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WESF ^{137}Cs GAMMA RAY SOURCES

by

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ABSTRACT

The Waste Encapsulation and Storage Facility (WESF) at Hanford, Washington has been separating cesium from stored liquid defense waste since 1945. This is done to alleviate the heat generated by the decay of radioactive ^{137}Cs.The cesium is converted to CsCl, doubly encapsulated in 316L Stainless Steel, and placed in storage. Recently, the By-products Utilization Program has demonstrated the potential utility of these WESF ^{137}Cs capsules as gamma radiation sources. Registration of the WESF ^{137}Cs capsule with the NRC as a sealed gamma source would facilitate the licensing of non-DOE irradiation facilities using this source. To grant this registration, the NRC requires information on the physical, chemical and radiological characteristics of the capsule. It must also be demonstrated that the capsule will maintain its integrity under both normal circumstances and specified abnormal conditions. This report provides the required information through collation of results of studies and tests done previously by other laboratories.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Con't)

TABLE OF CONTENTS (Con't)

1.0 INTRODUCTION

The chemical reprocessing of irradiated nuclear fuels in the Hanford Chemical Separations areas since 1945 has resulted in generation of significant volumes of high-level liquid radioactive wastes [1-3]. These wastes have been contained as alkaline slurries in underground, carbon steel-lined, reinforced concrete tanks. A program has been undertaken with the main goal being the ensured isolation of hazardous radioisotopes from life forms. One part of this program is the B-Plant Waste Encapsulation and Storage Facility (WESF) in Hanford, Washington, which reprocesses the liquid portion of the stored wastes to remove cesium and strontium individually, followed by conversion to and separate encapsulation of the solid forms, CsCl and SrF_2 [4-6]. The remaining wastes are converted to salt cake in the underground waste storage tanks for an indefinite storage period.

The initial impetus for the separation of cesium and strontium from the liquid waste was to reduce heat generation (from the radioactive decay of ^{90}Sr and ^{137}Cs) within the defense waste and to provide physical systems suitable for long-term, interim storage of ^{90}Sr and ^{137}Cs [7, 8]. However, these encapsulated materials recently have been recognized to have possible utility which could delay their immediate disposal. For example, SrF_2 has proven to be an effective heat source for use in thermoelectric systems [9-11].

To investigate additional possibilities, the By-product Utilization Program (BUP) was initiated with the mission to develop the means for application of radioactive fission products for the benefit of society [12-14]. At the present time, effort is being focused on ^{137}Cs. About 33 percent of the cesium recovered in WESF processing is radioactive ^{137}Cs (30-year half-life) which decays by beta emission in conjunction with 0.662 MeV gamma rays (see Fig. 1) [15, 16]. The remainder of the cesium is stable ^{133}Cs with small amounts (<1 percent) of 2.06-year ^{134}Cs and 2.3×10^6-year ^{135}Cs. The gamma ray emission rate (1.6×10^{14} gamma rays/min-g ^{137}Cs) and energy (0.662 MeV) from ^{137}Cs indicate that a WESF Cs capsule could serve as a gamma-radiation source ($0.9\text{-}1.5 \times 10^{17}$ gamma rays/min-capsule). One possible use is the gamma irradiation of sewage sludge to disinfect it sufficiently so that it can be used legally as an unrestricted soil amendment or fertilizer [14-17]. This has shown sufficient promise so that a pilot plant has been built by SNLA and used for several years [18]. This technology is being made available to municipalities who would want to include it in their sewage treatment plants.

However, the WESF Cs capsules were designed for waste storage, not as gamma radiation sources [4-8], and have not been registered by the NRC for use as sealed radiation sources. DOE facilities are exempt from NRC licensing requirements. However, this registration would facilitate the licensing for non-DOE operation of ^{137}Cs irradiators which could use these sources [19]. For the WESF Cs capsules to be considered by NRC for registration, specific information must be provided, e.g. the radiation and physical characteristics, the normal and possible adverse conditions of environment and operation, test descriptions and results which establish the gamma source integrity under normal and adverse conditions, and the quality control (QC) program used to ensure reproducibility in the gamma source production [20, 21].

RAD.	E(MeV)	% ABUND.
β-1	0.5116	94.6
β-2	1.1732	5.4
γ-1	0.6616	85.2

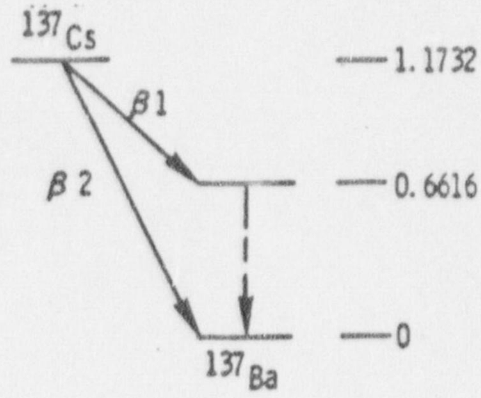


Figure 1. Decay Scheme for ^{137}Cs.

The purpose of this publication is to provide in detail the information required by the NRC for registration of the WESF Cs capsule as a sealed gamma source. Appendix A outlines the information required. The document to be presented to NRC will follow the format in Appendix A, using information condensed from this publication.

2.0 WESF Cs CAPSULES (SEALED GAMMA RADIATION SOURCE)

At the present time, WESF Cs capsules are being used as the gamma radiation source in the pilot plant known as the Sandia Irradiator for Dried Sewage Solids (SIDSS) facility (Fig. 2) [18]. The environment experienced by radiation sources in SIDSS is described below and is expected to be similar to that which will be present in full scale irradiators.

2.1 Environment and Operating Conditions. The normal operating environment to be experienced by gamma-source pins (WESF Cs capsules), which are suspended by a mechanical fixture, will be a forced air flow. Loading and unloading operations from a shipping cask will be done in a water-filled pool and will involve storage of the capsules in the pool for various periods of time. The exterior surface temperature of a pin in quiescent air is nominally 200-220°C while the centerline temperature of each pin is approximately 450°C. The capsules will have a useful lifetime as a gamma source of at least 30 years (one half-life of ^{137}Cs).

As currently envisioned, a source plaque will hold approximately 20 of the source pins and is open to enhance heat dissipation by convection. During operations, the only physical contact made by the source pins is with the source plaque structure. Material to be irradiated is transported by a mechanical conveyor and does not come into contact with the gamma-source pins.

2.2 <u>Production of WESF Cs Capsules.</u> The solution containing cesium in the underground storage tanks is removed and purified by ion exchange, and subsequently converted to solid cesium chloride [22-26]. This salt is melt-cast into a doubly encapsulated 316L stainless steel source pin (WESF Cs capsule) at a temperature of 740°C (melting point of CsCl is 646°C). The ^{137}Cs content of each pin, determined by calorimetry, is nominally 50-70 kCi with 80 kCi being the maximum allowed [22]. The chemical and physical processing involved from the purification through melt casting of cesium chloride can be divided into five steps. Each of these is discussed below and shown schematically in Figures 3 and 4. The concentrations given for both cesium and impurities are representative and should not be considered as specifications.

2.2.1 Ion Exchange Purification. Crude cesium feed is diluted with water, the pH is adjusted to 9 ± 3 with NaOH, and the solution is passed through a Zeolon ion exchange bed in a downflow mode as shown in Figure 3. The Zeolon removes cesium from solution. A dilute $(NH_4)_2CO_3/NH_4OH$ scrub solution

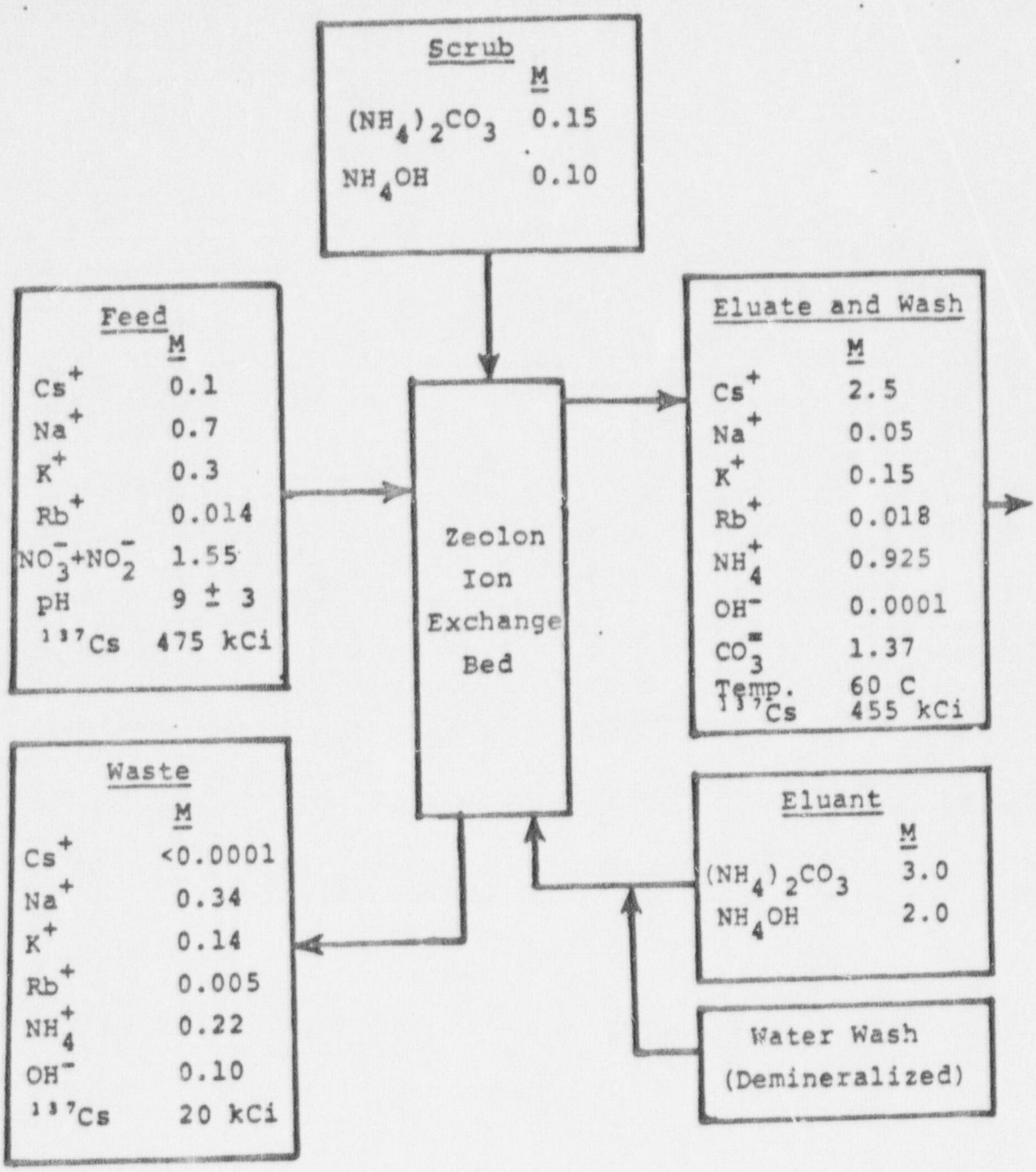


Figure 3. Flow Diagram With Representative Solution Compositions for Ion-Exchange Purification of Cesium. Subsequent Processing to Produce CsCl Removes NH_4, CO_3, and OH (See Figure 4). The concentrations given in this table are representative and should not be considered as specifications.

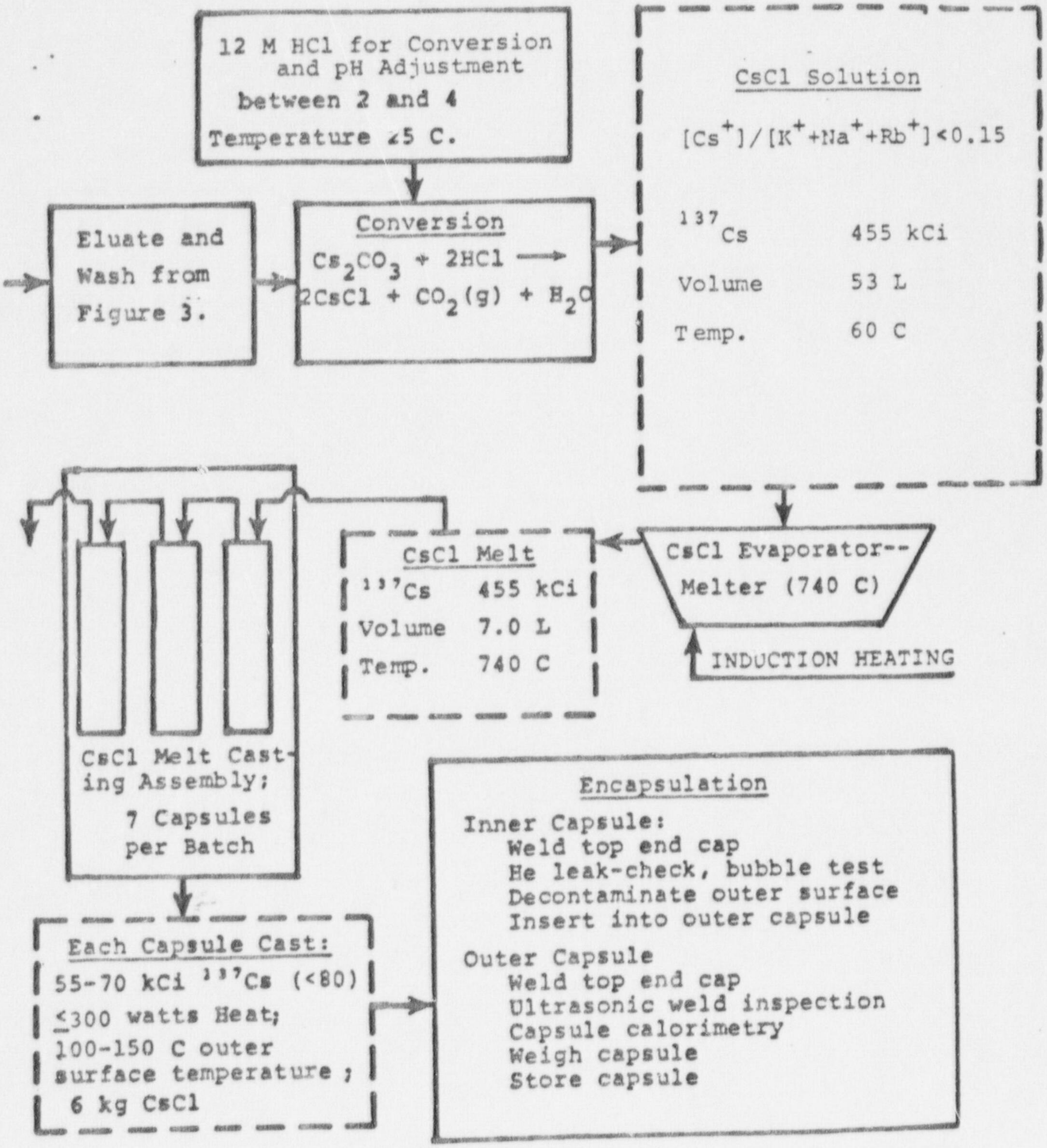


Figure 4. Outline of Cesium Carbonate to Cesium Chloride Conversion and Subsequent Encapsulation by Melt-Casting.

Only the $[Cs^+]/[K^+ + Na^+ + Rb^+]$ ratio is a specification; all other numbers are only representative.

is passed down through the bed to both flush out anionic impurities and to remove as many cationic impurities (e.g. Na^+, K^+, Rb^+) as possible. Elution of cesium from the Zeolon ion exchange bed is accomplished by upflow of 3 M $(NH_4)_2CO_3$/2 M NH_4OH followed by a water wash. After concentrating the eluate plus wash cesium product to 2.5 M Cs_2CO_3 by boiling, the solution is cooled.

2.2.2 Conversion to CsCl. As shown in Figure 4, the controlled addition of 12 M HCl converts cesium carbonate to cesium chloride according to the exothermic reaction shown here:

$$Cs_2CO_3 + 2HCl \longrightarrow 2CsCl + CO_2(g) + H_2O$$

Final solution pH is between two and four to minimize possible equipment corrosion.

2.2.3 Evaporation. The solution of purified CsCl, containing about 455 kCi ^{137}Cs, is boiled down to a solid salt while maintaining a vacuum to remove radiolytically generated hydrogen and other gases. Any additional heat required to supplement the radiolytic heat is provided by an induction heater. The evaporation step is complete when the temperature of the CsCl reaches 130 C. This step volatilizes water and free HCl. Any residual NH_3 and CO_2 is also removed, viz.

$$2NH_4^+(aq) + CO^=(aq.) \xrightarrow{heat} H_2O + 2NH_3(g) + CO_2(g)$$

2.2.4 CsCl Drying and Melting. While still under vacuum, the induction heat is turned off and the CsCl salt self-heats to 600 C. This completes the drying process. The induction heater is turned on and the salt is brought to 740 C and held at that temperature for 15 minutes to guarantee that all CsCl is in the molten state.

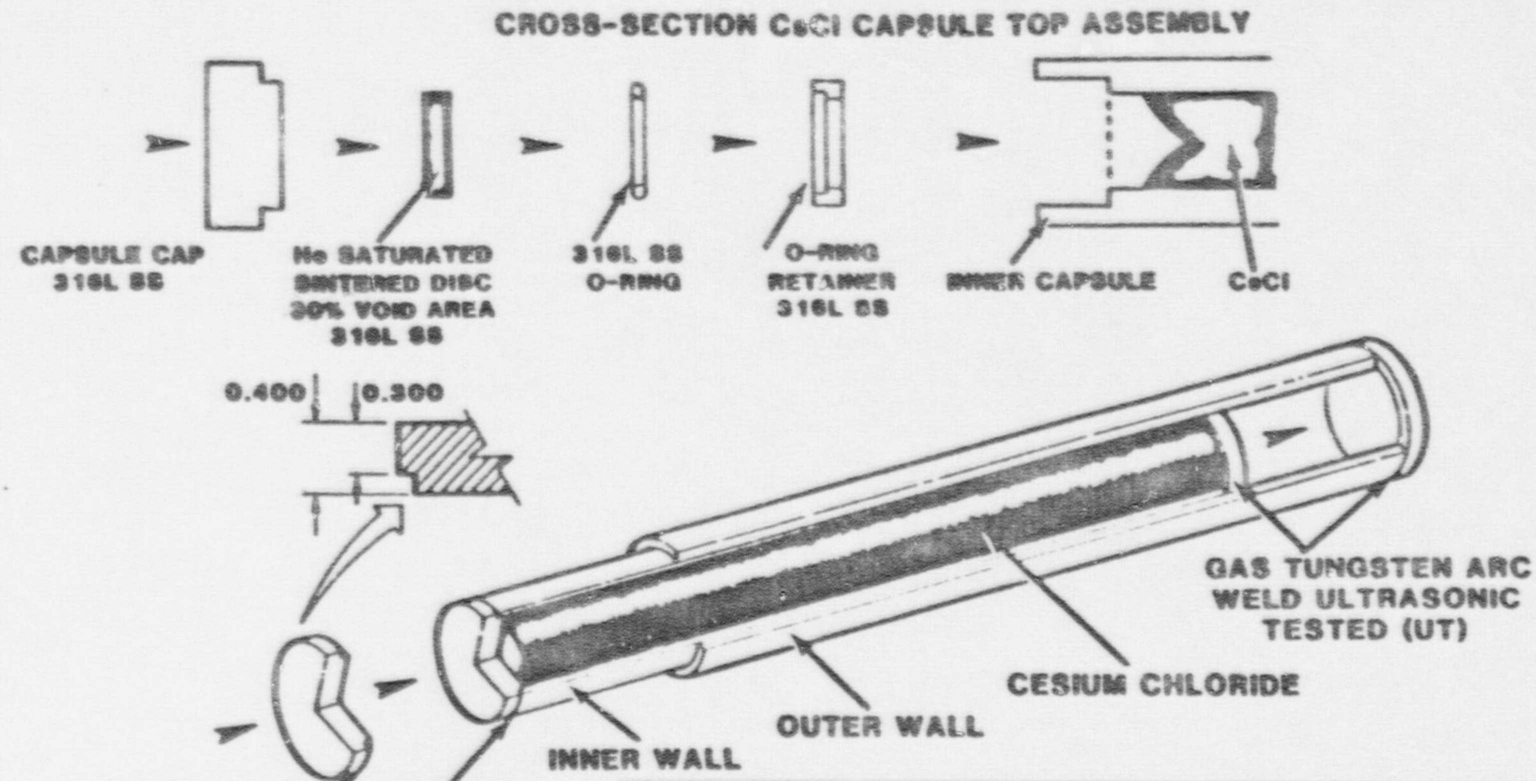
2.2.5 Melt-Casting into Capsules. Inner capsules, made of 316L stainless steel, are sealed onto fill nozzles on the side of the melter. The bottom ends of these capsules have end caps which have been welded in place by tungsten-inert gas welding and subsequently inspected by ultrasonic testing. The molten CsCl is poured into the capsules sequentially. After one hour, the salt has solidified, and the capsules are removed from the melter and placed in a shielded storage area.

After solidifying, CsCl undergoes a phase change with an accompanying decrease in volume of up to 17 percent [27]. The exact temperature at which this occurs is dependent on the type and quantity of impurities present and can range from approximately 350 to 470 C [28].

Every batch process can produce about seven capsules. Each filled capsule contains ≤80 kCi ^{137}Cs (generally the ^{137}Cs content is 55-70 kCi). If the last capsule on line is only partially filled, it is moved to the first capsule position on the melter to be filled when the next batch of CsCl is prepared.

2.3 Encapsulation. Figure 5 illustrates the physical dimensions and characteristics of the doubly encapsulated gamma source pin [29].

2.3.1 Inner Capsule. The melt-casting of CsCl into the inner capsules has been described above. A filled inner capsule is removed from the shielded storage area and placed in the tungsten-inert gas (TIG) welder. A sintered metal disc is placed on top of the salt. The capsule is then purged for 15 minutes with He to trap He gas in the disc voids. After the welding surface has been cleaned, the end cap is placed over the



RADIO-ACTIVE MATERIAL	FORM	137 Cs LOADING	PERCENT OF THEORETICAL DENSITY BASED ON TOTAL VOID SPACE OF CAPSULE	TEMPERATURE			
				AIR		WATER	
				CENTER LINE	SURFACE	CENTER LINE	SURFACE
CESIUM CHLORIDE	MELT-CAST	70 KCi	85	450°C	200°C	250°C	30°C

RADIO-ACTIVE MATERIAL	CAPSULE									
	INNER					OUTER				
	MATERIAL	WALL THICKNESS	OUTSIDE DIAMETER	TOTAL LENGTH	TOTAL CAP THICKNESS	MATERIAL	WALL THICKNESS	OUTSIDE DIAMETER	TOTAL LENGTH	TOTAL CAP THICKNESS
CESIUM CHLORIDE	316L STAINLESS STEEL (UT)	0.136 (UT)	2.250	19.725	0.400	316L STAINLESS STEEL (UT)	0.136 (UT)	2.625	20.775	0.400

NOTE: ALL DIMENSIONS ARE IN INCHES

FIGURE 5. ^{137}Cs GAMMA SOURCE PIN DETAIL.

open end of the inner capsule and is welded in place, using a TIG process (welding gas is 95 percent Ar, 5 percent H_2) [22, 24, 30].

The inner capsule weld verification consists of both He leak testing and bubble testing. The He leak rate must be $<1 \times 10^{-8}$ atm cc/sec. A capsule which fails the test is rechecked and, if the failure is confirmed, the capsule is rewelded or reworked. On passing the He leak check, the capsule is placed in a tank of water for 15 minutes. If bubbles appear, the capsule is rewelded or reworked. The bubble test is a secondary test to verify that the He leak check is working properly [22].

Gross contamination is cleaned off the capsule by scrubbing with wire brushes under a water spray. Any remaining contamination is removed by electropolishing and rinsing with demineralized water. These processes are repeated until decontamination is verified by swipe tests of the capsule exhibiting no more than 200 counts per minute (background level activity). A unique serial number is etched on the cap, side and bottom of the capsule prior to alignment to WESF. This facilitates tracking of the capsule through the processing steps.

2.3.2 Outer Capsule. The completed inner capsule is placed within a 316L stainless steel outer capsule which already has a bottom end cap that has been welded on and ultrasonically inspected. The weld area is cleaned with a wire brush and the top cap is welded on using the TIG welding process as before. The outer capsule weld is scanned by an ultrasonic weld inspector which prints a picture of weld penetration for evaluation, i.e. the outer capsule end cap must have at least 55 percent penetration [22, 24, 30]. A unique serial number is etched on the top end cap, side and bottom of the outer capsule during fabrication. This number is used for capsule identification in the storage pool and throughout the life of the capsule.

The ^{137}Cs content is determined by calorimetry (heat generation from radioactive decay is essentially constant during the measurement and is directly proportional to the ^{137}Cs curie content). The gamma-source pin is weighed on an electronic balance before and after filling to determine the mass of CsCl contained, and the salt density is calculated. It is generally ca. 65 percent of the theoretical density of CsCl (3.97 g/cm^3) based on the total void space (approx. 1000 cm^3) of the inner capsule. It must be <80 percent because of the phase transition/volume expansion CsCl undergoes when the temperature is raised to between 360 and 470 C (the exact temperature depends on the impurities).

2.4 Radiation Characteristics. Two factors must be considered for the WESF Cs gamma source when discussing radiation characteristics. One is the gamma radiation flux available for use and the other is the health physics area of radiation exposure. Source efficiency is common to both, i.e. the actual gamma ray flux present at the surface of the source as compared to the total gamma ray flux produced within the source. Both the practical and health physics parameters have been discussed elsewhere [31-33] and are summarized here.

2.4.1 Usable Gamma Ray Flux. The total gamma ray output by the gamma source is not seen at the exterior of the capsule because the CsCl within the capsule and the encapsulating material itself absorb and scatter the gamma rays. Kenna [31], Morris [32], and Harmon [33] are in agreement that ca. 55-60 percent of the 0.662 MeV gamma rays emitted during the decay of ^{137}Cs will be available at the surface of the source capsule, i.e. the source efficiency is 55-60 percent. For distances less than 50 cm from the source surface, the gamma ray flux in air can be approximated by the relationship, $f_R = f_{surface}e^{-0.0512R}$.

The interrelationship of the parameters influencing gamma ray absorption is discussed by Kenna [31]. A simple means is also given to determine source efficiencies for gamma ray sources.

2.4.2 Health Physics. The common unit of radiation exposure is the roentgen, abbreviated r. The roentgen is defined as the amount of gamma-radiation required to dissipate 87.6 ergs in one cm^3 of dry air at STP. In health physics operations, the exposure is usually expressed as a rate, i.e. r/hr. The lethal dose of gamma radiation which kills 50 percent of the exposed population within 30 days (LD 50/30) is 400-500 r. Thus, a 5-hour exposure to 100 r/hr would be lethal to 50 percent of those exposed.

Table 1 summarizes the gamma radiation exposure possible from a WESF Cs capsule as a function of distance from the capsule surface. Obviously, a 30-second exposure at 50 cm from the capsule would give an LD 50/30. Therefore precautionary measures must be taken--e.g. remote handling, adequate shielding, security--to avoid accidental exposure.

Table I

External Radiation Levels of WESF Cs Capsule (33)

Distance from surface of source (cm)	Measured r/hr	Calculated r/hr
0	---	7.7×10^5*
5	---	6.1×10^5*
20	3.02×10^5	3.0×10^5
30	1.69×10^5	1.6×10^5
50	0.55×10^5	0.68×10^5

* Extrapolated

3.0 INTEGRITY TESTS

As discussed in Section 2, the normal environment and operating conditions are relatively benign. However, the persistence of source integrity must be demonstrated for actual conditions-of-use in air, and especially for adverse handling and conditions-of-use. The guidelines for satisfying this requirement are provided by the NRC and involve the American National Standard N542 (ANSI N542) standard [20]. This standard establishes a system of classification of sealed radioactive sources based on performance specifications related to radiation safety, and it provides a series of tests for evaluating the safety of a sealed gamma ray source under specified conditions. Appendix B summarizes ANSI N542.

3.1 Classification of WESF Cs Gamma Source. The severity of the test conditions which a source must be subjected to is defined by the classification of the source which in turn depends on the radiotoxicity of the radionuclide, the activity level within the capsule, and how the source is to be used.

Category III is the appropriate classification for the WESF ^{137}Cs capsule, i.e. a self-contained source which experiences wet storage [21]. This should not be confused with the classification of the Irradiation Facility in which the gamma sources are to be used. A facility such as SIDSS would be a Category II gamma irradiator. The capsule must be evaluated in terms of the tests listed here under the conditions noted. In addition, an evaluation must be made of any hazard possibly resulting from fire, explosion or corrosion. The conditions which a Category III sealed gamma source must meet are given below:

Test	Conditions
Temperature	-40 C (20 min), + 400 C (1 h) and thermal shock 400 C to 20 C three times.
External Pressure	25 kN/m^2 abs. to 2 MN/m^2abs. (3.6 psig to 290 psig)
Impact	2 kg (4.4 lb) from 1 m.

Test	Conditions
Vibration	10 min. to go from 25 to 500 back to 25 Hz at 5 g peak amplitude; repeat three times.
Puncture	50 g (1.76 oz.) from 1 m.

3.2 Performance Tests. Successful compliance with the tests is demonstrated by the ability of at least one of the two source encapsulations (inner capsule or outer capsule) to maintain its integrity as indicated by leak checks after a test. Each test is listed below with the minimum requirements in brackets, followed by a brief summary of the studies which have been done.

3.2.1 Temperature [400 C for one hour]. A significant portion of the energy released during the radioactive decay of ^{137}Cs is absorbed within the gamma-source pin and is converted into heat. Surface temperatures in the range of 200-220 C are experienced by the outer and inner capsules, respectively, of an individual pin in air, and expected centerline temperature is about 450 C. In a source array, the temperatures might be slightly higher. However, a test temperature of 800 C has been used by most investigators which is well above the required test temperature of 400 C. This demonstrates that neither expected conditions-of-use temperatures nor unexpected temperature excursions will have an immediate deleterious effect on the 316L stainless steel capsule material or the end cap weldments.

Hammond [34] has applied the temperature test (800 C for 90 minutes) to outer, inner and complete capsules (filled with stable CsCl). Although a slight swelling (0.010 to 0.038 in.) was observed at the upper and lower ends of the inner capsule (Table II), no capsule failure or loss of capsule contents occurred. There was no evidence of tearing or cracking in the welds.

TABLE II

Results of Temperature, Impact and Percussion Tests

as Reported by Hammond [34]

Capsule Type	Average Diametral Distortion ($\times 10^{-3}$ inches)*					
	Temperature (800 C)		Impact on Ends (15-45° from vertical)		Percussion	
	D 1	D 2	D 1	D 2	D 1	D 2
Inner-1	+17	+17	+39	+39	-11	- 2
Inner-2*8	+ 1	+ 1	+16	+14	- 3	- 3
Outer**	+ 6	+ 4	+33	+44	-23	-12

* The two diameters, D 1 and D 2, are perpendicular to each other.

**Formed complete WESF capsule; Inner-1 and Inner-2 contained inactive CsCl.

N.B. There were no capsule failures or loss of contents during any of the tests. Post-test examinations revealed no evidence of tearing, cracking or other defects in the welds. The capsules maintained their integrity.

This slight swelling of the inner capsule was also observed by Dunn [35], when complete pins (filled with stable CsCl) were held at 675 C for 5 hours. Again, there were no apparent deleterious effects on the pin integrity. Haff [36] did not report any swelling after heating a complete capsule (filled with ^{133,137}CsCl) to 800 C for 10 minutes; no leak was detected following the test.

The characteristics of 316L stainless steel are well known and a brief summary is provided in Appendix C. At a continuous temperature of 800 C, the physical strength properties of 316L stainless steel are degraded, and creep rate increases. This could explain the slight swelling observed at elevated temperatures. This also implies that capsules which experience temperatures of 800 C or more should be inspected thoroughly. Precipitation of chromium carbide at grain boundaries is inhibited because 316L is a low carbon steel; thus elevated temperatures, even those experienced during welding, should not enhance corrosion phenomena [37-41].

The -40 C criterion is not deemed appropriate for WESF Cs sources. There simply are no expected or unexpected conditions of use which would cool a capsule, which normally has a surface temperature of 200-220 C, to a temperature of -40 C. In an environment of -40 C, the capsule surface temperature would be >150 C. Therefore the -40 C test has not been performed.

Therefore, on the basis of this information, the gamma-source pin would comply with the temperature test.

3.2.2 Thermal Shock [400 C to 20 C, three times]. Operation of the irradiator involves periodic replacement of gamma-source pins. The loading/unloading procedures involve the pins being placed in a water-filled pool, thereby producing a thermal shock.

The concern is that this may stress the 316L stainless steel or the end cap welds. Although the test requires only three repetitions of thermal shock from a temperature of 400 C to 20 C, Dunn [35] has shown that 10 repetitions from a temperature of 800 C to 20 C do not affect the integrity of the pin (Table III). The literature on 316L stainless steel indicates that thermal shock does not produce adverse effects [37]. Thus the gamma-source pin will comply with the thermal shock test.

3.2.3 External Pressure [3.6 psig to 290 psig, two times]. Following production at the Hanford-WESF site, the gamma-source pins are stored in a pool of deionized water; the hydrostatic pressure during storage is ca. 5.6 psig. Although this pressure would not be exceeded during normal operating conditions, circumstances can be envisioned during pin transfer or transport in which a higher external pressure might be encountered.

Dunn [35] has verified that the inner capsule alone will withstand 700 psig external pressure (Table III). Therefore, the gamma-source pin complies with the external pressure requirements.

There is no requirement for internal pressure. However, as discussed in Appendix D, the WESF Cs capsule will withstand 7000 psig (395 atm) at room temperature, even though the probability of internal pressurization is remote.

3.2.4 Impact (Percussion) [200 g (7 oz) dropped from one meter]. There is a finite probability that during the lifetime of a gamma-source pin, it will inadvertently be subjected to impact. Hammond [34] and Haff [36] have subjected gamma-source pins to impact tests using 5 kg rods from a 1 m height and observed no impairment to the integrity of the capsules (Tables II and III), i.e. leak tests were negative. Note that the

TABLE III

Results of Physical Tests as Reported by Dunn [35]

	Maximum Diametral Distortion (x 10^{-3} inches)*								
	Temperature 675 C	Thermal Shock		Impact On:			Puncture	Pressure	
		Single	Multiple	Bottom	Top	Side	Resistance	External	Internal
Inner-1	+0.5 -1	+6.5 -3.5	+4 -1	+2	ND	+60 -106	95**	NC	+5 -88
Inner-2	+5 -3	+5 -5	+8 -3	+4 -2	ND	+48 -44	ND	+1 -1	+15 -34
Outer	+1 -1	+12 -10	+23 -15	+1 -4	+2 -3	+247 -383	43**	+8 -10	+333 -161
Complete Capsule	+1 -2	+15 -17	+13 -9	+5 -3	+2 -6	+107 -175	40**	NC	+174 -134

ND = Not determined; NC = No change.

* The positive and negative values denote the maximum expansion and concurrent contraction, respectively, which occurred for each test.

**Indentation.

effects are minimized on the inner capsule when it is contained within an outer capsule.

An extension of the Impact Test is a free drop test onto a steel billet. Results obtained by Hammond [34] for multiple drop tests per capsule from a 30-ft height are shown in Table II. Dunn [35] used a 15-ft drop height in testing both ends and side in multiple drops (Table III). None of the capsules suffered loss of integrity in either case.

On the basis of these results, the gamma-source pin complies with the impact test.

3.2.5 Puncture [10 g pointed rod dropped from one meter]. The puncture test involves impact with a rod with a pointed end. Gamma-source pins have been tested for impact onto a 3-mm diameter point of a steel rod from a free-fall height of 4.57 m (velocity at impact 945 cm/sec) rather than the required 1-m height [35]. No loss of integrity was observed (Table III). Therefore, the gamma-source pin complies with the puncture test.

3.2.6 Vibration [Sweep from 25 to 500 back to 25 Hz at 5 g peak amplitude in 10 min; three cycles]. Vibration of the capsules during use in an irradiation facility such as SIDSS will be minimal. The capsules are secured in a source plaque in a horizontal position. After more than three years of operating SIDSS, no difficulties have arisen due to capsule vibration. During transportation, the capsules are within a large, shielded transportation cask. The capsules, which were designated by ERDA as special form material for shipping (Appendix E), have been shipped to ORNL and SNLA with no apparent difficulties due to vibration.

Therefore, the vibration test is not considered critical for the presently planned usage of WESF Cs capsules, and no vibration tests have been performed to date. If the use changes in the future, this aspect will have to be reconsidered.

3.2.7 Additional Tests. The gamma-source pin has been subjected to other, nonrequired tests for thoroughness. The gamma-source pin will experience an aqueous environment at various times during storage and transfer operations. Hammond [34] has done immersion tests for 24 hours with tap water at room temperature. No change in capsule weight was found. Haff [36] immersed capsules in water having a pH of 6-8 and a maximum conductivity of 10μ mho/cm. The capsules and water were heated to 50 C and maintained at this temperature for 4 hours. The activity of the water was found to be $\not<$50 nCi (the detection limit of the method used). The capsules were stored in air for seven days and the immersion test was repeated with the same result. A He leak test indicated no leaks (sensitivity 4.2×10^{-8} STP cc/min).

Previous work of Hammond [34], Dunn [35], Haff [36], Jackson [46], and Fullam [47] provide confidence that 316L stainless steel has the chemical inertness and physical properties necessary for a $^{137}CsCl$ gamma-source pin.

3.2.8 ORNL Program. A new program initiated by Sandia National Laboratories is concerned with the continued integrity of gamma-source pins in use. It involves the removal of source pins from SIDSS and subsequent characterization of the pins. ORNL is performing the analytical work on the first pin under Sandia's direction. It is planned to periodically remove a source pin from SIDSS and characterize it. While the results from one pin may not provide adequate information in all areas of interest, valuable information will be obtained, e.g. pin corrosion, isotopic and chemical purity of CsCl and weld integrity. The data will become statistically significant in all areas over a period of several years. Preliminary results from the first pin have been reported herein (Table IV). The total analytical scheme planned for the first pin is presented in Table V.

The work presently is being documented at SNLA in the form of internal reports and will be published in the open literature when analysis of the first pin is complete. Prior work of this nature has been minimal and addressed source pins containing only 1-2 kCi ^{137}Cs [48, 49]. H. Fullam at PNL is also currently undertaking a controlled study of corrosion of the inner surface of the WESF capsule [50].

3.2.9 Summary. A summary of the test conditions used in comparison to those required by ANSI N542 is provided in Table VI. Note that with two exceptions, the tests actually done were more severe than those required. Although the reduced external pressure test was not done per se, the internal pressure test is equivalent and, in fact, exceeds the requirement in terms of force per unit area experienced by the capsule. The two exceptions are: (a) -40 C temperature test, and (b) vibration test. None of these is considered critical to the presently planned use of WESF Cs capsules. When the use environments require extension to include these parameters, the tests will be done and an amendment to the existing registration will be requested.

3.3 Corrosion and Fire. Present studies of a gamma-source pin at ORNL, under the direction of Sandia National Laboratories, are resulting in data which indicate that corrosion of the 316L stainless steel in WESF Cs capsules is minimal [42]. Preliminary results indicate that only slight, general corrosion (maximum 0.0004-0.0006 in./year) exists on the interior surface of the inner capsule which is in agreement with the results of Fullam

Table IV

Analysis of Residual Gases in Gam a-Source Pin*

Gas	% Gas b Volume Inner Capsule	Outer Capsule
H_2	0.03	2.08
He	43.34	<0.08
CH_4	0.01	0.05
H_2O	0.02	<0.02
N_2 + CO **	21.1	88.95
O_2	0.03	0.05
Ar	33.47	8.22
CO_2	0.01	1.02
Surface Temperature (C)	260	220
Void Volume (cm^3)	245	134
Gas Volume @ STP (cm^3)	56.2	65.6
Internal Pressure, calculated (atm)	0.46	0.88
CsCl Contained (kg) ***	2.74	--

*This gamma-source pin was removed from he Sandia National Laboratories SIDSS irradiator and trans orted to ORNL for characterization studies under Sandia's direction. This table contains a portion of the results obtained [42].

**Mass spectrometric analysis was unable o distinguish between these two gases at mass 28. However, i is very probable that the primary component is N_2.

***The inner capsule contained 71.8 kCi ^{13} Cs (828 g), 99 Ci ^{134}Cs (0.761 g) and 1.91 kg ^{133}Cs

Table V

Summary of Analytical Studies Planned for WESF Cs Capsule

Task

I. Gas Analysis

A. Sample atmosphere between inner and outer capsules

1. General qualitative analysis
2. Quantitative analysis

B. Sample atmosphere within inner container

1. General qualitative analysis
2. Quantitative analysis

II. Outer Container (316L SS)

A. "Corrosion" analysis (of inner surface)
1. SEM/EDAX
2. Metallographic

B. Integrity/corrosion of weldment
1. SEM(EDAX)
2. Metallographic

C. Physical testing
1. Tensile

III. Inner Container

A. "Corrosion" analysis of both inner and outer surfaces

1. SEM/EDAX
2. Metallographic

B. Integrity/corrosion of weldment

1. SEM(EDAX)
2. Metallographic

Table V (cont'd)

C. Physical testing

1. Tensile

IV. Cesium Analysis

A. Isotopic purity

1. ^{137}Cs vs. ^{134}Cs vs. ^{133}Cs
2. Other radionuclides

B. Impurity levels

1. Qualitative analysis
2. Quantitative analysis for Na, K, Fe, Cr, Ni, and others

C. Physical properties

1. Melting point
2. Temperature of phase transition

V. Virgin Capsule

A. Physical testing

1. Tensile

B. Metallographic

1. SEM
2. Optical

Table VI

Comparison of Test Conditions Required by ANSI N542

vs. the Test Conditions Used for WESF Cs Capsule Studies

Test	Conditions: Required	Conditions: Used
Temperature	+400 C (1 hr) -40 C (20 min)	800 C (90 min) N/A
Thermal Shock	400 C to 20 C three times	800 C to 20 C ten times
Pressure		
External*	25 kN/m^2 abs to 2 MN/m^2 abs (0.24 atm to 19.7 atm)	1.0 MN/m^2 to 4.8 MN/m^2 abs (1.0 atm to 47.3 atm)
Internal*	-	46.7 kN/m^2 to 40 MN/m^2 (0.466 atm to 395 atm)
Impact	2 kg (4.4 lb) weight dropped from 1 meter	5 kg (11 lb) weight dropped from 1 meter; also free drop of filled capsule from 27 meters
Vibration	30 min to go from 25 to 500 Hz @ 5 g peak amplitude	N/A
Puncture	50 g (1.76 oz) pointed rod dropped onto capsule from height of 1 meter	Complete capsule (2.7 kg) dropped from height of 4.6 meters onto pointed rod

*The internal pressure test is used in place of the reduced external pressure test and exceeds the requirement in terms of force per unit area experienced by the capsule.

[49], who conducted extensive compatibility tests. This is significant because it permits the inner capsule to serve both as a primary containment barrier and as providing structural strength.

Although the probability of a capsule experiencing a fire environment is remote, the 800 C temperature used in the tests performed provides assurance that fire should not pose a threat. Even if a fire occurs during transportation, the cap sules will be protected and contained within a transportation cask which itself must pass a fire test.

4.0 QUALITY CONTROL

Gamma-source pins are manufactured under a documented quality control program. There is continual assurance that this control is maintained for each pin. References 22 and 45 delineate the specific programs in detail and they are summarized here in terms of the four areas of production.

4.1 Cesium Processing. Control is maintained on the chemicals used in recovering cesium from fuel reprocessing (Figures 3, 4), subsequent conversion to the carbonate (Cs_2CO_3) and final conversion to the chloride (CsCl). The cesium chloride processing and encapsulation flowsheet was developed through extensive studies [22-26, 30, 45] of process conditions, material compatibility, product purity, effect of impurities, and other areas. Because of this prior work, and the fact that adherence to the flowsheet is maintained, direct testing of cesium purity is not routinely done. Visual observation is maintained to ensure the material behaves as expected. The evaporation, drying, heating, melting, and finally pouring of the molten CsCl into capsules, follows a prescribed procedure. Procedures are delineated for stopping the process, and recycling if possible, if there is any question regarding the chemical impurities or any of the physical steps.

The amount of CsCl and ^{137} Cs in the final gamma-source pin is determined by calorimetry and a tared weighing technique. Records are maintained for each "batch" of ^{137}Cs in each capsule.

4.2 Capsules. The outer and inner capsules are manufactured according to the specifications reported previously. These are verified upon receival at the WESF facility. The capsules are marked with unique identification numbers, so a historical log can be maintained from the time of their receival until their final disposal. Capsules which do not meet specifications are not used for gamma-source pins. The receival, acceptance and use of each capsule is recorded.

4.3 Welding. The inner weld integrity is checked with a helium leak checker and bubble test. A capsule with an acceptable weld ($<1 \times 10^{-8}$atm-cm^3/sec leak rate) is decontaminated and placed into another capsule and a cap is welded over the end to seal the outer capsule. The outer capsule weld is verified with an ultrasonic scanner (55 percent minimum weld penetration). Capsules with unacceptable welds are either reworked or rewelded, depending on the severity of the weld deficiency. The development of the welding process and the standards which must be met are recorded [22, 30]. Test results for welding verification are maintained for each acceptable capsule in a QC file.

4.4 Storage. Once a capsule has passed all tests for decontamination and weld integrity, the capsule is stored in a pool cell (13 ft of water). It is specified that the water must contain $6 \times 10^{-4} \mu$ Ci ^{137}Cs/ml. A loss of pin integrity which exposes the CsCl to the water will be recognized because the radioactivity level of the water is monitored. The exact location of each capsule in the pool is recorded.

5.0 SUMMARY

Registration of the WESF Cs capsule with the NRC as a sealed gamma-source is desirable to facilitate transfer of sludge irradiation technology to the waste water treatment community. The environment and operation conditions are relatively benign for the gamma-source pin under consideration. Considerable prior work has been done concerning the integrity of the gamma-source and its ability to maintain this integrity under prescribed adverse conditions as required by ANSI N542. There is assurance that this work is directly applicable to all ^{137}Cs gamma-source pins manufactured at WESF because of the WESF Quality Assurance Program.

The minimum specifications which each gamma-source pin will meet are given in Table VII. These specifications are based on the results of tests conducted over the past decade on both prototype and actual source pins. The source pins were determined by ERDA to meet special form requirements (Appendix E).

Table VII

Specifications for ^{137}Cs Gamma-Source Pin

Capsule Material	316L Stainless Steel
Physical Dimensions	Per Figure 5
Gamma Source	^{137}Cs
Purity	90% (by mass)
Maximum Activity Level	80 kCi
Welding Process	TIG (Tungsten-Inert Gas of 95% Ar - 5% H_2)
Weld Verification	
Inner Capsule	He Leak Check and Bubble Test Leak Rate 1 x 10^{-8}atm-cm^3/sec
Outer Capsule	Ultrasonic 55% penetration minimum
Maximum External Temperature	800 C
Maximum External Pressure	700 psi
Maximum Internal Pressure	7000 psi (room temperature)
Maximum Impact	Equivalent to free drop of gamma-source pin 9.1 m onto hard surface
Immersion	Indefinite - Monitor activity level of water
Inertness	Corrosion 0.0006 in./year

APPENDIX A

REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
SAFETY EVALUATION OF SEALED SOURCE

NO.: NR____-S______ - ________ DATE: Page of

SEALED SOURCE TYPE:

MODEL:

MANUFACTURER/DISTRIBUTOR:

ISOTOPE: MAXIMUM ACTIVITY:

LEAK TEST FREQUENCY:

PRINCIPAL USE:

CUSTOM REVIEW: _____Yes ____No

DESCRIPTION:

LABELING:

DIAGRAM:

CONDITIONS OF NORMAL USE:

PROTOTYPE TESTING:

EXTERNAL RADIATION LEVELS:

QUALITY ASSURANCE:

LIMITATIONS AND/OR OTHER CONDITIONS OF USE:

SAFETY SUMMARY EVALUATION:

REFERENCES:

ISSUING AGENCY:

Applicable Section of

American National Standard N542

Sealed Radioactive Sources, Classification

1.0 SCOPE

This standard establishes a system of classification of sealed radioactive sources based on performance specifications related to radiation safety. It provides a manufacturer of sealed sources with a series of tests for evaluating the safety of his product under specified conditions, and also assists a user of such sources to select a type which suits the intended application insofar as maintenance of source integrity is concerned. Tests are prescribed for temperature, external pressure, impact, vibration, and puncture over a range of severity. Sealed source performance requirements are identified for a variety of source applications, in terms of a specific degree of severity of each test. Appendices are included on the subjects of leak test methods, and quality assurance and control.

2.0 DEFINITIONS

The definitions and terms contained in this standard, or in other American National Standards referred to in this document, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard.

capsule--protective envelope used for prevention of leakage of the radioactive material.
device--any piece of equipment designated to utilize a sealed source(s).

dummy source--facsimile of a sealed source of exactly the same material and construction as a sealed source but containing, in place of the radioactive materials, a substance resembling it as closely as practicable in physical and chemical properties.
model--descriptive term or number to identify a specific sealed source design.
non-leachable--term used to convey that the radioactive material is virtually insoluble in water and is not convertible into dispersible products.
prototype source--original of a model of a sealed source which serves as a pattern for the manufacture of all sources identified by the same model designation.
prototype testing--performance testing of a new sealed source before sources of such design are put into actual use.
radiotoxicity--the toxicity attributable to the radiation emitted by a radioactive substance within the body.
sealed source--radioactive source sealed in a capsule or having a bonded cover, the capsule or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.
source holder--mechanical support for the sealed source.

The following two terms apply to industrial radiography, gamma gauges, and irradiator sources:
source in device--sealed source which remains in the shielding during use.
unprotected source--sealed source which, for use, is removed or exposed from the shielding by mechanical or other means.

3.0 CLASSIFICATION DESIGNATION

The classification of a sealed source shall be designated by the code ANSI, followed by two digits to indicate the year in which approval of the American National Standard was obtained, followed by a letter and five digits.

If the classification is based on performance tests prescribed in this standard (N542-1977), the two digits preceding the letter shall be 77.

The letter shall be either a C or an E. A C designates that the activity level of the sealed source does not exceed the limit established in Table 3. An E designates that the activity level of the sealed source exceeds the limit established in Table 3.

The first digit following the letter shall be the Class number which describes the performance for temperature.

The second digit following the letter shall be the Class number which describes the performance for external pressure.

The third digit following the letter shall be the Class number which describes the performance for impact.

The fourth digit following the letter shall be the Class number which describes the performance for vibration.

The fifth digit following the letter shall be the Class number which describes the performance for puncture.

Example: The minimum classification of the WESF Cs capsule (a Category III sealed gamma irradiation source) would be

ANSI 77E 43424.

Since the WESF capsule generally has met more stringent tests than required, it would be designated as

ANSI 77E 64515.

3.1.1 Classification of Sealed Source Performance Tests (Table 1). This is a list of environmental test conditions to which a sealed source may be subjected. The test classes are arranged in order of increasing severity with the possible exception of Class X, which may be any special designated test.

The classification of each source type shall be determined by actual testing of two prototype or dummy sources for each test in Table 1, or by derivation from previous tests which demonstrate that the source would pass the test if the test were performed.

Compliance with the tests shall be determined by the ability of the sealed source to maintain its integrity after each test is performed. Methods of testing sources for integrity after testing are set out in Appendix B-1.

3.1.2 Activity Level (Table 3). This Table establishes a maximum activity of sealed sources without further evaluation. Sources containing more than the maximum activity shall be subject to further evaluation of the specific usage and design. The activity shall be determined at the time of manufacture of the sealed source.

3.1.3 Sealed Source Performance Requirements for Typical Usage (Table 4). Table 4 is based on current practice and typical environments in which a sealed source or source-device will be used. Average environment includes normal and abnormal use (taking into account reasonable accidental risks), but does not include exposure to fire or explosion. For sealed sources normally mounted in devices, consideration was given to the additional protection afforded the sealed source by the device when the Class number for a particular usage was assigned. Thus, for all usages shown in Table 3, the Class numbers specify the tests to which the sealed source shall be subjected.

3.1.4 Leak Test Methods (Appendix B-1). Appendix B-1 lists currently acceptable leak test (integrity test) methods.

3.1.5 Quality Assurance and Control (Appendix B-2). To ensure that production sources will have performance characteristics equal to the tested prototypes used in classifying the sources, a good Quality Assurance and Control program is necessary. Appendix B-2 is included as a guide to aid a manufacturer in establishing a specific program.

3.2 Fire, Explosion or Corrosion. Table 4 does not consider exposure of the source-device to fire, explosion or corrosion. In the evaluation of sealed sources and source-device combinations, the manufacturer and user must consider the probability of fire, explosion and corrosion and the possible results. Factors which should be considered in determining the need for actual testing are:

(1) consequence of loss of activity;

(2) quantity of active material contained in the source;

(3) radiotoxicity;

(4) chemical and physical form and the geometrical shape of the radioactive material;

(5) environment in which it is used; and

(6) protection afforded the source or source-device combination.

3.3 Radiotoxicity and Solubility. Except as required in Section 4.2 radiotoxicity of the radionuclide shall be considered only when the activity of the sealed source exceeds the value shown in Table 3. If the activity exceeds this value, the specifications of the source must be considered on an individual basis.

4.0 PROCEDURE TO ESTABLISH CLASSIFICATION AND PERFORMANCE REQUIREMENTS

4.1 Establish radiotoxicity group.

4.2 Determine amount of activity allowable from Table 3. If the desired quantity does not exceed the allowable quantity of Table 3, an evaluation of fire, explosion, and corrosion probabilities shall be made.

4.3 If the desired quantity exceeds the allowable quantity of Table 2, an evaluation of fire, explosion or corrosion probability and a separate evaluation of the specific source usage and source design shall be made.

4.4 After the required classification of the source for the particular application or usage has been established, the performance test conditions can be obtained directly from Table 1.

4.5 Alternatively, the source may be tested, the source Class determined from Table 1, and some suitable application selected from Table 4. Sources of an established classification may be used in any application having less severe specific performance requirements (classification numbers).

5.0 IDENTIFICATION

The designation according to Section 3 shall be marked on the sealed source or source container or source holder or accompanying document.

6.0 TESTING PROCEDURES FOR TABLE 1

6.1 General. The testing procedures given in this section present acceptable procedures for determining the performance classification numbers. All the test environments provide the minimum requirements. Procedures which can be demonstrated to be at least equivalent are also acceptable. All tests, except the temperature tests, shall be carried out at ambient temperature.

6.2 Temperature Test[1].

6.2.1 Equipment. The heating or cooling equipment shall have a test zone volume of at least five times the volume of the test specimen. If a gas or oil-fired furnace is used for the temperature test, an oxidizing atmosphere shall be maintained throughout the test.

6.2.2 Procedure. All tests shall be performed in air except in the low temperature test, when an atmosphere of carbon dioxide is permitted. All test sources shall be held at the maximum (or minimum, for low-temperature tests) test temperature for a period of at least 1 h.

Although Table 1 specifies a low temperature of -40°C, "dry ice" may be used as the cooling material. Thus the low temperature may approach -75°C.

Sources to be subjected to temperatures below ambient shall be cooled to the test temperature in less than 45 minutes.

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[1]Part of this test for Class 6 is similar in principle to the heating test given in IAEA regulations for the safe transport of radioactive materials.

Sources to be subjected to temperature above ambient shall be heated to the test temperature at least as rapidly as indicated by the following time-temperature table.

Time min	Temperature °C
0	ambient
5	100
10	220
30	450
60	750
120	1010

For Classes 4, 5 and 6, test sources shall also be subjected to a thermal shock test. Either a second test source or the source used in the temperature test may be used. If the latter is used, it shall be evaluated for passage of the temperature test before it is subjected to the thermal shock test.

For the thermal shock test, the source shall be heated to the maximum test temperature (required for that particular Class) and held at that temperature for at least 15 minutes. The test source shall be transferred, in 15 seconds or less, to water at a maximum temperature of 20°C. The water shall be flowing at a rate of at least ten times the source volume per minute, or, if the water is stationary, it shall have a volume of at least 20 times the source volume.

6.2.3 Evaluation. Test sources shall be examined visually and subjected to an appropriate integrity test such as that described in Appendix B-1.

6.3 External Pressure Test.

6.3.1 Equipment. The pressure gauge shall have been recently calibrated and should have a pressure range of at least 10 percent greater than the test pressure. The vacuum gauge must read to a pressure at least as low as 20 kN/m^2 absolute. Different test chambers may be used for the low- and high-pressure tests.

6.3.2 Procedure. Place the test source in the chamber and expose it to the test pressure for two periods of 5 minutes each. Return the pressure to atmospheric between each period. Conduct the low-pressure test in air. For the high-pressure test only water shall be used.

6.3.3 Evaluation. Test sources shall be examined visually and subjected to an appropriate integrity test such as that described in Appendix B-1.

6.4 Impact Test[2].

6.4.1 Equipment. This comprises:

(1) A free falling steel hammer which has a flat striking surface, 25 mm in diameter with the edge rounded to a radius of 3 mm. The center of gravity of the hammer lies on the axis of the circle which defines the striking surface.

(2) A steel anvil, the mass of which is at least 10 times that of the hammer. It is rigidly mounted so that it does not deflect during impact. It has a flat surface, large enough to take the whole of the source.

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2 This test is similar in principle to the percussion test given in IAEA regulations for the safe transport of radioactive materials.

(3) For the Class 2 drop test, the steel plate shall be rigidly mounted so that it will not deflect appreciably during the test.

6.4.2 Procedure. Choose the mass of the hammer according to the mass specified in Table 1.

Adjust the drop height to 1 m measured between the top of the source positioned on the anvil and the base of the hammer in the release position. Position the source so that it offers its most vulnerable area to the hammer.

Drop the hammer onto the source.

6.4.3 Drop Test. For the Class 2 drop test, the test sources shall be dropped so that all surfaces are impacted at least once.

6.4.4 Evaluation. Test sources shall be examined visually and subjected to an appropriate integrity test such as that described in Appendix B-1.

6.5 Vibration Test.

6.5.1 Equipment. A vibrating machine capable of producing the specified test conditions.

6.5.2 Procedure. Fix the source securely to the platform of the vibrating machine so that at all times the source will be rigidly in contact with the platform.

For Classes 2 and 3, subject the source to the three complete test cycles for each condition specified. Conduct the test by sweeping through all the frequencies in the range at a uniform rate from the minimum frequency to the maximum frequency and return to the minimum frequency in 10 minutes, or longer. Test each axis[3] of the source. A maximum of three axes shall be used. In addition, continue the test for 30 minutes at each resonance frequency found.

6.5.3 Evaluation. Test sources shall be examined visually and subjected to an appropriate integrity test such as described in Appendix B-1.

6.6 Puncture Test.

6.6.1 Equipment. This comprises:

(1) A hammer, the upper part of which is equipped with means of attachment and the lower part of which has a pin rigidly fixed to the hammer. The characteristics of this pin are as follow:

(a) hardness from 50 to 60 Rockwell C;
(b) free height 6 mm;
(c) diameter 3 mm;
(d) lower surface hemispherical.

The center line of the pin is in alignment with the center of gravity and with the point of attachment of the hammer.

(2) A hardened steel anvil, rigidly mounted and with a mass at least 10 times that of the hammer. The contact surface between the source and the anvil is large enough to prevent

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[3]A spherical source has one axis taken at random. A source with an oval or disc type cross section has two axes: one of revolution and one taken at random in a plane perpendicular to the axis of revolution. Other sources have three axes taken parallel to the significant overall dimensions.

deformation of this surface when impact takes place. If necessary, a cradle of suitable form may be interposed between the source and the anvil.

6.6.2 Procedure. Choose the mass of the hammer and pin according to the Class as required in Table 1.

Adjust the drop height to 1 m measured between the top of the source positioned on the anvil and the point of the pin in the release position.

Position the source so that it offers its most vulnerable area to the pin.

Drop the hammer onto the source.

If the source has more than one vulnerable area, carry out the test on each of them.

If the dimensions and mass of the source concerned do not permit unguided fall, lead the striker to the impact point in a smooth vertical tube.

6.6.3 Evaluation. The test sources shall be examined visually and subjected to an appropriate integrity test such as that described in Appendix B-1.

TABLE 1--Classification of Sealed Source Performance Tests

Test	Class						
	1	2	3	4	5	6	X
Temperature	No Test	-40°C(20 min) +80°C (1 h)	-40°C(20 min) +180°C (1 h)	-40°C(20 min) +400°C(1 h) and thermal shock 400°C to 20°C	-40°C(20 min) +600°C(1 h) and thermal shock 600°C to 20°C	-40°C(20 min) +800°C(1 h) thermal shock 800°C to 20°C	Special Test
External Pressure	No Test	25 kN/m^3 abs. (3.6 lb/in.^{3}) to atmosphere	25 kN/m^3 abs. to 2 MN/m^3 (290 lb/in.^{3}) abs.		25 kN/m^3 abs. to 70 MN/m^3 (10 153 lb/ in.^{2}) abs.	26 kN/m^3 abs. to 170 MN/m^3 (24 656 lb/ in.^{2}) abs.	Special Test
Impact	No Test	50 g (1.8 oz) from 1 m (3.28 ft) and free drop ten times to a steel surface from 1.5m (4.92 ft)	200 g (7 oz) from 1 m	2 kg (4.4 lb) from 1 m	5 kg (11 lb) from 1 m	20 kg (44 lb) from 1 m	Special Test
Vibration	No Test	30 min 25 to 500 Hz at 5 g peak amp.	30 min 25 to 50 Hz at 5 g peak amp and 50 to 90 Hz at 0.635 mm amp peak to peak and 90 to 500 Hz at 10 g	90 min 25 to 80 Hz at 1.5 mm amp peak to peak and 80 to 2000 Hz at 20 g	Not Used	Not Used	Special Test
Puncture	No Test	1 g (15.4 gr) from 1 m(3.28 ft)	10 g (154 gr) from 1 m	50 g (1.76 oz) from 1 m	300 g (10.6g) from 1 m	1 kg (2.2 lb) from 1 m	Special Test

Table 2. Group B-1 Medium Toxicity Classification of Radionuclides According to Radiotoxicity. Based on ICRP Publication 5.

^{228}Ac	^{144}Ce	^{124}I	^{212}Pb	^{160}Tb
^{110m}Ag	^{36}Cl	^{125}I	^{224}Ra	^{127m}Te
^{211}At	^{58}Co	^{126}I	^{106}Ru	^{129m}Te
^{140}Ba	^{60}Co	^{132}I	^{124}Sb	^{234}Th
^{207}Bi	^{134}Cs	^{133}I	^{125}Sb	^{204}Tl
^{210}Bi	^{137}Cs	^{114m}In	^{44}Sc	^{170}Tm
^{249}Bk	$^{152(13y)}Eu$	^{192}Ir	^{90}Sr	^{236}U
^{45}Ca	^{154}Eu	^{54}Mn	^{182}Ta	^{91}Y
^{115m}Cd	^{181}Hf	^{22}Na	^{230}Pa	^{95}Zr

TABLE 3--Activity Level

Radionuclide group (from Table 2)	Maximum activity, Ci	
	Leachable[4] and/or reactive[6]	Nonleachable[5] and nonreactive[7]
A	0.3	3
B1	30	300
B2	300	3000
C	500	5000

[4]Leachable--greater than 0.1 milligram per gram in 100 ml still H_2O at 20°C in 48 h.

[5]Nonleachable--less than 0.1 milligram per gram in 100 ml still H_2O at 20°C in 48 h.

[6]Reactive--reactive in ordinary atmosphere or water (Na, K, U, Ca, metals, etc.).

[7]Nonreactive in ordinary atmosphere or water (Al, Au, Co, Kr, Ceramics, etc.).

Note--In the expression "milligram per gram" the "milligram" refers to the dissolved or removed radionuclide, and the "gram" to the total weight of radioactive material present, not including the weight of the capsule.

TABLE 4--Sealed Source Performance Requirements for Typical Usage

Sealed Source Usage		Sealed Source Test and Class				
		Tempera-ture	Pres-sure	Impact	Vibra-tion	Punc-ture
Radiography--Industrial	Unprotected source	4	3	5	1	5
	Source in device	4	3	3	1	3
Medical	Radiography	3	2	3	1	2
	Gamma teletherapy	5	3	5	2	4
Gamma gauges (Medium and high energy)	Unprotected source	4	3	3	3	3
	Source in device	4	3	2	3	2
Beta gauges and sources for low energy gamma gauges or X-Ray fluorescence analysis (excluding gas-filled sources)		3	3	2	2	2
Oil Well logging		5	6	5	2	2
Portable moisture and density gauge (including hand-held or dolly-transported)		4	3	3	3	3
General neutron source application (excluding reactor start-up)		4	3	3	2	3
Calibration sources--Activity greater than 30/ Ci		2	2	2	1	2
Gamma Irradiators[9]	Categories II, III, IV	4	3	4	2	4
	Category I	4	3	3	2	3
Ion Generators[8]	Chromatography	3	2	2	1	1
	Static Eliminators	2	2	2	2	2
	Smoke Detectors	3	2	2	2	2

[8]Source-device combination may be tested.

[9]For the purpose of this Standard, gamma irradiators have been divided into four distinct categories.

Category I--Self-Contained--Dry Source Storage.

Category II--Panoramic--Dry Source Storage.

Category III--Self-Contained--Wet Source Storage.

Category IV--Panoramic--Wet Source Storage.

APPENDIX B-1

Leak Test Methods

(This Appendix is not a part of American National Standard N542, Sealed Radioactive Sources, Classification. It is included for informative purposes and as a guide to promote uniformity of practice to meet the objectives of the standard.)

A1. GENERAL

Maintenance of its integrity after testing of the sealed source is the criterion for determining that a source meets the specifications of a particular class for a given test. Testing for the presence of radioactive material on the exterior of a sealed source, after it has been subjected to a test, is a method of determining whether the source has fulfilled the requirements of the test or has failed the test.

Visual examination of source surfaces and weldments at magnifications from 2 to 20 X is a useful supplement to the leak test methods described in section A2. Visual examination alone will not prove the presence or absence of leaks, but it may reveal porosity capable of retaining radioactive materials in sufficient quantities that a source will not pass tests A2.1.1 or A2.1.2, yet is found not to leak.

1.0 Acceptable Leak Test Methods.

1.1 By Radioactive Means. For the tests by radioactive means, it is assumed that the source has been cleaned and is free from radioactive surface contamination before the performance test is initiated.

1.1.1 Wipe (Smear) Test. Wipe all external surfaces of the sealed source thoroughly with a piece of filter paper or other suitable material of high wet strength and absorbent capacity, moistened with a solvent which will not attack the material of which the outer surfaces of the source are made and which, under conditions of this test, has been demonstrated to be effective in removing the radioactive substance involved. Measure the activity on the wiping material. If the activity is less than 5 nCi the source is considered to be leak-free.

1.1.2 Dry Wipe Test. Wipe all external surfaces of the source thoroughly with a piece of dry filter paper. Measure the activity on the filter paper. If the activity is less than 5 nCi, the source is considered to be leak-free.

1.1.3 Immersion with Boiling Test. Immerse the sealed source in a solvent which will not attack the material of which the outer surfaces of the source are made and which, under the conditions of this test, has been demonstrated to be effective in removing the radionuclide involved. Boil for 10 minutes, remove the source (retaining the solvent) and allow to cool, then rinse the source, using fresh solvent. Repeat these operations twice, for a total of three tests, using the original solvent for the boiling. Measure the total activity in the solvent. If the activity is less than 5 nCi the source is considered leak-free.

1.2 By Nonradioactive Means. Note: Before any of these tests, the source should be cleaned thoroughly.

1.2.1 Vacuum Bubble Test[1]. Using analytical reagent grade ethylene glycol, water or silicon oil[2] as the leak-test fluid in a suitable vacuum chamber, lower the air content of the fluid by evacuating the chamber for at least 1 minute and then return to atmospheric pressure. Submerge the source capsule completely to a depth of at least 5 cm (2 in) below the fluid level. Reduce the pressure in the chamber to between 15 and 25 kN/m^2 (2 and 3.6 $lb/in.^2$) absolute. Observe for bubble(s) over a period of 2 minutes. If none are observed, the source is considered leak-free.

1.2.2 Hot Liquid Bubble Test. Ensure that the sealed source is at ambient temperature. Immerse it in a water bath which is at a temperature between 90 and 95°C. Observe for bubble leaks over a period of at least 2 minutes. If none are observed, the source is considered leak-free.

Note: Glycerol at 120 to 150°C is an acceptable alternative for water.

1.2.3 Helium Pressurization Bubble Test. Place the sealed source in a suitable pressure chamber of volume at least twice that of the source and at least five times the free volume inside the source. Pressurize the chamber with helium gas to at least 1 MN/m^2 (150 $lb/in.^2$) gauge and maintain it at that pressure for 15 minutes. Release the pressure, remove the source from the chamber and submerge it below 5 cm of water, alcohol or acetone. Observe for bubble(s) over a period of 2 minutes. If none are observed, the source is considered leak-free.

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[1]C. R. King, USAEC Rpt. ORNL-3664, Oak Ridge National Laboratory (January 1963).

[2]Mass density at 20°C; 890 kg/m^3.
Kinematic viscosity at 20°C: 25 centistokes.
Kinematic viscosity at 50°C: 9.0 centistokes.

1.2.4 Pressurization Test. This test is essentially an operational consequence to the external pressure test of Classes 3, 4, 5 and 6. Weigh the source. Perform the external pressure test with water and weigh the source again. If there is no gain in weight, the source is considered leak-free. For this test to be valid, the calculated void volume within the source has to be capable of holding water which would weigh at least five times the sensitivity of the weighing equipment.

Note: Water is the only pressurizing fluid acceptable for this test.

1.2.5 Helium Sealing Test. Make the final seal on the sealed source in an atmosphere containing at least 5 percent commercial grade helium. Evacuate the space around the source, let it stand for at least 5 minutes and sample the space around the source for the presence of helium, following the recommendations of the manufacturer of the leak-testing equipment. If less than 1×10^{-8} standard cubic centimeter per second of helium is detected, the source is considered leak-free.

1.2.6.1 Helium Pressurization Test.

A.2.2.6.1 Procedure. Place the sealed source in a pressure chamber. Purge the chamber of air with helium. Pressurize the chamber to at least 1 MN/m^2 (150 $lb/in.^2$) gauge with helium and maintain for a period of 30 minutes. (Other pressures and time periods are acceptable if the through-put is equivalent.) Depressurize the chamber and remove the source assembly to a vacuum chamber. Evacuate that chamber, monitored with a leak detector, to a specified pressure, following the recommendations of the manufacturer of the leak-testing equipment.

1.2.6.2 Helium Leak Testing. Operations of the l ak detector shall be strictly in accordance with the manu acturer's instructions.

The leak detector and vacuum system must be cal orated by using a calibrated leak before and after leak-testin of each source capsule.

A.2.2.6.3 Testing of Source.

A.2.2.6.3.1 Before each finished source assembly s tested, the following blank tests must be performed. Sourc -assembly background is to be determined by testing a solid b r of the same dimensions and material and with approximately the same configuration as the source assembly. The bar is to be subjected to the previously described pressurization befc e it is leak-tested.

A.2.2.6.3.2 Place the finished source assembly i side the vacuum chamber.

A.2.2.6.3.3 Evacuate the chamber and begin monitc ing when the system pressure falls within the range of the leak detector.

A.2.2 6.3.4 Measure helium signal after continuou pumping with an open throttle valve for 1 minute; isolate th chamber from the vacuum pumps, accumulate any helium for 30 mi utes and measure helium signal.

A.2.2.6.4 Data Required. Record the magnitude of leak indication for each of the following:

a. Chamber background.

b. Solid-bar background, after 1 minute and after 30 minutes.

c. Each source after 1 minute and after 30 minutes. If c is less than b or equal to or less than 1×10^{-8} standard cubic centimeter per second of helium, consider the source leak-free.

A.2.2.7 Liquid Nitrogen-Alcohol Bubble Test (only for sources having high decay heat). Immerse the source into a liquid nitrogen bath for a period of at least five minutes. Remove the source from the liquid nitrogen and immediately immerse in a clear (glass) vessel containing clear alcohol (isopropyl or ethylene glycol) at ambient temperature. Observe for leakage of gas from the source, with particular attention to the weld areas, for a period of at least two minutes. If none is observed, the source is considered leak-free.

APPENDIX B-2

Quality Assurance and Control

(This Appendix is not a part of American National Standard N542, Sealed Radioactive Sources, Classification. It is included for informative purposes and as a guide to promote uniformity of practice to meet the objectives of the standard. It is not intended as a substitute for each manufacturer's evaluation of the applicable requirements.)

B1 INTRODUCTION

A quality assurance program or plan is essential in both the design and manufacture of sealed sources. This is not to be considered as a complete program. Each manufacturer should add to it or delete from it as may be necessary in his particular case.

B1.1 Definitions

Quality Assurance[1]--All those planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service.

Quality Control[1]--Those quality assurance actions which provide a means to control and measure the characteristics of an item, process, or facility to established requirements.

Certificate of Compliance[1]--A written statement, signed by a qualified party, attesting that the items or services are in accordance with specified requirements and accompanied by additional information to substantiate the statement.

---

[1]ANSI N45.2.10--1973. Quality Assurance Terms and Definitions.

B2 INTENT

The intent of this appendix is to ensure that production sources meet the required standard.

To accomplish this intent, all failures (either from the field or in process) should be analyzed. If the record keeping and traceability procedures are adequate, the cause of the failures can be located and corrected. Without systematic record keeping, the cause of failure frequently cannot be determined. Hence the lesson to be learned from the failure is lost.

B3. SCOPE

The fabrication of sealed radioactive sources can be broken down into three separate functions, 1) preparation for assembly, 2) assembly, and 3) verification and/or certification. Each of these functions will be dealt with in detail since each function has separate and distinct approaches to quality assurance and control.

B4 PREPARATION FOR ASSEMBLY

In order to fabricate sealed sources the manufacturer should have:

Specifications and/or engineering drawings
Trained personnel
Proper equipment and procedures
Approved materials

B4.1 Specifications and/or Engineering Drawings. All production sealed sources should be fabricated to specifications and/or engineering drawings. These documents should list all pertinent information such as dimensions, materials, tests required, and fabrication techniques.

All specifications and/or engineering drawings should be kept current.

B4.2 Trained Personnel. The manufacturer should be responsible to ensure that only trained and competent personnel are involved in the fabrication and testing of sealed sources.

The manufacturer should maintain pertinent records of the training given to these personnel.

B4.3 Equipment and Procedures. The manufacturer should have written operating procedures for all major production and test equipment. These procedures should include who is responsible for calibration, maintenance and repair, and when such operations are to be performed.

B4.4 Approved Materials. All incoming parts and materials should be inspected to ensure that they meet the requirements of the specifications and/or engineering drawings. Alternately, a certificate of compliance is acceptable. The manufacturer should maintain a materials control program. The records of this program should be adequate to ensure traceability of all parts and materials shipped as sealed sources.

B5. ASSEMBLY

All pertinent fabrication records, or cross-references to such records, should be maintained in one file for each order, lot or other systematically separate group of sealed sources. For purposes of discussion, this file of records is called a traveller.

The traveller should contain, in addition to materials control records, a work sheet(s) which lists the operations performed, quantities of materials used, equipment settings, tests performed and results for all fabrication steps. Work sheets should be signed and dated.

Inspection sheets or tests performed by quality control are to be added to the traveller. Copies of all pertinent shipping documents or cross-references to them are also to be included in the traveller, which is then filed.

Each sealed source or some accompanying tag, label or certificate, should show some designation such as lot number, model number or serial number which refers to the traveller.

B6. CERTIFICATION

Each sealed source or, where appropriate, sealed source lot, should be certified by the manufacturer to meet the specifications. This certification should include, at least, the following information:

Isotope and Amount
Date of Measurement
Leak Test Results
Removable Contamination Levels
Source Identification
ANSI Classification Designation

Unless otherwise specified, statistical sampling and testing may be used for large lot sizes. Such systems are described in Mil-STD-105 and 10 CFR 32.110.

B7. QUALITY ASSURANCE MANUAL

A quality assurance manual should be kept by the sealed source manufacturer. The manual should contain policies covering each facet of quality assurance or reference thereto, all test procedures, and all procedures covering personnel training, vendor qualifications, document control, and equipment operating procedures.

This manual should be audited by the manufacturer at least once a year.

All personnel directly involved in the fabrication of sealed sources should have a copy of the manual available to them.

The quality assurance manual should have sections covering, or referring to, at least the following subjects:

a) Department and Quality Organization
b) General Quality Policy
c) Specifications and/or Engineering Drawings Control and Revision
d) Incoming Inspection and Vendor Qualification
e) Test Procedures
f) Operating Procedures
g) Personnel Training
h) Nonconforming Items Policy
i) Document Control
j) Equipment Calibration
k) Quality Audits and Reports

APPENDIX C*

316L STAINLESS STEEL

The classic 18/8 (18 percent Cr - 8 percent Ni) stainless steels (SS) are austenitic, i.e, the face centered cubic structure is stable at room temperature. Compositional modifications for 316 and 316L SS are made to improve certain characteristics of the parent 302 and 304 SS [37,38], e.g., (a) lower carbon content to reduce intergranular corrosion in welded structures, (b) addition of Mo to improve pitting and crevice corrosion resistance, (c) addition of Ni and Cr to improve strength and high temperature oxidation resistance, and (d) addition of Ni to improve stress corrosion resistance. The composition specifications for these SS are given in Table C-I. Typical mechanical properties are listed in Table C-II. The effect of elevated temperature on specific properties of 316L SS is presented in Table C-III. The relationships between these properties and elevated temperature can indicate any unexpected features or points of concern, e.g., if a capsule is subjected to temperatures 800 C and integrity is maintained, the capsule should be recovered and critically examined.

*Reference numbers refer to references in main text.

Table C-1

Composition of Stainless Steels

AISI Grade	Composition (%)* Cr	Ni	C	Mn	Si	P	S	Mo
302	17-19	8-10	0.15	2.0	1.0	0.045	0.030	-
304	18-20	8-10.5	0.08	2.0	1.0	0.045	0.030	-
316	16-18	10-14	0.08	2.0	1.0	0.045	0.030	2.0-3.0
316L	16-18	10-14	0.03	2.0	1.0	0.045	0.030	2.0-3.0

*Balance iron. Single values are maximum values.

Table C-II

Typical Mechanical Properties

AISI Grade	Tensile Strength (M Pa)*	Yield Strength (0.2% offset) (MPa)*	Elongation (%)	Hardness (Rockwell B)	Thermal Conduct. Btu/ft^2/hr/F/ft 212°F	920°F	Mean Coefficient of Thermal Expan. in./in./°F x 10^{-6} 68 F to 1600 F
302	620	276	60	85	9.4	12.4	11.0
304	586	241	55	80	9.4	12.4	11.0
316	620	276	50	79	9.4	12.4	10.7
316L	517	220	50	79	9.4	12.4	10.7

*1 MPa = 145.03 psi.

Table C-III

Elevated Temperature Strengths of 316L Stainless Steel [9,10]

Parameter/Temperature (°F)	Stress (MPa)* 72	200	600	1000	1200	1400	1600
Tensile **	517	428	386	345	283	159	110
Yield **	220	159	103	86	76	-	-
Avg. Creep ($0.01\%/10^3$hr)	-	-	-	152	103	13	7.0
Rupture (10^4hr) **	-	-	-	255	90	38	14
Rupture (10^5hr) **	-	-	-	234	69	21	11

*1 MPa = 145.03 psi

**For pipe or tube form of 316L stainless steel

Appendix D*

Internal Pressure In WESF Cs Capsule

There is the possibility of internal pressure being generated within the WESF Cs source. Pressure within the outer capsule could arise from two sources: residual gases trapped during assembly or gases escaping from the inner capsule. Recent studies [42] have determined the composition and total volume of the gas in the outer and inner capsules (Table IV). These gases (primarily N_2 and Ar as shown in Table IV) trapped between the inner and outer capsules could expand if heated. With this information and using the ideal gas law (Equation 1), the calculated pressure within the outer capsule was 1 atm (14.7 psi), i.e., a partial vacuum existed.

$$P = \frac{nRT}{V} \tag{1}$$

This would be expected since the capsule was sealed while at elevated temperature (220 C) and a partial vacuum would be created on cooling to a lower temperature if there were no leaks. This is in agreement with results of previous work [45]. Therefore, normal operating conditions would not create an internal pressure in the outer capsule.

Tests have shown that the capsule will withstand internal pressures of up to at least 7000 psi [44]. Knowing the gas volume and void volume of the outer capsule (Table IV) and making use of the ideal gas law again, temperatures above the melting point of 316L stainless steel (1400-1455 C) [37,41] would be required to produce an internal pressure of 7000 psi in the outer capsule.

---

*Reference and Table numbers refer to references and tables in main text.

Pressurization of the inner capsule could occur if the internal temperature increases, thereby expanding gases either trapped during assembly or any additional gas that may be generated by radiolysis of contained material. In the first case, the considerations wou ? be analogous to those for the outer capsule, i.e., a negative pressure exists within the inner capsule (Table IV) which is consistent with prior studies done over a period of three years [43]. In the second case, possible contaminants in CsCl which may be affected by radiolysis are water (H_2O), nitrate (NO_3), carbonate (CO_3) and organics (represented by the methylene structure CH_2) as illustrated below.

$2H_2O \xrightarrow{\text{radiation}} 2H_2 + O_2$ (3 moles gas from 2 moles reactants)

$2NO_3 \xrightarrow{\text{radiation}} N_2 + 3O_2$ (4 moles gas from 2 moles reactants)

$2CO_3 \xrightarrow{\text{radiation}} 2CO_2 + O_2$ (3 moles gas from 2 moles reactants)

$(CH_2) \xrightarrow{\text{radiation}} CO_2 + H_2$ (2 moles gas from 1 mole reactants)

The undetectable concentration of CO_2 in the atmosphere found within the inner capsule (Table IV) suggests that the last two reactions are of no concern since the CsCl either contained 10^{-6} percent (CO_3 + CH_2) or radiolysis of these two is nil. The former is very probable since decomposition temperatures of $CsCO_3$ (610 C) and most simple organics are exceeded during the melting operation [45]. The decomposition temperature (420 C) of alkali metal nitrates is exceeded during the drying and melting operations [45], and therefore radiolysis of NO_3 also should be negligible. This leaves only the radiolysis of water to be of concern. Certainly CsCl is hygroscopic, but this tendency should be reduced by the elevated temperature of CsCl during the capsule sealing operation. The analysis of the atmosphere within the inner capsule (Table IV) supports this, i.e., there was $<10^{-5}$ mole of water.

In summary, the atmosphere within the inner capsule described by the results in Table IV should represent residual gases and radiolytic products. Using Equation 1, the temperature required to pressurize the inner capsule to 7000 psi is above the melting point of 316L stainless steel. A final consideration is the possibility that the CsCl is molten and has undergone the phase transition with the accompanying 17 percent volume increase as discussed in Section 2.3.2. If only one cm^3 void space remained to contain the 56.2 cm^3 volume of gas after the phase transition, a temperature of 800 C would produce a gas pressure of 3300 psi which is below the guide in Table VII, vis. 7000 psi rupture strength of 316L stainless steel at room temperature. However, it is greater than the 10^4 hr rupture strength at 800 C (Appendix C Table C-III). This implies that capsules which have experienced temperatures of 800 C or more should be inspected thoroughly.

APPENDIX E

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
RICHLAND OPERATIONS OFFICE
P. O. BOX 550
RICHLAND, WASHINGTON 99352

OCT 23 1975

Atlantic Richfield Hanford Company
ATTN: Mr. G. T. Stocking, President
Richland, Washington

Gentlemen:

SHIPMENT OF CESIUM CHLORIDE CAPSULES IN THE NRBK-43 CASK

The RL Safety Staff have reviewed your October 14, 1975 request to approve the WESF Cesium Chloride Capsules in the NRBK-43 Cask [USA/5974-3/DLF (ERDA-NR)]. Based upon the results of capsule testing described in ARH-CD-440, "Cesium Chloride Capsule Testing for Special Form Qualification" dated August 29, 1975, RL concurs with ARHCO's determination that the capsules meet special form requirements.

Accordingly, the WESF Cesium Chloride Capsule is approved for use as an inner container in the NRBK-43 Cask.

Very truly yours,

P. G. Rhoades, Acting Director
Safety Division

SAF:DWT

cc: E. F. Curren, ARHCO

OCT 24 1975
ARHCO

RECEIVED

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Addendum to
SAND 82-1492

WESF CESIUM-137 GAMMA RAY SOURCES

The following information is provided to amplify and clarify material presented in SAND82-1492 and is based, in part, upon data obtained since the publication of the document.

Irradiator Classification Category:

As discussed in the Registration Application, most contemplated cesium-137 irradiator designs require intermittent exposure of the source capsules to a water environment during (1) initial loading, (2) periodic recharging and/or (3) operation where source is not in use. However, some facilities such as the TransPortable Cesium Irradiator (TPCI) will not require such exposure to water and will operate as self-contained, dry source storage systems.

Because most irradiator designs require source exposure to water, Category III of ANSI N542 is appropriate for these facilities. In these systems, the cesium-137 is self-contained within the double encapsulation of the WESF capsules and, through irradiator design, is isolated from the environment in an irradiation chamber. The sources are occasionally exposed to water so Category III - self-contained, wet source storage is appropriate even though in most designs the sources will only be exposed to water for a small fraction (less than 1 percent) of their useful lives in these facilities. In a facility such as TPCI, Category I, self-contained, dry source storage is the appropriate classification. It should be noted that the ANSI N542 performance test requirements are identical for sources used in Categories II, III and IV irradiators.

Puncture Test Requirement:

The ANSI N542 requirement for puncture testing for sources in Category III irradiators is Class 4 (50 gms from 1 m). Paragraph 3.2.5 on page 25 incorrectly cites 10 gms in the first line. However, note that the test conducted and survived by the WESF capsule involved dropping the capsule itself (approximately 7,600 gms) onto a steel rod from 4.57 meters.

Vibration Test Requirement:

Currently contemplated irradiator designs will restrain the WESF capsules rigidly in a source plaque which is housed in a massive concrete structure or an approved shipping cask (as in TPCI). In these environments, vibration of the sources is extremely unlikely. During shipment to the facilities, the sources will be transported in approved regulatory containers and would experience only those low-level vibrations experienced by a truck on a highway which can be transmitted through the cask to the capsules. However, SNLA has conducted a vibration test of a WESF capsule (loaded with non-radioactive CsCl) according to the Category III ANSI N542 requirements (30 min, 25-500 Hz @ 5 g peak amplitude). Preliminary visual results indicate no effect of this loading on the capsule integrity. Helium leak checks of the welds are currently being conducted [Phone conversation - McMullen/Kenna - 8/4/83].

Temperature Test Requirement:

The static temperature test requirement for Category III irradiator sources is -40°C for 20 minutes. As noted on page 22, due to the internal heat generation through decay of the cesium-137 within the WESF capsule (approximately 300 watts), it is very difficult to achieve a -40°C condition on the external surface of the outer capsule. In fact, with a doubly encapsulated WESF cesium chloride capsule generating 300 watts of decay heat, an external still air temperature of -200 to -400°F is required to cool the outer capsule surface to -40°C.

Quality Assurance:

Fabrication of the WESF cesium chloride sources is accomplished by Rockwell-Hanford Operations under strict procedures. The 316L stainless steel capsule tubing is procured according to Rockwell specification HWS-8835 outlining physical, chemical, mechanical and dimensional parameters which must be met. Rockwell specifications H2-66760 and H2-66761 outline procedures for inner and outer capsule fabrication while Rockwell document SDWM-OCD-003 establishes welding criteria for capsule welds. With regard to encapsulation of the cesium chloride at WESF, Rockwell has published an "Operating Specifications Document for B Plant and WESF." Three pertinent specifications are PSD-B-257-00053 (Rev. D-0) which defines process parameters and purity levels for preparation of the molten cesium chloride; PSD-B-257-00054 (Rev. D-0) which outlines procedures for capsule welding, leak checking, decontamination and calorimetric analysis; and PSD-B-257-00055 (Rev. D-0) which establishes procedures for storage of the capsules in the WESF pool.

Capsule Destructive Analysis:

As discussed on page 26, ORNL did destructively analyze a cesium WESF capsule. This capsule was produced and filled with cesium chloride by DOE/Rockwell-Hanford in 9/75, was stored in the WESF pool from 9/75 to 8/78, was shipped in an NRBK 43 cask to SNLA in 8/78, was stored in a SNLA pool from 8/78 to 5/79, was loaded and used in the Sandia Irradiator for Dried Sewage Solids from 5/79 to 8/81 and was shipped to ORNL for destructive analysis on 8/81. During the 2 years of use in the SIDSS, the capsule was one of 15 arranged in a source plaque and resided in air for the major part of the time. The results of the ORNL analysis are presented in SAND83-0928. The measured inner capsule outer surface temperature upon opening at ORNL was 127°C (Table II, page 15). The outer capsule exterior surface temperature was 104°C. The source contained about 60,000 Ci of cesium-137 (page 24). Note that Table IV, page 28 of SAND82-1492 contains the following errors: (1) surface temperatures are in °F and <u>not</u> °C as stated, and (2) inner capsule contained 61.8 kCi cesium-137, <u>not</u> 71.8 kCi. Metallographic, SEM, microprobe, gas analysis and mechanical tests were conducted on the sectioned capsule and, as the report states on page 26, "the cesium chloride appears to be a benign resident within the capsule to this point in time." In effect, no notable corrosion phenomena were observed and no effect on mechanical properties due to any contact with CsCl was discovered after 8 years in various operational environments.

<u>Recycle of Cesium:</u>

The comments on page 32, paragraph 4.1 referring to recycling of cesium chloride pertain to operating procedures at Rockwell-Hanford by which newly encapsulated sources can be reopened, the CsCl remelted and reintroduced into the process for subsequent filling of another capsule. These procedures would be followed if, typically, one of the weld tests (leak check or ultrasonic test) indicated a substandard weld on one of the capsules.