U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD

CESIUM AND STRONTIUM CAPSULES

OVERVIEW[1]

Cesium and strontium[2] were extracted from the liquid high-level radioactive waste (HLW) stored in underground tanks at the Hanford site in order to remove them as a heat source and, thus, reduce the temperature of the waste in the tanks. The cesium and strontium were precipitated in the form of cesium carbonate and strontium nitrate, respectively, at the Hanford B Plant from 1967 to 1985. From 1974 to 1985, the cesium carbonate and strontium nitrate were converted into cesium chloride and strontium fluoride, respectively, and sealed within double-walled capsules at the Waste Encapsulation and Storage Facility (WESF). The loaded capsules were then transferred to water-filled pools at the facility for storage. There are 1,335 cesium capsules and 601 strontium capsules stored at the WESF.

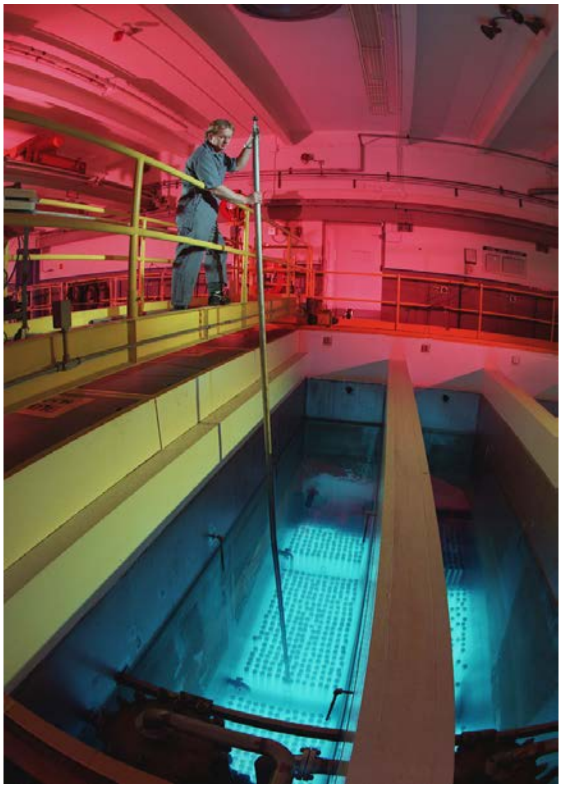

Figure 1. Pool Storage of Cesium and Strontium Capsules at the Waste Encapsulation and Storage Facility at Hanford (Gephart 2003).

STORAGE AND LOCATION

At the WESF, the cesium and strontium capsules are stored under 13 ft (4.0 m) of water in pools lined with stainless steel. Figure 1 shows one of the WESF water pools. The water aids both in cooling the capsules and in providing shielding to protect plant operators and equipment from radiation.

Some cesium and strontium capsules were sent to the Oak Ridge National Laboratory Office of Isotope Sales for dismantling and to allow the sale of the cesium and strontium for potential commercial use (e.g., thermoelectric generators or sterilizers). Hundreds of cesium capsules also were leased for commercial use and government research purposes in the 1980s. However, in 1988, after a cesium leak from a leased capsule was detected at Radiation Sterilizers, Inc. in Decatur, Georgia, the capsules were recalled and returned to the WESF. In 1983, four strontium capsules were permanently disposed of in a shallow, 36-m (120-ft) test borehole at the Nevada Test Site (Cochran *et al.* 2001).

COMPOSITION

Cesium Capsules

The cesium capsules were created by melting cesium chloride at 730 to 750°C (1,350 to 1,380°F) and pouring the molten cesium chloride into stainless steel inner capsules that were welded shut (DOE 1990).

[1] Unless explicitly stated, this fact sheet does not present Board findings, conclusions, or recommendations and none should be inferred from its content.

[2] Cesium and strontium are fission products of uranium and their radioisotopes are considered biological hazards because of their potential uptake into plants and, thus, transmission through the food chain into the human body.

These capsules subsequently were placed into stainless steel outer capsules that also were welded shut. The inner and outer capsules together are referred to as a “standard capsule.” Figure 2 shows a schematic diagram of a standard cesium capsule. The outer capsule has an outside diameter of 2.63 in (6.68 cm) and a total length of 20.78 in (52.78 cm) (SNL 2014). The cesium chloride content of the capsules ranges from approximately 2.9 to 7.1 lb (1.3 to 3.2 kg) (Tingey *et al.* 1984).

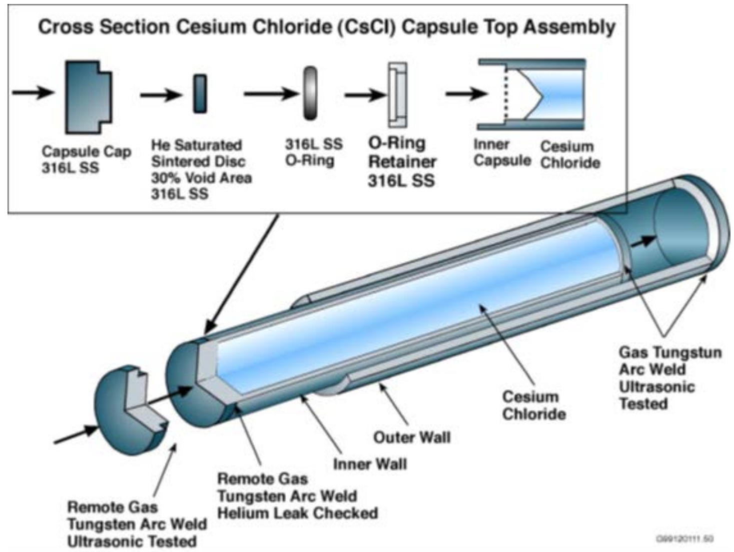

Figure 2. Schematic Diagram of a Standard Cesium Capsule (Plys and Miller 2003).

The 1,335 cesium capsules stored at the WESF include 1,312 standard capsules and 23 Type W overpack capsules. The Type W overpack capsules, which also are made of stainless steel, have an outside diameter of 3.25 in (8.26 cm) and a total length of 21.83 in (55.45 cm) (SNL 2014). Most of the Type W overpacks contain cesium capsules that have swelled because of expansion of the cesium chloride due to a phase change. The phase change is explained further in the Stability and Radionuclide Release section. Due to this swelling, the cesium capsules do not meet the acceptance criteria for the WESF storage pools without an overpack.

The radioisotope content of the cesium capsules is mostly short-lived cesium-137 (with a half-life of 30.2 years), while the rest is long-lived cesium-135 (with a half-life of 2.3 million years). Cesium-137 initially is the main contributor to radioactivity but, after several hundred years, cesium-135 will become the dominant source of radioactivity. Eventually, all of the cesium will decay to barium-137 and barium-135, which are both stable isotopes. The cesium capsules also contain chemical impurities, including chloride compounds of alkali and alkaline earth elements, aluminum, chromium, iron, lead, and silicon. (DOE 1990).

Strontium Capsules

In preparation for loading into capsules, the strontium nitrate was converted into strontium fluoride at the WESF and then dried at temperatures in the range 800 to 950°C (1,470 to 1,740°F) in a drying pan (SNL 2014). Capsules fabricated from Hastelloy™ (a metal alloy composed mainly of nickel, chromium, and molybdenum) were loaded with dried strontium fluoride that was chipped from the drying pan and compacted. Capsules were welded shut and placed into outer capsules made of stainless steel or Hastelloy™, which also were welded shut. The strontium capsules are approximately the same size as the standard cesium capsules. Strontium-90 has a half-life of 28.8 years and decays to yttrium-90, which has a half-life of 64 hours. Eventually, all of the yttrium-90 will decay to stable zirconium-90.

Of the 601 strontium capsules stored at the WESF, 411 were filled using the method described in the preceding paragraph. These capsules are referred to as “standard capsules.” An additional 189, referred to as “waste capsules,” were filled with strontium fluoride that had fallen onto surfaces such as floors and tables during the strontium chipping process. One strontium capsule, called the tracer capsule, was filled with non-radioactive strontium.

The strontium “standard capsules” contain chemical impurities consisting of barium, lead, cadmium, chromium, and silver (Fluor Hanford 2000). The strontium “waste capsules” also could contain inorganic materials from the drying room surfaces and some of these capsules contain pieces of equipment, building materials, metals and metal fluorides, and other chemicals that were inadvertently mixed with the waste while collecting strontium fluoride from facility surfaces. Some strontium waste capsules may contain as much as 50% foreign materials (SNL 2014). Figure 3 shows the distribution of the different types of cesium and strontium capsules in inventory.

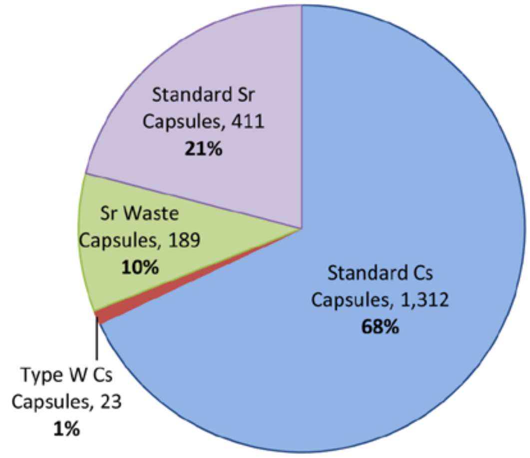

Figure 3. Distribution of Radioactive Cesium and Strontium Capsule Types Stored at Hanford.
Note: Data from SNL (2014). The single non-radioactive strontium capsule is not represented in the figure.

MASS AND RADIOACTIVITY

The total mass of the cesium and strontium capsules and their contents is approximately 15 metric tons (National Research Council 2003). The cesium and strontium capsules contain an average of approximately 6 lb (2.7 kg) of their respective materials (Randklev 1994). The total radioactivity of the cesium, strontium, and daughter products in the capsules is projected to decrease to 82 million curies (Ci) by January 1, 2021 (SNL 2014). The cesium and strontium capsules contain over a third of the total radioactivity at the Hanford Site, the remainder of which is stored mostly as HLW in underground tanks (SNL 2014). Due to the relatively short half-lives of cesium-137 and strontium-90, capsule radiation will diminish significantly over several hundred years, rather than tens of thousands of years, or longer, for longer-lived radionuclides (OTA 1991).

STABILITY AND RADIONUCLIDE RELEASE

Cesium chloride can undergo a phase change as a result of the heat produced by radioactive decay. This phase change occurs at about 450°C (840°F) with pure cesium chloride. However, depending on the impurities present with the cesium chloride, the phase change may occur between 300 and 500°C (570 and 930°F) (DOE 1990). When cesium chloride undergoes a phase change, its crystal structure alters, resulting in an increase in volume that can cause the cesium capsule to bulge. This can result in failure of the capsule, increasing the possibility of radioactive material being released. Cesium chloride is very soluble in water, so any breach of a stainless-steel capsule could release radioactive cesium to the environment, for example to the pool water at the WESF. In contrast to cesium chloride, strontium fluoride is highly insoluble in water, which would result in a low radionuclide release rate if a strontium capsule were breached due to corrosion. The WESF pool water temperature is maintained below 50°C (122°F) (DOE 1990), which minimizes the potential for cesium chloride capsule swelling and breach during storage at the facility.

PATH FORWAD FOR MANAGING CESIUM AND STRONTIUM CAPSULES

The WESF is more than 10 years past its 30-year design life and “is experiencing degradation of key structures and safety systems, including the concrete walls of the storage pool due to gamma radiation emitted by the capsules” (DOE 2018). In 2018, the U.S. Department of Energy (DOE) concluded that “its preferred alternative for interim storage of the capsules is in a new dry storage facility” (DOE 2018). The cesium and strontium capsules will be packaged and sealed into protective, stainless steel sleeves, which then will be packed into steel-lined, reinforced concrete casks for storage on an outdoor concrete pad, similar to how commercial spent nuclear fuel is currently stored (DOE 2020). DOE currently is working to construct the dry storage facility where the capsules will be stored until a decision on their final disposition is made.

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The U.S. Nuclear Waste Technical Review Board is an independent federal agency established in the 1987 amendments to the Nuclear Waste Policy Act (NWPA).

The Board evaluates the technical and scientific validity of U.S. Department of Energy activities related to implementing the NWPA and provides objective expert advice on nuclear waste issues to Congress and the Secretary of Energy.

The eleven Board members are nominated by the National Academy of Sciences and are appointed by the President.

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