

LEARNING OBJECTIVES:

- 2.08.01 Identify the requirements for radioactive sources at LANL.
- 2.08.02 Identify the types and emissions of common radionuclides.
- 2.08.03 Identify the packaging, marking and labeling requirements for radioactive materials and sources.
- 2.08.04 Identify the requirements for radioactive materials storage.
- 2.08.05 Describe the procedures used at LANL for radioactive sources.

LANL STANDARDS AND PROCEDURES

LP 107-04	Documenting Equipment and Item Removal
ESH-1-07-01	Releasing Equipment and Items
ESH-1-07-03	Integrity Testing Sealed Radioactive Sources
ESH-1-14-01	Packaging, Transporting, Storing, Controlling, and Handling of Radioactive Material and Radioactive Waste

REFERENCE

Implementation Guide for Occupational Radiation Protection: Sealed Radioactive Source Accountability and Control; G-N 5400.9/M1 - Rev. 1 November 1994

INTRODUCTION

A wide variety of radioactive materials are used at LANL. RCTs should know what radioactive emissions to expect, and know how these materials should be controlled.

A radioactive source is radioactive material designed to be used repeatedly as a source of radiation. These are usually sealed to prevent dispersal of the radioactive material in normal use. Radioactive sources are used for instrument response checks, performance tests, calibration, radiography, soil testing, etc.

To ensure the safety and welfare of all personnel it is important to maintain control of radioactive sources. The purpose of controlling radioactive materials and sources includes:

Minimize potential for

- Spread of contamination
- Unnecessary exposure to personnel
- Loss or theft
- Improper disposal

REQUIREMENTS FOR RADIOACTIVE SOURCES

2.08.01 Identify the requirements for radioactive sources at LANL

A radioactive source is radioactive material designed to be used repeatedly as a source of test radiation, e.g. to test radiation detectors.

The following hierarchy of regulations apply to radioactive materials and sources.

10CFR835.601a says "Radioactive materials shall be individually labeled". This applies to radioactive sources everywhere, and to other items if they are located outside a posted Contamination or High Contamination Area. Radioactive sources must always be individually labeled, even in a High Contamination Area.

Chapter 4 of the RadCon manual discusses radioactive material. Section 431 refers to DOE notice N5400.9, but this has not yet been implemented at LANL. There is also a new 1995 notice, N441.1, which is similar. Meanwhile the old LANL Administrative requirement AR3-4 applies. These are essentially similar; differences are discussed below.

The **user** of a radioactive source is accountable to the group **source custodian**.

The group **source custodian** is responsible for all sources owned by the group, and coordinates with the ESH-12 **source registrar**. At present (May 1995) the source registrar is Gil Estrada.

The following provisions apply to sealed and unsealed radioactive sources:

- Radioactive sources shall not be brought on-site without the approval of the ESH-12 source registrar.
- The group source custodian keeps an inventory, and arranges to have sources surveyed and leak tested when they are received, and periodically thereafter.

CONTROL OF SOURCES

Radioactive sources are classified according to their activity and their emissions. Obviously, the radiation from a 1 mCi source is 1000 times as much as from a 1 μ Ci source. But less obviously, 1 mCi of Pu-239 is more dangerous than 1 mCi of tritium.

Class discussion: Compare tritium, Co-60 and Pu-239; list the reasons affecting how dangerous each one is.

The Table 1 from N5400.9 and N441.1 is attached. The nuclides in the first sections have low energy emission (H-3, C-14, etc.). Nuclides with higher energy emissions have lower limits (Co-60, Cs-137, Sr-90). The alpha emitters are controlled on the basis of their ALI for internal dose, since their external radiation is small.

Sources at LANL are classified as

"**Registrable**" which corresponds roughly to "High Radiation Area";
 "**Accountable**" which corresponds roughly to "Radiation Area". and
 "**exempt**" which corresponds roughly to "Controlled Area".

The following definitions are from 10CFR835. Appendix E is from 10CFR835

•**Accountable Sealed Radioactive Source** - A sealed source with an activity equal to or greater than the value in Appendix E of 10CFR835, which is attached to this study guide.

•**Exempt Sealed Radioactive Source** - A sealed source with an activity less than the value in Appendix E of 10CFR835, which is attached to this study guide.

The following definition is from LANL AR3-4.

•**Registrable Source** - A radioactive source with activity greater than or equal to the activity listed in appendix A of the LANL AR3-4.

In summary, the following analogies may be helpful.

Registrable	Danger	High Radiation
Accountable	Caution	Radiation
Exempt	Notice	Controlled

Responsibilities:

• The **source custodian**:

- (1) is responsible for arranging leak tests (N5400.9 (7.b)) and inventory checks (N 5400.9 (7.b)).
- (2) shall notify and obtain approval of the source registrar prior to:
 - on-site transfer of a sealed radioactive source to a new permanent storage location
 - disposal or off-site transfer of a sealed radioactive source
 - any procurement or acquisition of additional sealed radioactive sources

• The source **user**

should be trained as a radiological worker, and receive appropriate training on handling specific source(s).

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surveys and leak-tests sources as requested by the custodian

Use the following precautions with radioactive sources:

- inspect the source before use.
- Wear gloves.
- Sources such as alpha emitters that cannot be covered during use shall have a container that encloses the source when not in use.
- Unsealed sources are not leak tested, but the container is leak tested.

A **user authorization agreement** (see RCT lesson 2.01) could authorize a user or custodian to perform the leak test.

TYPES OF MATERIALS AND SOURCES**2.08.02 Identify the types and emissions of common radioactive nuclides.**

Nuclide	emissions	comments
H-3	beta	very low energy
C-14	beta	low energy
P-32	beta	short half life (14 days)
S-35	beta	short half life (90 days)
Co-60	beta + gamma	

Fission Products:

Sr-90	beta (gamma)	Y-90 daughter
Tc-99	beta	
Tc-99m	gamma	short half life (6 hours)
I-131	beta + gamma	
Cs-137	beta + gamma	

Alpha emitters

Rn-222	alpha (beta, gamma)	short half life (daughters: 0.5 hour)
Ra-226	alpha (beta, gamma)	
U-235	alpha (beta, gamma)	fissile
U-238	alpha (beta, gamma)	
Pu-239	alpha (beta, gamma)	fissile

RaBe, PuBe, PuO₂ etc. neutrons

Notes:

1. emissions listed in parentheses come from the daughters
2. nuclides with $A < 140$ emit beta and/or gamma
3. nuclides with $A > 200$ have a chain of daughters emitting alpha, beta and gamma.
4. Metastable states (like Tc-99m) emit gamma
5. In a criticality accident, fissile materials emit neutrons
6. Any alpha emitter mixed with a light element (e.g. Be or O) emits neutrons

Do not confuse "fissile materials" with "fission products". Fissile materials are used to make reactors and bombs, and could fission, emitting neutrons. Fission results in "fission products" like Cs-137, I-131, Sr-90, which emit beta and/or gamma radiation but not neutrons.

Common terms related to radioactive materials:

fissionable: capable of being fissioned, e.g. U-238;

fissile: fissionable with thermal neutrons and therefore useful in a bomb or a reactor;

activated: made radioactive by external irradiation, e.g. from an accelerator beam or by an intense source of neutrons;

mixed fission products: the result of fission is generally a mixture of fission products identified on the Chart of the Nuclides with a black triangle in the corner of the square;

transuranics: long-lived nuclides with atomic number $Z > 92$.

Note: you do not need to memorize a long list of radionuclides. You need to understand notes 2 through 6 and the common terms listed above. More details on tritium, uranium, and plutonium are given in the appendix.

Class discussion. Make a list of radionuclides that you have worked with. Discuss their properties, uses, and what instruments are used to detect them.

LABELING OF RADIOACTIVE MATERIAL AND SOURCES

2.08.03 Identify the packaging, marking and labeling requirements for radioactive materials and sources.

Radioactive items or containers of radioactive materials shall be individually labeled if adequate warning is not provided by control measures and posting (10 CFR 835.601 (a) and RadCon 412.1).

Sources shall be clearly marked with the words "CAUTION, RADIOACTIVE MATERIAL" and the standard radiation symbol (10CFR835.601 b, c and d, N5400.9 (7.c.1) and RadCon 412). This applies to sources whether they are in a Contamination Area, or not.

If the radioactive source is an integral part of a larger piece of equipment, the equipment may be labeled instead of the radioactive source itself. Extremely small radioactive sources may be marked with the standard radiation symbol only, if they are stored in a larger container with space for the required identification.

The Health Physics Radioactive Materials Survey Tag **HPRMS** may be used to label radioactive materials or sources.

Class exercise. Suppose that you find an object that you suspect is radioactive. List all the information that you would want to know about it, and expect to find on the label. After making the list, compare with the information on an HPRMS tag.

RADIOACTIVE MATERIALS STORAGE AREAS

2.08.04 Describe the requirements for radioactive materials storage.

Inside a Contamination Area, everything is considered potentially radioactive. Therefore most items in the area do not have to be specifically labeled, except for sources (RadCon 411.2). Anything removed from a Contamination Area must be surveyed before being removed. This includes equipment, as well as people and anything they are carrying such as notebooks. Release of material from a radiological area is discussed in RCT lesson 2.10 objective 13.

Radioactive items outside a Contamination Area must be free of removable contamination, i.e. items must be decontaminated or bagged and tagged. Decontamination is preferable to long term storage of contaminated items.

Radioactive items outside a Contamination Area must be labeled with an HPRMS tag, or the words CAUTION, RADIOACTIVE MATERIAL and the standard radiation symbol.

Storage rooms or cabinets containing radioactive sources or materials must be:

- posted
- Located to minimize damage from fire
- Free of flammable substances
- Isolated from occupied areas or located in radiological areas or radiological buffer areas
- In continuously occupied controlled areas, the radiation level at the closest approach must not exceed 0.5 millirem per hour

PROCEDURES

2.08.05 Describe the procedures used at LANL for radioactive sources.

SURVEY

Immediately upon receipt of accountable sealed radioactive sources, the RCT should be notified.

The packaging should be inspected for damage.

The RCT surveys both for contamination and external radiation (RadCon 431.3, and ESH-1-14-01 section 7.1.1).

A source integrity test is performed upon receipt if visible damage to the package exists (N5400.9 (7.d)), or prior to initial use.

LEAK TEST (INTEGRITY TEST)

A test of source integrity shall be made every 6 months, or whenever damage might have occurred. The source custodian should initiate this process.

- **Plan** ahead.
- An **RWP** is required for registrable sources. Remember these are the equivalent of High Radiation Areas. Special posting may be required. Supplementary dosimetry is required for a registrable source.
- **Calculate** the expected dose, both whole body and extremity. The guideline in the LANL procedure is to limit the dose to 100 mrem. Without careful planning, this could easily be exceeded. Consider remote handling and finger rings.

Exercise: calculate the dose rate at 1 foot and at 1 inch from a 20 mCi Co-60 source. Calculate the stay time.

- Take an RO3 to **check** your calculations of the external radiation.
- Take a contamination monitoring instrument to read the **smears** (e.g. Ludlum 139, or ESP-1 with HP260 probe).
- Wear **gloves**. Inspect the source for damage.
- **Consult** with the source custodian. Some sources have extremely thin windows which are easily damaged. Decide whether to do a direct or an indirect test.
- The integrity of a sealed source is established by either a **direct** or **indirect** test. A direct test is made by smearing the surface of the source and counting the smear. An indirect test is made by smearing the container, or a part of the apparatus where contamination would be most likely to occur from a failure of the source integrity.
- The leak test must be capable of detecting **5 nCi**. If the smear indicates 5 nCi or more of removable contamination, the source is leaking and must be removed from service. If you detect an amount above background but less than 5 nCi, the problem should be discussed with the source custodian.

Class discussion: do you think you can detect 5 nCi with a portable instrument? Choose some examples from the list in section 2.08.02, and discuss what minimum activity you could detect with a suitable instrument.

Note. An integrity test is not required if the sealed source contains a radionuclide with a half-life of less than 30 days, liquid, or gaseous radionuclide(s). Sealed gaseous radionuclides are exempted from integrity testing because the rapidity with which the gas escapes and diffuses into the air renders the test of little value. Gaseous and liquid sealed radioactive sources should be treated as radioactive materials.

SOURCE DISPOSAL

To dispose of obsolete, excess, or leaking radioactive sources, contact the ESH-12 source registrar.

SUMMARY

The RCT needs to be knowledgeable of radioactive source controls to prevent contamination and minimize exposure. Sources may be sealed or unsealed, and accountable or exempt. Accountable sources are identified, inventoried, surveyed and leak-tested regularly.

DOE N5400.9 Exempt Quantity Values**Values for Exemption of Sealed Radioactive Sources from Inventory and Integrity Testing*****Less than 300 μCi (10^7 Bq)***

H-3	Be-7	C-14	S-35	Ca-41	Ca-45	V-49	Mn-53
Fe-55	Ni-59	Ni-63	As-73	Se-79	Rb-87	Tc-99	Pd-107
Cd-113	In-115	Te-123	Cs-135	Ce-141	Gd-152	Tb-157	Tm-171
Ta-180	W-181	W-185	W-188	Re-187	Tl-204		

Less than 30 μCi (10^6 Bq)

Cl-36	K-40	Fe-59	Co-57	Se-75	Rb-84	Sr-85	Sr-89
Y-91	Zr-95	Nb-93m	Nb-95	Tc-97m	Ru-103	Ag-105	In-114m
Sn-113	Sn-119m	Sn-121m	Sn-123	Te-123m	Te-125m	Te-127m	Te-129m
I-125	La-137	Ce-139	Pm-143	Pm-145	Pm-147	Sm-145	Sm-151
Eu-149	Eu-155	Gd-151	Gd-153	Dy-159	Tm-170	Yb-169	Lu-173
Lu-174	Lu-174m	Hf-175	Hf-181	Ta-179	Re-184	Re-186m	Ir-192
Pt-193	Au-195	Hg-203	Pb-205	Np-235	Pu-237		

Less than 3 μCi (10^5 Bq)

Be-10	Na-22	Al-26	Si-32	Sc-46	Ti-44	Mn-54	Fe-60
Co-56	Co-58	Co-60	Zn-65	Ge-68	Rb-83	Y-88	Zr-88
Zr-93	Nb-94	Mo-93	Tc-95m	Tc-97	Tc-98	Ru-106	Rh-101
Rh-102	Rh-102m	Ag-108m	Ag-110m	Cd-109	Sn-126	Sb-124	Sb-125
Te-121m	I-129	Cs-134	Cs-137	Ba-133	Ce-144	Pm-144	Pm-146
Pm-148m	Eu-148	Eu-150	Eu-152	Eu-154	Gd-146	Tb-158	Tb-160
Ho-166m	Lu-176	Lu-177m	Hf-172	Ta-182	Re-184m	Os-185	Os-194
Ir-192m	Ir-194m	Hg-194	Pb-202	Bi-207	Bi-210m	Cm-241	

Less than 0.3 μCi (10^4 Bq)

Sr-90	Cd-113m	La-138	Hf-178m	Hf-182	Po-210	Ra-226	Ra-228
Pu-241	Bk-249	Es-254					

Less than 0.03 μCi (10^3 Bq)

Sm-146	Sm-147	Pb-210	Np-236	Cm-242	Cf-248	Fm-257	Md-258
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Less than 0.003 μCi (10^2 Bq)

Gd-148	Th-228	Th-230	U-232	U-233	U-234	U-235	U-236
U-238	Np-237	Pu-236	Pu-238	Pu-239	Pu-240	Pu-242	Pu-244
Am-241	Am-242m	Am-243	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
Bk-247	Cf-249	Cf-250	Cf-251	Cf-252	Cf-254		

Less than 0.0003 μCi (10^1 Bq)

Ac-227	Th-229	Th-232	Pa-231	Cm-248	Cm-250		
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Tritium, ^3H , or T.

Tritium emits only a very low energy beta (18 keV maximum energy). This makes it very difficult to detect. Special detectors are used, see RCT lesson 2.18.05 and 2.19.02.

Tritium diffuses rapidly and is absorbed through intact skin, so a simple respirator is not sufficient. With high tritium concentrations, protective equipment includes a supplied air system (e.g. SCBA) with a pressurized suit (bubble suit) to keep the tritium out of the lungs and away from the skin.

Tritium gas (T_2 or HT) is not useful to the body and so diffuses out almost as fast as it diffuses in. Tritiated water (T_2O or HTO) is taken into the body just like regular water. Biological half life is about 10 days, physical half life is 12 years, so effective half life is about 10 days. Treatment following an intake of tritium is to drink lots of water, beer, etc., to dilute and excrete the tritium as much as possible. Bioassay is urinalysis.

Uranium, U

Natural uranium is found in the soil everywhere in concentrations of about 1 part per million (ppm), and in higher concentrations, about 1 part per thousand, in uranium ore. Natural uranium is 99.3% U-238 and 0.7% U-235. Highly enriched uranium, (sometimes called Oralloy, "Oak-Ridge alloy", or Oy) is about 93% U-235. Depleted uranium, sometimes called D-38, is what is left after most of the U-235 has been extracted from natural uranium.

Weapons grade: 93% U-235

Reactor grade: few % U-235

Natural: 0.7% U-235

Depleted: 0.3% U-235.

Uranium emits alphas, and the daughters emit alphas, betas, and gammas. Generally you can detect alphas, betas, and gammas from uranium.

U-235 and U-233 are fissile. U-238 is fissionable. Criticality is a hazard with enriched uranium but not with depleted uranium.

A small sample of pure uranium metal emits a very small number of neutrons from spontaneous fission. If the sample includes a light element (e.g. uranium oxide) there will be more neutrons from the (α, n) reaction.

After an uptake, uranium behaves somewhat like calcium and deposits on the bone. The biological half life depends on the chemical form, typically about a year.

Like most heavy metals (lead, etc.) uranium is chemically toxic. It oxidizes in air, and oxidizes rapidly in water. Under some conditions it is pyrophoric, i.e. it can catch fire. Water must not be used around uranium for two reasons: first, water is a moderator and so could cause a criticality accident, and second, water reacts chemically with

uranium.

Plutonium, Pu

There are three general categories of plutonium:

Weapons grade: 93% Pu-239, with small percentages of other isotopes

Reactor grade: smaller percentage of Pu-239, larger percentage of other isotopes

Heat-source: mostly Pu-238.

All grades of plutonium are fissile, so criticality is always a potential hazard.

All grades of plutonium emit alphas.

There are some gammas and x-rays from the daughters, but these are mostly low energy and so are easily shielded by the steel in a glove box. Pu-241 has a daughter which emits a 60 keV gamma, so the apparent activity of a freshly made sample of plutonium can increase as the plutonium decays to form more of this daughter.

There are some neutrons from spontaneous fission, mostly from Pu-240. It was the spontaneous fission of Pu-240 that made it necessary to develop the fast implosion type of bomb.

If plutonium is mixed with a light element (e.g. Be or O) there are neutrons from the (alpha,n) reaction. If plutonium oxide is shielded with a few mm of steel or lead, the low energy gammas are mostly shielded, and the neutrons become the biggest external radiation hazard.

After an uptake, plutonium deposits mostly on the bone. The biological half life is greater than 100 years, so if it gets inside you, most of it is there for life.

Like uranium, plutonium is toxic, reacts with water, and is pyrophoric. As discussed in the uranium section, do not use water around plutonium.

Summary

There are four major health concerns with uranium and plutonium:

- radioactive (alpha, beta, gamma, neutron)
- fissile (criticality)
- toxic (poison)
- pyrophoric (fire)