontamination could be quite high [13].

### 3.3 Acceptable Methods

The measurements of parameters related to SRS should be carried out in order to verify the compliance with the normative requirements and monitoring equipments should be suitable for the emitted radiation and properly calibrated [1]. In the case of leakage tests on SRS, direct monitoring is not possible, because of the influence of the radioactive material contained in the source, therefore, it is necessary the collection of samples for accomplishment of the test.

In that type of monitoring, the sampling, including the technique chosen, the material used to collect the sample, and the counting geometry may compromise the full extent of activity measurement, therefore, it is necessary to establish acceptable sampling methods for each application, for instance, gaseous emanation test for sources of $^{226}Ra$ or $^{85}Kr$ [5].

The counting should also be done in order to accurately reflect the activity in the sample. The sample counter should be sensitive to the radiations emitted by the sample and it should be calibrated for the sample geometry and energies of interest. The sensibility of the counting method should also be such that it has the ability to measure smaller activities than that stated in the approval criteria of the applied leakage test.

Additional features in the sample counter that allows it to distinguish different types of radioactive emissions may also be useful. There was one case in that IPEN-CNEN/SP received wipes contaminated with natural radionuclides, for the reason that they were used to smear a $^{137}Cs$ nuclear gauge sited in a production plant of fertilizers with phosphate compounds, which can present traces of uranium and its progeny [14]. That contamination could be only detected because the sample counter presented different channels for beta-gamma and total alpha counting.

### 3.4 Documentation

A good documentation should be complete and organized in order to allow the assessment and recovery of the information relative to the recorded facts, as well as to make possible tracking the filed data. When the document is used to prove the effective accomplishment of an action, it should contain the signature of the person who has the responsibility for the registered information. The keeping time of the records is function of the need of tracking of the contained information. The national nuclear regulatory authority could establish the keeping time in accordance, for instance, with the surveillance program for a facility type.

The sampling records should contain information to allow identifying the SRS, the sampler, the SRS owner or user, the sitting of the equipment containing the SRS and should also contain the description of the sampled surfaces, the identification of each wipe and the date of sampling.

The certificate of leakage test on SRS should contain the SRS owner or user's data, the SRS data, the chosen method for monitoring, the sampler's data, the date of sampling, the date of measurements, the sample counter data, including the identification of its certificate of calibration, the minimum detectable activity, the activity in each sample, the total activity and the conclusion if the SRS met the approval criteria or not.

It is important that the activity values found in the samples be also included in the certificate of the leakage test, because, even if the approval criteria of the method is met, the measured values can give subsidy for the user to determine more frequent tests in a SRS that presents some transferable activity on its external surface.

## 4. Conclusions

The leakage test is an important component in the radiological control of the SRS. Several practical and operational aspects may influence the choice of the method to be used and the information's that are important to be recorded for effective control of the SRS. The issue of a regulatory guide providing guidelines and recommendations on some aspects of the leakage test on SRS, as exemptions, frequency, acceptable methods and keeping time of records, can be quite useful to encourage licensees to effectively carry out these tests. It also could facilitate the surveillance, by the national nuclear regulatory authority, of the radiological controls applied to the SRS.

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