**LOW-LEVEL RADIOACTIVE WASTE FORUM, INC.**

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**Disposition Costs for Certain Radioactive Sealed Sources and Devices**

***Prepared by the Disused Sources Working Group***

***of the Low-Level Radioactive Waste Forum***

Radioactive sealed sources and devices are used in a variety of applications including, but not limited to, healthcare, manufacturing, construction and mineral exploration. When the radioactive sealed sources have decayed to a point where the source or device no longer functions as designed, the source can either be replaced or the entire source or device can be properly dispositioned.

Final disposition of radioactive sealed sources or devices that contain sealed sources may be accomplished by return of the item to the manufacturer, transfer to a third party for reuse or recycle, or by disposal as low-level radioactive waste. All options may not be viable, however, depending on the radionuclide and its activity. Moreover, a significant number of sources may exceed the waste acceptance criteria at licensed low-level radioactive waste disposal facilities. For such sources, if available, return to the manufacturer or transfer to a third party would be the only viable disposition options.

When evaluating disposition alternatives, a user of sealed sources or devices that contain sealed sources needs to consider long-term liability. The user should seek written assurance or confirmation of transfer of title of the source or device to the receiving facility. This will help, though not necessarily ensure, to limit future financial liability for the source or device.

The following report is intended to assist stakeholders in understanding the estimated costs to disposition radioactive sealed sources and devices that are currently in use. Readers are cautioned that the information contained in this report is intended as a guide only and does not include the entire universe of radioactive sealed sources and devices. The listed costs are provided as estimates only based on current information and guidance and should not be relied upon as determinative of actual future disposal costs.

*For additional information, please visit the website of the Disused Sources Working Group (DSWG) of the Low-Level Radioactive Waste Forum (LLW Forum) at* [*www.disusedsources.org*](http://www.disusedsources.org)*.*

The following sections provide information on the available options and estimated costs to disposition certain radioactive sealed sources and devices as identified in Table 1. Additional information regarding the current commercial sealed source disposal landscape is contained in Table 2.

**Industrial Radiography**

Industrial radiography is a non-destructive inspection technique used to determine the integrity of pipes, vessels and other components and identify manufacturing defects and other flaws that may impact system performance. Defects including cracks, incomplete welds and porosity in tubes can be identified. Radiography can be accomplished using gamma or x-rays.

The primary radionuclides used in industrial radiography are Ir-192 and Co-60. The source is housed in a shielded storage container when not in use. When used, the source is advanced through a tube using a cable drive system to the item being inspected. The gamma rays passing through the item are recorded on film placed on the other side from the source or detected electronically.

Ir-192 has a relatively short half-life of 75 day. These sources require frequent exchange with used sources being returned to the manufacturer, the cost of which is included in the price of the new source. At the time of final source disposition, the source can be returned to the manufacturer or disposed as low-level radioactive waste.

The cost to return to industrial radiography sources to a manufacturer is typically *[need to add amount].*

**Fixed Industrial Gauges**

Fixed industrial gauges are used throughout industry to monitor and control process equipment. Example uses include devices to measure thickness, density, specific gravity, flow rate or tank fill level. The primary radionuclides used in fixed industrial gauges are Cs-137 and Am-241/Be. The source activity ranges from a fraction of a curie to tens of curies.

When the device is no longer needed, the source/device may be returned to the manufacturer, transferred to a source distributor/recycler or disposed as low-level radioactive waste. The cost to recycle these sources range from approximately $1,500 to $5,000 not including removal, packaging and transportation. Technician costs to package and transport can add approximately $6,000 to $8,000, depending on the number of sources and the transportation distance. The cost to dispose of an industrial gauge ranges from approximately $1,000 to $5,000. The cost to remove a fixed industrial gauge is a function on how hard it is to remove the gauge from service. Gauges that are mounted high on a vessel are more labor intensive than a gauge mounted at floor level, resulting in a higher cost.

**Well Logging Sources**

Well logging is a technique to measure the properties of geologic strata by inserting specialized instruments down a borehole. Most downhole well logging occurs in the oil and mineral exploration industry. Some of these instruments use radioactive sealed sources.

Primary radionuclides used in well logging include Am-241 and Cs-137. These sources range in activity from one-half curie to 20 curies. The cost to transfer these sources to a distributor will range from approximately $2,500 to $4,500 per source. This does not include packaging or transportation. The fee for a service technician to package and transport the sources to the distributor is approximately $6,000 to $8,000, depending on the number of sources and transportation distance.

**Brachytherapy**

Brachytherapy or internal radiation therapy involves placing small radioactive sealed sources in or near the tissue to be treated or injecting radioactive material in the bloodstream or body cavity. The type of radioactive material and delivery method is determined based on the tissue being treated and the required dose to be administered. Placement of the sources can be temporary or permanent. In temporary brachytherapy, the source is placed inside a catheter or tube that has been inserted in or near the tissue to be treated for a short period of time and then withdrawn. Permanent brachytherapy involves placing the source in or near the tissue to be treated and leaving it there permanently.

Table 1 identifies the radionuclides associated with brachytherapy. Some of the radionuclides have short half-lives and can be decayed in storage until it is no longer radioactive. Disposal and recycling of the longer-lived radionuclides range from approximately $5 per Ir-192 seed to $4,500 for the Cs-137 and Co-60 sources. An Sr-90 beta eye applicator disposal cost range is approximately $2,000 to $3,000.

**Portable Gauges**

Portable gauges are primarily moisture/density gauges used in the construction industry to measure soil, asphalt and concrete density, as well as soil and rooftop moisture. The American Portable Nuclear Gauge Association describes the devices as follows:

Mechanically, all soils and asphalt moisture density gauges work the same. The gauges have a source rod that lowers into the ground to measure wet density and another stationary source contained in the base of the gauge that measures moisture.

The gauges use Cs-137 sources to measure density and Am-241 sources to measure moisture. When purchasing a new gauge, most gauge manufacturers will accept back an old gauge as part of the purchase price. Disposal cost for a gauge without purchase of a new gauge ranges from approximately $750 to $1,500 plus shipping.

**Teletherapy**

Teletherapy devices use ionizing radiation to treat diseases such as cancer. These devices can precisely focus high-energy gamma rays to treat diseases. The use of external beam teletherapy using radioactive sealed sources has decreased over time corresponding with the increase use of linear accelerators. External beam teletherapy units can be used to treat any part of the body.

There is a multi-beam teletherapy device called a Gamma Knife that utilizes approximately 200 Co-60 sealed sources arranged to focus the gamma rays on a specific locus in the brain. The patient can be moved so that the tissue to be treated can be located at this locus. This device is limited to treating tissue in the brain only.

From a radioactive material inventory perspective, these items are similar to self-contained irradiators. Due to the high activity, these sources are not suitable for disposal at the current low-level radioactive waste disposal facilities. The cost to return these items to the manufacturer is approximately in the $200,000 to $400,000 range. There are some site-specific conditions that may dramatically impact the cost. Because these units require shielding, some building dismantlement may be needed to get the units out of the facility.

**Irradiators**

The American National Standards Institute (ANSI) has established four categories for irradiators. They include Category I – Self-Contained Irradiator (dry source storage); Category II – Panoramic Irradiator (dry source storage); Category III – Self-Contained Irradiator (wet source storage); and, Category IV – Panoramic Irradiator (wet set source storage). These categories should not be confused with the International Atomic Energy Agency (IAEA) radioactive sealed source categories.

Panoramic Irradiators:

Panoramic irradiators are used for the bulk sterilization of medical supplies and equipment, consumer goods (such as cosmetics) and some food products. These facilities use millions of curies of cobalt-60, a gamma emitter. The sources in a Category II and IV irradiators are typically stored below floor level and are raised to room level when in use. Source storage is either in a shielded storage container (Category II) or in a pool of water (Category IV). The irradiator room has access controls to prevent the sources from being raised while personnel are in the room.

The panoramic irradiator can be operated in either batch mode or in a continuous mode. When operated in batch mode, the items to be sterilized are placed in the irradiator room in an arrangement where they will be exposed to the sources when the sources are raised. In a continuous mode, the items to be irradiated are passed in front of the raised sources via an automated conveyor system. Exposure time is determined based on the desired dose the products are to receive.

Category IV irradiators contain millions of curies of Co-60. With this large quantity of sealed sources, the most viable disposition path is returning the sources to the manufacturer. Disposing of this quantity of radioactive material is not viable at the existing low-level radioactive waste disposal facilities.

There are many cost components in decommissioning a panoramic irradiator. These cost components include onsite source removal, equipment rental, Type B shipping container rental, transportation and source disposal fee. As a reference for the total cost to decommission, the aggregate costs can range from $750,000 to $2,500,000. Source disposal costs represent approximately 50% of the total cost to decommission. The remainder of the costs is associated with onsite work and transportation. Costs may vary due to location, distance for transportation and total source activity.

Self-Contained Irradiators:

Self-contained or self-shielding irradiators are used to irradiate small quantities of material in a batch mode process. These irradiators can use radioactive material (Cs-137 or Co-60) or x-rays to provide the required dose. The size of these irradiators will vary, but they typically have a footprint of 8 to 15 square feet and can weigh two thousand to six thousand pounds.

A Cs-137 blood irradiator is one example of a self-contained irradiator. These irradiators typically have a 15to 20-year operating life and with a 30-year half-life they don’t require re-sourcing during their useful life. Total activity of the sources range from 600 to 3,000 curies or more. Disposal of Cs-137 at the existing low-level radioactive waste disposal facilities can be problematic. The waste acceptance criteria limits source activity. Also, these items require transportation in a Type B container, which currently costs approximately $80,000 to $100,000 to rent. Irradiator manufacturers maintain their own Type B containers so this cost is not incurred when returning the device to the manufacturer.

Disposition costs including return of the device to the manufacturer ranges from approximately $60,000 to $100,000. This cost is reduced if the device is being swapped out with a new irradiator. There are substantial cost savings since manufacturer staff is onsite and there are no empty Type B container shipments.

There are larger self-contained irradiators in use, primarily in research applications. These irradiators will use tens of thousands of curies of Co-60 to achieve a higher dose rate. Costs to return these irradiators to the manufacturer are approximately $200,000.

**Table 1 – Widely Used Radioactive Sealed Sources[[1]](#footnote-1)**

| **Device** | **Radionuclide** | **Typical Activity in Curies (Ci) Range** | **IAEA Source Categorya** | **Waste Classb** |
| --- | --- | --- | --- | --- |
| Panoramic irradiators used to irradiate single-use medical devices and products, cosmetics, food, and plastics. | Cobalt-60c | 150,000 -5,000,000 | 1 | B |
| Self-shielded irradiators/blood-tissue irradiators. | Cesium-137 | 2,500-42,000 | 1,2 | B, C, GTCC |
| Cobalt-60c | 1,500-50,000 | 1 |
| Gamma knife (fixed, multibeam teletherapy). | Cobalt-60c | 4,000-10,000 | 1 | B |
| Teletherapy, which uses radiation directed at a human or animal body to treat many serious diseases, most notably cancer. | Cesium-137 | 500-1,500 | 2 | B, C |
| Cobalt-60c | 1,000-15,000 | 1 |
| Calibration sources, generally used to calibrate various radiation measuring and monitoring instruments | Americium-241 | 1-25 | 2,3,4 | A, B, C, GTCC |
| Cesium-137 | 1.5-14,000 | 1,2,3,4 |
| Cobalt-60c | 0.55-16,000 | 1,2,3,4 |
| Plutonium-239/ Beryllium | 2-25 | 2,3 |
| Strontium-90 | 0.05-2 | 4 |
| Industrial radiography widely used in the chemical, petrochemical, and building industries for radiographic inspection of pipes, boilers, and structures where consequences of failure can be severe. | Cesium-137 | 5-12 | 3 | A, B, C, GTCC |
| Cobalt-60c | 11-330 | 2 |
| Iridium-192 | 5-290 | 2,3 |
| Selenium-75 | 80 | 2 |
| Thulium-170 | 20-200 | 4 |
| Ytterbium-169 | 2.5-20 | 3,4 |
| Fixed industrial gauges (level, dredger, conveyor, blast furnace, and spinning pipe) used for a wide variety of industrial and manufacturing purposes, primarily to monitor production processes. | Cesium-137 | 0.1-40 | 2,3,4 | A, B, C, GTCC |
| Cobalt-60c | 0.1-20 | 2,3,4 |
| Plutonium-238 | 20 | 2 |
| Californium-252 | 0.034 | 4 |
| Krypton-85 | 0.05-1 | 5 |
| Well-logging sources used for characterizing subsurface properties such as density and moisture percentages. Most commonly associated with oil and mineral exploration. | Americium-241/ Beryllium | 0.5-20 | 2,3,4 | A, B, C, GTCC |
| Californium-252 | 0.027-1.61 | 3,4 |
| Cesium-137 | 0.5-20 | 3,4 |
| Cobalt-60c | 1-20 | 2,3 |
| Plutonium-238/ Beryllium | 5-70 | 2,3 |
| Radium-226 | 20 | 2 |
| Tritium | 1-20 | 5 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Brachytherapy (high, medium and low dose rate), which uses either beta or gamma sources to irradiate tumors over a very small area and thickness of tissues. | Cobalt-60c | 1-20 | 2,3 | A, B, C, GTCC |
| Cesium-137 | 0.1-8 | 3,4,5 |
| Iridium-192 | 0.02-15 | 3,4,5 |
| Radium-226 | 0.005-0.05 | 4,5 |
| Iodine-125 | 0.005-1.3 | 4,5 |
| Gold-198 | 0.08 | 4 |
| Californium-252 | 0.083-0.54 | 3,4 |
| Strontium-90 | 0.02-0.12 | 4,5 |
| Ruthenium/ Rhodium-106 | 0.00022-0.0006 | 5 |
| Palladium-103 | 0.03-0.0056 | 5 |
| Cardiac pacemakers. | Plutonium-238 | 2.9-8 | 3 | B, C GTCC |
| Research reactor startup sources. | Americium-241/ Beryllium | 2-5 | 3 | B, C, GTCC |
| Static eliminators used in the production of paper, textiles, plastic and electrical circuits. They are particularly useful in hazardous areas where electrical devices cannot be used. | Americium-241/ Beryllium | 0.03-0.11 | 4 | A, B, C, GTCC |
| Portable gauges (moisture and density) used in the field at construction sites and on farms. The gauges are typically used to determine the moisture and density of a material such as soil or asphalt. | Americium-241/ Beryllium | 0.01-3 | 3,4,5 | A, B, C, GTCC |
| a. The International Atomic Energy Agency (IAEA) categorization system is based on “the potential for radioactive sources to cause deterministic health effects. This potential is due partly to the physical properties of the source, especially its activity, and partly to the way in which the source is used.” See, IAEA Safety Guide No. RS-G-1.9, Categorization of Radioactive Sources 2005, Annex I, page 37, available at http:// www-pub.iaea.org/MTCD/publications/PDF/Pub1227\_web.pdf.  b. Refers to Nuclear Regulatory Commission’s (NRC’s) classification of LLRW for land disposal found in 10 CFR Part 61. Activity per unit mass or volume classification limits are related to relative hazard and necessity for waste isolation. Class A represents the least hazard, Class B represents a greater hazard, and Class C the greatest hazard appropriate for near surface disposal. Waste with an activity concentration Greater- Than-Class-C (GTCC) must be disposed of in a geologic repository unless NRC approves an alternate disposal site.  c. There are no limits established for cobalt-60 in Class B or C wastes. Practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations for these wastes. These wastes shall be Class B unless the concentrations of other nuclides in Table 2 in 10 CFR § 61.55 determine the waste to be Class C independently of these nuclides. | | | | |

**Table 2 – The Current Commercial Sealed Source Disposal Landscape[[2]](#footnote-2)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Maximum Limit Alloweda** | | | |
| **Non-GTCC Sources** | | | **GTCC Sources** |
| **Barnwell Facility (3 States)** | **Richland Facility (11 States)** | **Texas Facility**  **(36 States)** | **GTCC Facilityb** |
| Americium-241 Plutonium-238 Plutonium-239 | | 10 nCi/gm | 100 nCi/gm | 100 nCi/gm | >100 nCi/gm |
| Californium-252 | | 10 Ci | 13 Cic | 13 Cic | Not applicabled (NA) |
| Curium-244 | | 100 nCi/gm | 100 nCi/gm | 100 nCi/gm | >100 nCi/gm |
| Cobalt-60 | | 10 Ci | 145 Cic | 145 Cic | NAd |
| Cesium-137 | | 10 Ci | 976 Ci | 976 Ci | >976 Ci |
| Iridium-192 | | 10 Ci | 13 Cic | 13 Cic | NAd |
| Strontium-90 | | 10 Ci | 1,486 Ci | 1,486 Ci | >1,486 Ci |
| Radium-226 | | Disposal of radium-226 is available to all states at the Richland facility up to 1.2 Ci per source.e | | | NAd |
| Color Code | | | | | |
|  | Disposal available commercially for Compact states up to maximum Class C limits for applicable radionuclides, considering concentration averaging. | | | | |
|  | Disposal available commercially for Compact States but maximum limit is less than Class C limits for applicable  radionuclides due to site-specific administrative limits, waste acceptance criteria, or license conditions. | | | | |
|  | Disposal capability being developed by DOE.b | | | | |
| 1. The maximum curie or activity limit allowed for an individual sealed source containing the specified radionuclide based on site-specific administrative limits, waste acceptance criteria, application of concentration averaging, or license conditions. 2. A GTCC LLRW disposal facility does not currently exist; DOE is preparing an Environmental Impact Statement analyzing potential disposal alternatives for this waste. The maximum limit for the facility will be determined during the implementation and licensing phase for the selected alternative and will be greater than the Class C waste classification values shown in the Table (which assumes application of concentration averaging). 3. The facility may accept sources in excess of this limit on a case-by-case basis based on worker exposure and other site-specific considerations. 4. Sealed sources consisting of these radionuclides are not classified as GTCC LLRW when sent for disposal because there is no maximum Class C limit for the radionuclide or the radionuclide is not included in the list of radionuclides in 10 CFR § 61.55, Tables 1 and 2 that determine LLRW classification. 5. Diffuse radium-226 is still considered naturally occurring radioactive material (NORM) for purposes of disposal, but discrete Ra-226 sources are now considered "byproduct material" per the NRC and compatible Agreement State regulations. However, the *2005 Energy Policy Act* has excluded radium-226 sources as LLRW, and some compact regulations still consider radium-226 containing waste as NORM. Disposal options are therefore still available to all states. | | | | | |

1. Excerpted from *Sealed Source Disposal and National Security – Problem Statement and Solution Set,* which was a deliverable of the Removal and Disposition of Disused Sources Focus Group of the Radioisotopes Subcouncil of the Nuclear Government and Sector Coordinating Councils, dated December 9, 2009. This table identifies some of the sealed source devices and uses, the radionuclides and activity, categorization by the International Atomic Energy Agency (IAEA) and waste classification for disposal purposes. [↑](#footnote-ref-1)
2. Excerpted from *Sealed Source Disposal and National Security – Problem Statement and Solution Set” which was a deliverable of the Removal and Disposition of Disused Sources Focus Group of the Radioisotopes Subcouncil of the Nuclear Government and Sector Coordinating Councils,* dated December 9, 2009. This table was updated to reflect the acceptance criteria for the Texas Low-Level Radioactive Waste Disposal Compact facility that is located in Andrews County, Texas since the facility was not operational when the report was published. [↑](#footnote-ref-2)