Guidance Notes on the Storage of and Accounting for Radioactive Sources

Radiation Health Division
Department of Health
Hong Kong Special Administrative Region, China

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Content

Definitions (as prescribed by the Radiation Ordinance)

Radioactive Substance refers to any substance which consists of or contains any radioactive chemical element whether natural or artificial and whose specific activity exceeds 75 becquerels of parent radioactive chemical element per gram of substance.

Sealed source means a radioactive substance which is permanently enclosed in a container in such a manner that it or any part of it cannot be separated from the container unless the container is damaged, but also in such a manner as to permit the emission of radiation.

Foreword

This set of guidance notes is aimed at providing advice on the safe storage of and accounting for sealed radioactive sources. Nothing in this Guidance should be construed as precluding the use of good judgment.

Sealed radioactive sources are used in a wide range of applications in medicine, industry, research and other fields. If they are not managed properly, loss or mishandling of source may lead to unplanned exposure of workers and the public. The potential adverse consequences may include, in the case of high activity radioactive sources, serious radiation injuries to the handler as well as the public, and in extreme situations, deaths.

A proper system of management helps to maintain radioactive sources in good physical status and provides means of source tracking and control. It also provides a well documented process making any future management options safe, secure and cost effective. Moreover, it can substantially reduce the risk of accidents and malicious uses. Thus it is important to promote the staff awareness and safety culture on the management of radioactive sources.

Please be reminded that possessors and users of radioactive substance are bound by the Radiation (Control of Radioactive Substances) Regulations, Cap303A and the conditions of licence. This guidance is ***not*** a substitution for these legal provisions and compliance with this guidance will ***not*** diminish a person's duties under the law and the licence. Nonetheless, this guidance may help you in establishing and operating a sealed radioactive source accountability and control program. In case of doubt, please refer to the Regulations and the Conditions of individual licence.

If further advice is required, you may consult the Radiation Health Division at:

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This Guidance is available at:

https://www.rhd.gov.hk/english/pdf/guidance_rs_storage_english.pdf (English version)

https://www.rhd.gov.hk/tc/pdf/guidance_rs_storage_chinese.pdf (Chinese version)

(I) Management Responsibilities

1. The Management has an overall responsibility to make arrangements for the planning, organization, control, monitoring and review of control measures.

2. The responsibilities of Management also include the following:
   i. Carrying out suitable risk assessments before undertaking any activity involving work with radioactive substances and preparing contingency plans to deal with foreseeable adverse incidents.
   ii. Preparing written local rules prescribing the arrangements for controlling work with ionizing radiations for any designated controlled areas.
   iii. Appointing supervising persons approved by Radiation Board and specified in radioactive substances license conditions who are trained in radiation protection aspects to ensure that the arrangements set out in the local rules are followed.
   iv. Ensuring each Radiation Protection Supervisor has ready access to an inventory list of all accountable sealed radioactive sources.
   v. Maintaining records related to the accountability and control of sealed radioactive sources.
   vi. Assisting the Radiation Protection Supervisor in training the source users.
   vii. Coordinating procurement of all sealed radioactive sources with the Radiation Protection Supervisor or users.
   viii. Performing receipt monitoring and source leakage tests.
   ix. Monitoring areas of storage and use.
   x. Auditing regularly the storage and accounting of the radioactive sources located in the premises and keeping the appropriate records.

3. The Management may consult or appoint a suitable radiation protection adviser to prepare local rules, prescribe the arrangements for controlling the work, appoint radiation protection supervisors, conduct prior risk assessments, prepare contingency plans, perform dose assessments, and organize medical surveillance programmes etc.

(II) Risk Assessment

4. A risk assessment is to be carried out by the Management along with the radiation protection supervisor for each new or existing storage area. In general, a risk assessment is to:

i. Identify the potential threats and hazards and investigate how they may arise
ii. Predict the impact on those affected
iii. Examine options to mitigate the threats and risks

5. Safety measures should be introduced to eliminate or minimize the risks, as identified in the assessment. Information, instruction and formal training should be provided as appropriate to reduce radiation exposure.

6. The Management should identify processes in which any person may receive a radiation overexposure from a single exposure and a new controlled area would be required to restrict access to contaminated areas in case of an accident or incident. Risk assessments are to be reviewed at least annually or when changes occur.

(III) Receipt of Radioactive Sources

7. Prior to receiving sealed radioactive sources, the Management should assign the sources to the proper radiation protection supervisor. The radiation protection supervisor should be notified of the arrival of the sealed radioactive sources to ensure that proper accountability and controls are initiated.

8. The packaging should be inspected for any damage and contamination. Except for gaseous sealed radioactive sources and tritium for which wipe test is unsuitable, a source leakage test should be performed by the radiation protection supervisor or trained user upon receipt of all accountable sealed radioactive sources in accordance with Section VII of this Guide. The sources should be placed into the approved store room specified by the licence or into the licensed device in which they will be used. The records of both the radiation protection supervisor and the storage site should be updated to include the new sealed radioactive sources.

(IV) Labeling of Radioactive Sources

9. Labels should be applied to all sealed radioactive sources, regardless of the activity, to minimize the likelihood of loss or unauthorized usage. Standard colors and designs should be used to the extent practicable to foster instant recognition by affected individuals.

10. Labels should be applied directly to the sealed radioactive source or, if that is not practicable e.g. the source is too small to label, the source storage container / device or the source storage location should be labeled. A method of tracing a source to its label should be implemented in these cases such as using the serial numbers on the source or permanently marking a unique identification on the source without violating its integrity.

11. The label should identify the following information:
    i. Radionuclide
    ii. Source activity
    iii. Date of assay
    iv. Model and serial number of the source and container or device
    v. Method for identifying the radiation protection supervisor
    vi. Contact radiation dose rate levels
    vii. Removable contamination levels
    viii. Dates monitored
    ix. Name of the individual performing the monitoring
    x. Appropriate actions to be taken in case of accidental spillage or dispersal

12. The label should be sufficiently durable to remain legible for the useful life of the device or storage container and should be located in a readily visible place. The storage location should also be marked in order to ease location identification during inventory checks.

13. If the radiation intensity around the sealed radioactive source container will change significantly upon opening the container or changing the position of the source in the container, that information should be provided on a label so that it is easily observable by the operator.

14. Another method of labeling makes use of electronic means such as bar codes along with human-readable labels. These will minimize human errors and compensate for the small size of some sources.

(V) Storage of Radioactive Sources

15. Proper storage practices should be used to limit unauthorized handling of sealed radioactive sources and to minimize the potential for sealed radioactive source

rupture, excessive personnel exposure, or loss of the sealed radioactive source.

16. Storage locations, containers, and devices should be appropriate for the specific sources, and should only be used to contain radioactive substances. Radiation and contamination monitoring of the sealed radioactive source storage area or facility should be performed before its initial use, and periodically thereafter as specified by the radiological protection supervisor and whenever changes in status that may significantly affect radiological conditions e.g. receipt of a new sealed radioactive source or modification to shielding.

17. The storage location of the accountable sealed radioactive source should be:
    i. Isolated from occupied areas or located in restricted areas.
    ii. Designed to minimize damage from fire and offer protection from the weather.
    iii. Free of flammable or combustible substances.
    iv. Locked, either mechanically or electronically, and monitored routinely.
    v. Provided with sufficient shielding or use controls such that persons outside the store will not receive a dose exceeding 1mSv/yr. It is advisable that the radiation dose rate outside walls of the store to be less than 1 μSv/h.
    vi. Provided with adequate ventilation to prevent the build-up of gases and vapors or of any accidentally dispersed radioactive substance.
    vii. Prominently indicated by a radiation warning sign, with the name and telephone number of the Radiation Protection Supervisor on it. Where appropriate, a warning notice stating the contents of source stored and the risk arising from it should be posted at the entrance of the store room.

18. If only small number of minor sources are held, such items can be stored in a suitable metal cabinet within a general store and the cabinet should be:
    i. Designed to minimize damage from fire and foreseeable use/ misuse.
    ii. Free of flammable or combustible substances.
    iii. Locked, either mechanically or electronically, and monitored routinely.
    iv. Provide adequate shielding to ensure the ambient dose-rate near to the storage cabinet never exceeds 1μSv/h.
    v. Prominently indicated by a radiation warning sign.

19. Increased controls should be applied to the sources under the following situation:
    i. Single source with activity larger than the quantity of concern (D-value) in Table 1 of Appendix.

ii. Multiple co-located sources of the same radionuclide when the combined quantity exceeds the D-value.

iii. A combination of radionuclides, including multiple co-located sources of different radionuclides, when the aggregate quantities $A_1/D_1 + A_2/D_2 + A_3/D_3$ etc…≥ 1 where A_1, A_2, A_3, etc are the activities of the different radioactive sources and D_1, D_2, D_3, etc are the corresponding D-value of the respective radionuclides.

20. Using the source categorization methodology defined by IAEA as indicated in Table 2 of Appendix, the sources may be categorized and the following additional security requirement for Category 1 to 3 source should apply:

i. Category 1 source

It must be protected by, at a minimum, physical security measures capable of providing sufficient delay to allow immediate detection and assessment of an intrusion, and for security guard or police service to intercept and interrupt unauthorized removal of the source.

ii. Category 2 source

It must be protected by, at a minimum, physical security measures capable of providing sufficient delay to allow immediate detection and assessment of unauthorized access to the source location.

iii. Category 3 source

It must be protected by, at a minimum, physical security measures capable of preventing unauthorized access to the source by human force.

21. The security measures can be access control, key control, CCTV surveillance, personal surveillance, etc., or of any compatible form that fulfills the same security requirements.

(VI) Accounting for Radioactive Substances

22. An appropriate accounting procedure should be set up to ensure the locations of all radioactive sources are always known. All accountable sealed radioactive sources should be inventoried at intervals not to exceed 6 months. These inventories should accomplish the following:

i. Establish the physical location of each source.

ii. Verify the presence and adequacy of associated postings and labels.

iii. Establish the adequacy of storage locations, containers, and devices.

23. An accountability record with the following information should be completed for each accountable radioactive source:
    i. Name and authority holding the source
    ii. Radiation protection supervisor information
    iii. Date of initial receipt
    iv. Type of radionuclide
    v. Activity at a specified date
    vi. The location of the substance
    vii. The source status (e.g. disposal, new use, failure of leakage test etc.)
    viii. Initial/ receipt leakage test information
    ix. Photo of the radioactive source or device containing the radioactive source

24. The Management should maintain an individual record for each accountable sealed radioactive source at each facility. Each radiation protection supervisor should also maintain an accountability record for each accountable sealed radioactive source under their responsibility. When an inventory check and / or leakage test is scheduled, the record should be sent to the Management to update the accountability records.

25. For radioactive sources securely attached to machines or other fixed equipment, checks may be carried out once a month provided that additional checks are carried out following any maintenance or repair which could have affected the source. Records should be kept of these checks of the past 12 months as minimum.

26. For portable radioactive sources or radioactive sources in portable devices like nuclear moisture/ density gauges or gamma radiography projectors, daily checks and records should be taken by the Radiation Protection Supervisor. In laboratories using open sources, it will be necessary to know the radioactivity present and the radionuclides involved in each room, supported by records of ordering, receipt, stock and disposal of radioactive material.

27. Upon determination that an accountable sealed radioactive source has been lost or is not stored, posted and labeled, the Management should be notified.

28. Although exempt sealed radioactive sources are not likely to be dangerous to the

public, adequate steps should be taken to prevent the loss of these sources, regardless of activity. Measures should be implemented to restrict the removal of these sources from specified locations and, when sources are moved, to administratively track the source locations.

(VII) Leakage Tests

29. Except for those sources consisting solely of gaseous radioactive material or tritium for which wipe test is unsuitable, accountable sealed radioactive sources should undergo a source wipe test upon receipt, when damage is suspected such as measurable contamination is detected on handling or storage equipment, and at regular intervals according to the type, design and working environment of the sealed source and the applicable statutory or licence requirements as appropriate.

30. The integrity of an accountable sealed radioactive source should be established by a wipe test or other leakage test methods as recommended in international standards such as ISO 9978:1992 and ISO 2919:1999, or some national standards such as ANSI N43.6-1977, which provide acceptable procedures for performing source leakage tests. The wipe test or other leakage tests should be conducted by competent and qualified persons who have obtained the appropriate training in radiation protection as prescribed by the licence.

31. ***Electroplated sources*** should not be tested for leakage by wiping the foil directly. An indication of leakage can be obtained by checking the storage container for radioactivity or by checking the exhaust ports of items such as gas chromatography devices.

32. The integrity of an accountable ***sealed radioactive source contained within a shield or device*** may be checked by wiping the area where contamination is most likely to occur from a failure of source integrity.

33. Due to the high whole body or extremity doses that can result, leakage tests on ***high activity sources*** should never be performed by direct contact. Remote handling devices or indirect monitoring techniques, such as monitoring of exhaust ports or accessible areas likely to be contaminated by a leaking source, should be used.

34. When the wipe test is applied directly on the external surfaces of a sealed source,

the leak-tightness of the source can be considered as acceptable if the activity detected in the wipe test sample does not exceed 0.2 kBq or approximately 5nCi.

35. If it is not possible or is undesirable to apply the wipe test directly on a sealed source so that the test is applied on the nearest accessible part and on those areas likely to be contaminated by a leaking source, further action should be taken to establish whether the activity detected in the wipe test sample arises from source leakage even if the activity detected does not exceed 0.2 kBq. One procedure would be to repeat the wipe tests at regular intervals so as to determine whether the activity detected is increasing or not.

36. An accountable sealed radioactive source is not subject to periodic source leakage testing if that source has been removed from service. However, unless leakage testing is precluded by other radiological safety considerations, these sources should be leak tested periodically to determine the condition of the source. Such sources should be stored in a controlled location, subject to periodic inventory check and source leakage testing prior to being returned to service.

37. An accountable sealed radioactive source is not subject to periodic inventory and source leakage testing if that source is located in an area that is unsafe for human entry or otherwise inaccessible, e.g. oxygen deficient or very high radiation areas. In this case, appropriate measures should be implemented to control access to the affected area and to monitor for the presence of contamination that may be spread as a result of source failure.

38. Any sealed radioactive source that fails a leakage test should be immediately removed from service and placed in a separate container to prevent the spread of contamination. All personnel and equipment including transportation vehicles and work site that were in contact with the leaking source should be checked for contamination. The leaking source should be returned to the manufacturer or sent to other qualified personnel for repair or disposal according to the written approval of the Radiation Board.

39. A suitable record of the leakage test should be kept and the following information should be included:
    i. Identification of the source
    ii. Date and reason of test
    iii. Method of test

iv. Results of test
v. Any action taken if the source failed the test
vi. Name and signature of the person carrying out the test

(VIII) Retention of records

40. Accountable radioactive source registers as well as the records of leakage tests are to be retained by the Management indefinitely even following disposal of the item, until the concerned licence is cancelled by the Radiation Board.

41. A record of the annual audit on the storage of and accounting for the radioactive sources is to be kept by the Management for 5 years from the time they were undertaken.

42. The in-out activity of radioactive sources from the storage should also be logged by a proper records system. The records should be retained until the concerned sources are properly disposed of according to the written approval of the Radiation Board. The accuracy of all source records should be verified at least annually.

(IX) Disposal of Radioactive Sources

43. Regulation 9 of the Radiation (Control of Radioactive Substances) Regulations, Cap 303A provides that "no person shall dispose of, or cause or permit the disposal of, any radioactive waste from any place otherwise than by a method approved by the Board either generally by notification in the Gazette or in writing in any particular case". Disused sealed radioactive sources or devices containing sealed radioactive sources should be returned to the manufacturer for disposal.

(X) Incidents

44. When any loss or theft of radioactive source is discovered or radioactive sources on the inventory cannot be accounted for, the user should notify the radiation protection supervisor who in turn should notify the Management. The Management is advised to report the incident immediately to the police and the Radiation Board. If such report to the latter is made verbally, it should be followed by a report in writing made within 48 hours thereafter. The

Management is required to conduct a formal search of all designated use locations, likely transfer paths, and possible collection points for the source.

45. Events of abnormal occurrence involving patients under medical care should be dealt with according to the conditions prescribed by the licence. Events of spillage or other incidents involving radioactive substances of such a nature that the safety or health of any person is or may be adversely affected thereby should be reported to the Radiation Board so soon as the fact of the event is known to the Management. At the same time, the Management should invoke the contingency plan as specified in paragraph 2(i) to prevent further damage and minimize the spread of any contamination.

References

1. DOE 1999. DOE G 441.1-13. Sealed Radioactive Source Accountability and Control Guide, dated 04-15-99. Department of Energy, US.

2. DOE G 441.1-1B, Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection; Chapter 15 “Sealed Radioactive Source Accountability and Control; Department of Energy, US (2007).

3. Control of radioactive substances, Ionizing Radiation Protection Series No 8, Health and Safety Executive Information Sheet, UK (2001).

4. Fact Sheet on Sealed Radioactive Source Management, IAEA.

5. JSP 392: Instructions for Radiation Protection, Chapter 25 “Storage and accounting for radioactive materials”, Ministry of Defence, UK.

6. JSP 392 – Radiation Safety Handbook – Volume 2, Leaflet 9 – Storage, accounting and leak testing of radioactive material, Ministry of Defence, UK (2008).

7. Code of Practice for the Security of Radioactive Source, Radiation Protection Series No. 11, Australian Radiation Protection and Nuclear Safety Agency, January 2007.

8. International Atomic Energy Agency, Categorization of radioactive sources, IAEA-TECDOC-1344, Vienna (2003).

9. ISO 9978:1992, International Standard Radiation Protection – Sealed radioactive sources - Leakage test methods.

10. ISO 2919:1999, International Standard Radiation Protection – Sealed radioactive sources - General requirements and classification.

11. ANSI (American National Standards Institute) 1977. Sealed Radioactive Sources, Classification. ANSI N43.6-1977. New York.

Appendix

Table 1 Activity for a Dangerous Source (D-value)

Radionuclide	D-value Activity Level (GBq)
Americium-241	60
Americium-241/ beryllium	60
Cadmium-109	20, 000
Caesium-137	100
Californium-252	20
Cobalt-57	700
Cobalt-60	30
Curium-244	50
Gadolinium-153	1, 000
Germanium-68	700
Gold-198	200
Iodine-125	200
Iodine-131	200
Iridium-192	80
Iron-55	800, 000
Krypton-85	30, 000
Molybdenum-99	300
Nickel-63	60, 000
Palladium-103	90, 000
Phosphorus-32	10, 000
Plutonium-238	60
Plutonium-239/ beryllium	60
Polonium-210	60
Promethium-147	40, 000
Radium-226	40
Ruthenium-106 (rhodium-106)	300
Selenium-75	200
Strontium-90 (yttrium-90)	1, 000
Technetium-99m	700
Thallium-204	20, 000
Thulium-170	20, 000
Tritium gas (H-3)	2, 000, 000
Ytterbium-169	300

Table 2 Categorization of Sources by Activity Ratio

Category	**Activity ratio (A/D)[+]**
1	A/D ≥ 1000
2	1000 > A/D ≥ 10
3	10 > A/D ≥1
4	1 > A/D ≥ 0.01
5	0.01 > A/D > Exempt/D

[+]Where:

A is the total activity of a specific radioactive source, or aggregation of radioactive sources, containing a particular radioactive isotope, in units of GBq;

D is the value specified in Column 2 of Table 1, in units of GBq.

The D-value for the specific radionuclide corresponds to the activity level at which the radioactive source is considered to be a Dangerous Source. The category of the source is mainly determined by the ratio of the activity in the radioactive source to the corresponding D-value for the radionuclide in the source (A/D).