UT-BATTELLE

SNS Experience with Mercury

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June 28, 2011

SNS SPALLATION NEUTRON SOURCE

Introduction

- **SNS Experience with Mercury**
  - **Safety Analyses/Documentation**
  - **Clean Air Act**
  - **Waste Management**

Safety Analyses/Documentation

- **Source Term Development**
  - **Grouped Elements (based on volatility)**
  - **Source Term for Hot Cell Fire Accident Scenario**
  - **A conservative approach envisioned a fire surrounded by a puddle of exposed mercury**
  - **430 kg of Hg (2.4% of total) amount vaporized**

Safety Analyses/Documentation

- **Atmospheric Transport**
  - **US EPA Codes**
    - **SCREEN**
    - **ISCST3**

Safety Analyses/Documentation

- **Consequence Evaluation**
  - **Dose Conversion Factors (DCFs)**
    - **Deposition/Biokinetics Respiratory Tract**
    - **Systemic Biokinetic Model**
    - **Activity to Dose Conversion Model**

Safety Analyses/Documentation

- **Bottom Line**
  - **Unmitigated Scenario: 1.4 Rem MOI**
  - **Mitigated Scenario: 66 mrem MOI**

  - **Mitigation (Passive Structures)**
    - **Target Building (seismic-qualified)**
    - **Service Bay Walls (4 ft thick)**
    - **Hg Loop System (encased)**
    - **Service Bay Floors sloped to drain**

Clean Air Act

- **National Emission Standards for Hazardous Air Pollutants (NESHAPs), 40 CFR 61**
- **Subpart H**
- **National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities**

CAA

- **Emissions of radionuclides from DOE facilities are limited to 10 mrem/year**
- **EPA approved method – CAP88**
- **Unabated/Abated Releases**
- **Does dose exceed 1% of standard?**
- **Measure all radionuclides that contribute greater than 10% of dose.**

CAA

- **ANSI/HPS N13.1-1999**
  - **Select Monitoring or Sampling Site**
  - **Guidance for in-line detectors**
  - **Radionuclides shall be collected/measured**

CAA

- **Permit to Construct**
- **Operating Permit**
- **Who is the regulator?**

Waste Management

- Solid wastes generated at SNS fall into three major categories:
  - Low Level Waste
  - Mixed Low Level Waste
  - Hazardous (no rad added)

Characterization (Radioactivity)

- Calculations completed by SNS Nuclear Physics group
- CALOR96 Code System
  - 3D multimedia high energy transport code
  - Used to model nucleon-meson cascade
  - High energy physics model
- MCNP code coupled to HETC96
  - Low energy neutron transport
- ORIHET95 to study buildup and decay of activity
- These codes are state-of-the-art
- Present calculations for 5000 hr/year operation at 2 MW power level and are maximum activities
- Actual characterization calculations will use actual irradiation history of components

Characterization (Haz. Materials)

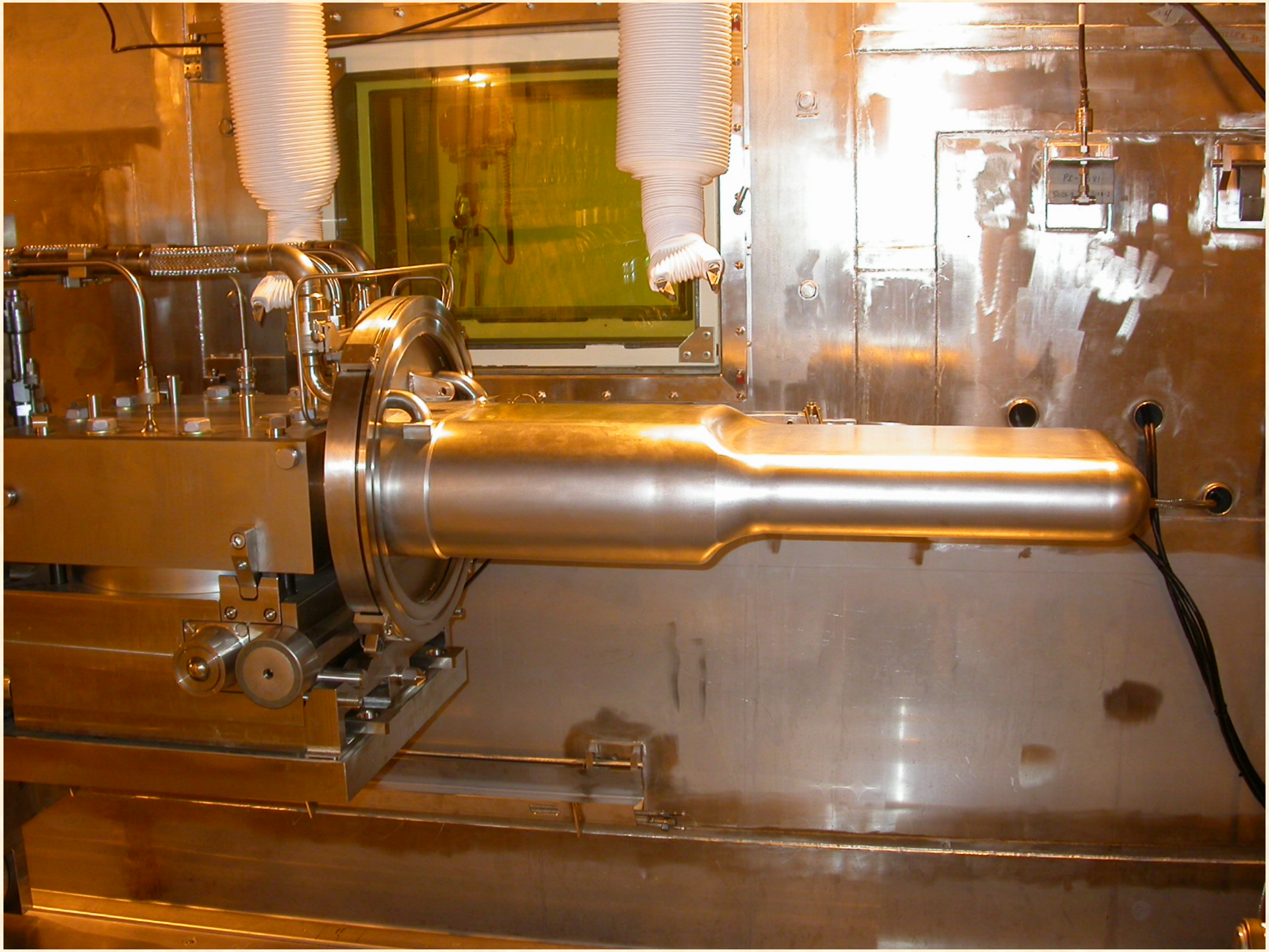
- Principal hazardous material is elemental mercury
- Some materials from the service bay will have been in contact with liquid mercury
- Generally, if these materials do not have visible mercury on them, they are considered to be RCRA-free
- If there are other materials (Cd, Pb), then they are known at the beginning of irradiation

Waste Classification Considerations

- NRC Regulations
  - Classification of Waste (Class A, B, C, GTCC, 10 CFR 61.55)
- DOT Regulations
  - Classification of Shipment

Target Module

- Assembly of type 316 stainless steel vessels suspended from a flange
- Inner vessel for containing the target mercury
- Outer vessel used for containing any mercury that may leak from the inner vessel
- Estimated lifetime 52 days; 4 operating periods per year
- Total weight (without mercury) is 1527 lb



Target Module

Target Module

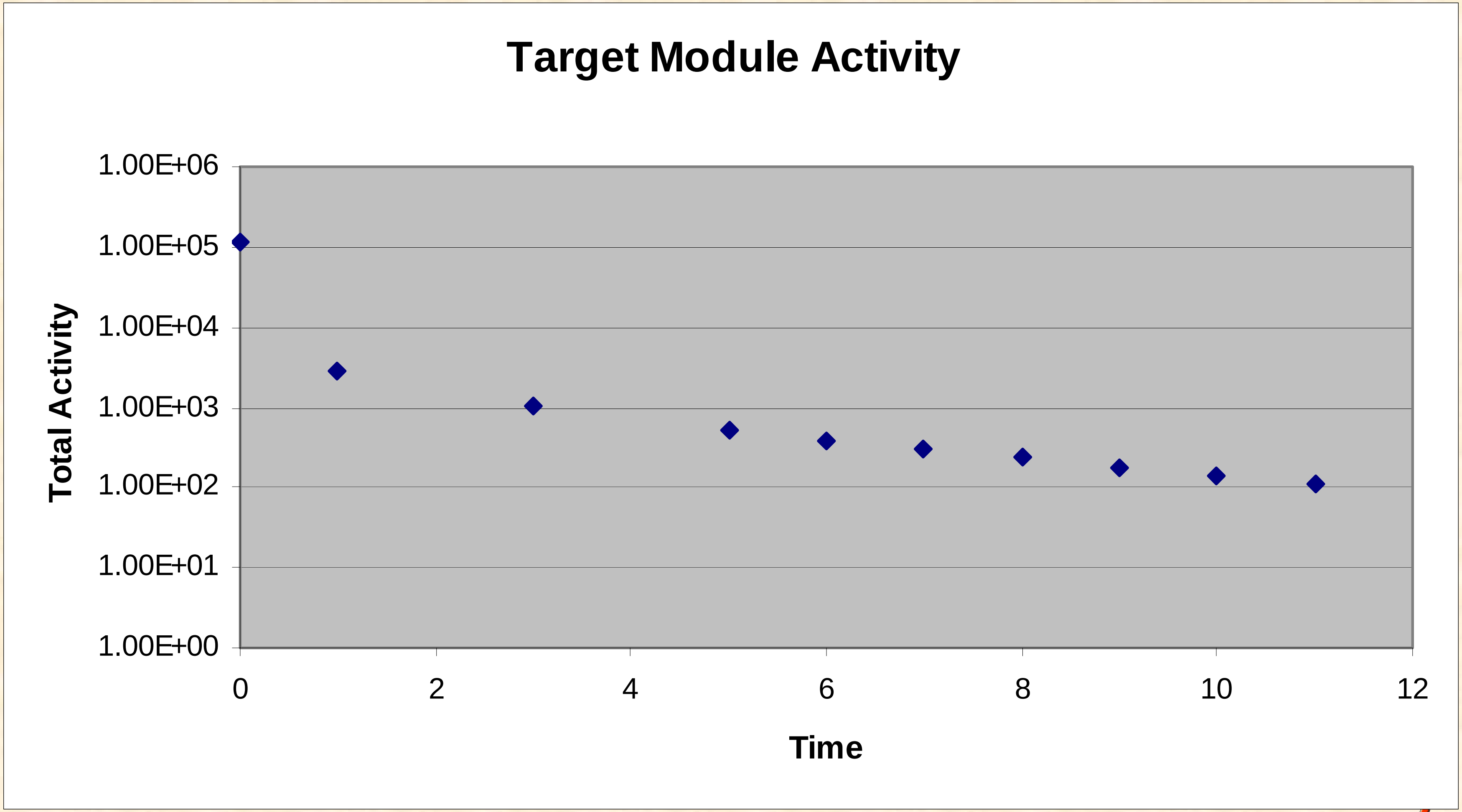
- Module is removed from service according to the following procedure:
  - Drain mercury from the process loop
  - Retract the target carriage to the maintenance position in the hot cell
  - Install the shield boot over the end of the module
  - Tilt module to drain more fluids (including mercury) from the module
  - Lift the module off its carriage (nose-down vertical position)
  - Move to shielded, ventilated container in the hot cell

Target Module

- Characterization
  - Draining and sectioning
  - <3% by weight of mercury remains
  - Container-like equipment < 110 gal volume
  - RCRA empty; manage as solid waste

- Modules will be studied for a period of time (PIE)
  - This involves sectioning of the steel
  - Ensures complete mercury drainage

Target Module



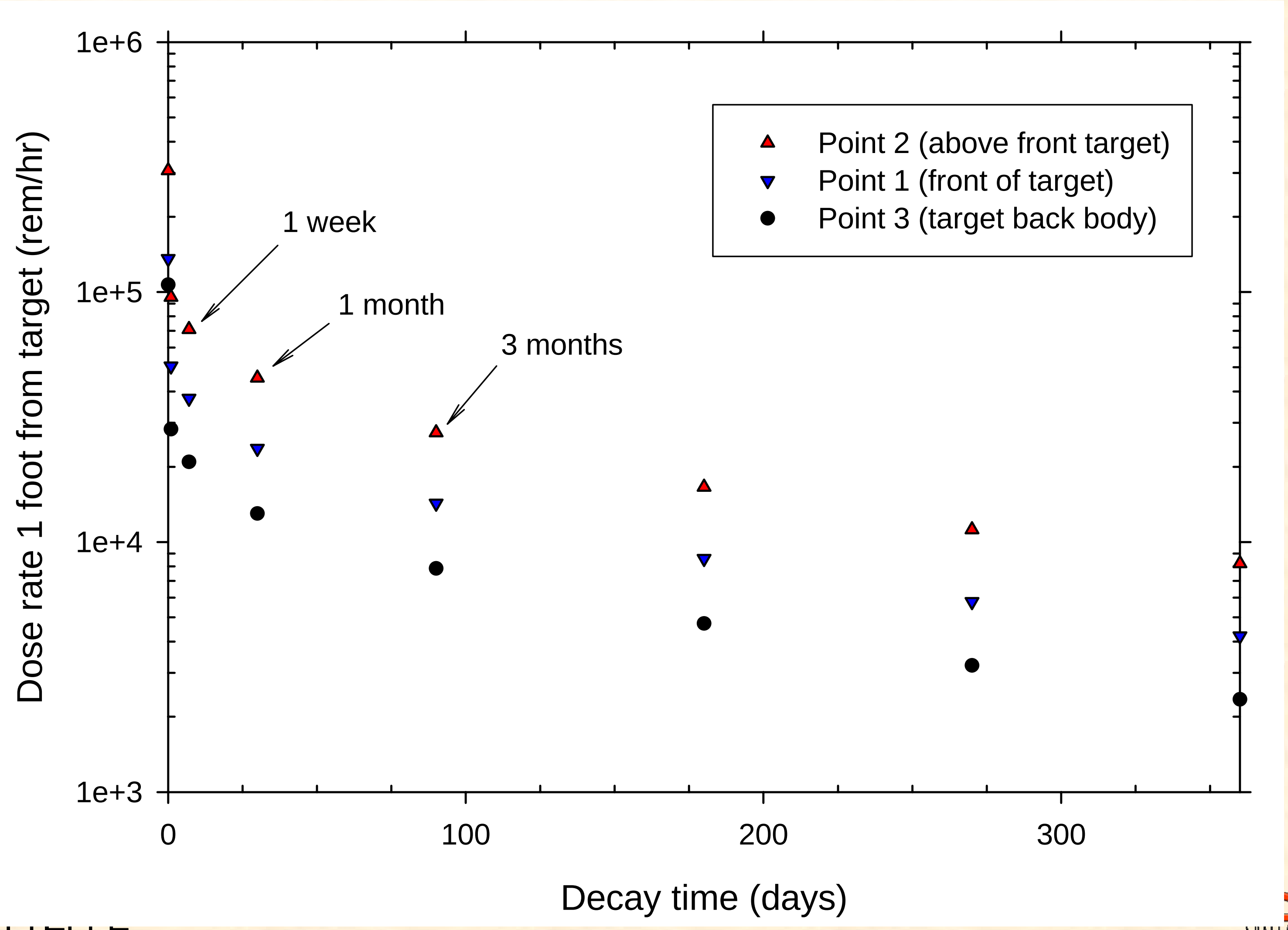
Target Module

Target Module Waste Analysis for Class A Waste

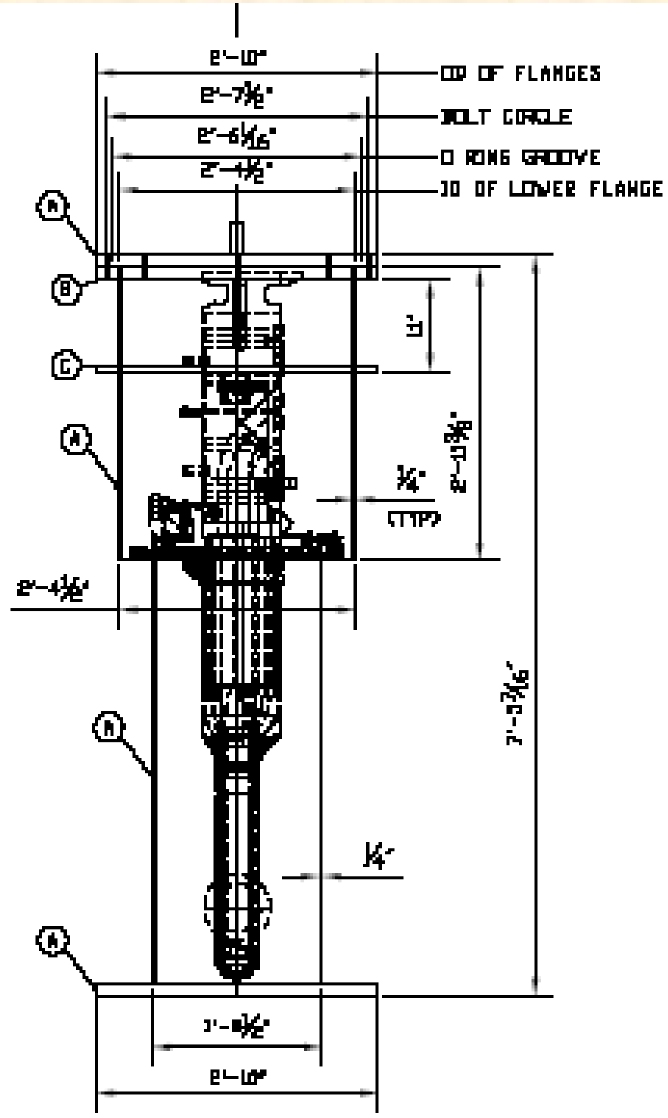
			Decay Period									
Isotope	Half Life (s)	Class A Limit Ci/m3	0	1y	3y	5y	6y	7y	8y	9y	10y	11y
H3	3.89E+08	40	1.32E+01	1.25E+01	1.11E+01	9.96E+00	9.41E+00	8.90E+00	8.41E+00	7.95E+00	7.52E+00	7.11E+00
Co60	1.66E+08	700	8.72E+00	7.65E+00	5.88E+00	4.52E+00	3.96E+00	3.47E+00	3.05E+00	2.67E+00	2.34E+00	2.05E+00
Ni63 (act metal)	3.16E+09	35	5.10E+00	5.07E+00	5.00E+00	4.93E+00	4.90E+00	4.86E+00	4.83E+00	4.80E+00	4.76E+00	4.73E+00
Ni59 (act metal)	2.37E+12	2.20E+01	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02	4.49E-02
Tc99	6.66E+12	3.00E-01	1.30E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03	1.41E-03
Sr90	8.88E+08	4.00E-02	1.10E-03	1.08E-03	1.02E-03	9.75E-04	9.52E-04	9.28E-04	9.06E-04	8.84E-04	8.62E-04	8.41E-04
Nb94 (act metal)	6.41E+11	2.00E-02	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04	5.65E-04
C14 (act metal)	1.81E+11	8.00E+00	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05
All Activity		7.00E+02	8.72E+04	2.25E+03	8.13E+02	4.05E+02	3.03E+02	2.32E+02	1.80E+02	1.41E+02	1.12E+02	8.92E+01
Sum of the fractions			5.50E-01	5.29E-01	4.90E-01	4.56E-01	4.40E-01	4.25E-01	4.10E-01	3.97E-01	3.84E-01	3.72E-01

In accordance with 10CFR61.55 the Target module is classified as a class A waste if classified by long lived radionuclide, but is a class B waste initially if classified by short lived radionuclides. Analysis shows that the target module is a class A waste after 5 years decay

Target Module



Target Module Packaging



TARGET LINER ENCLOSURE

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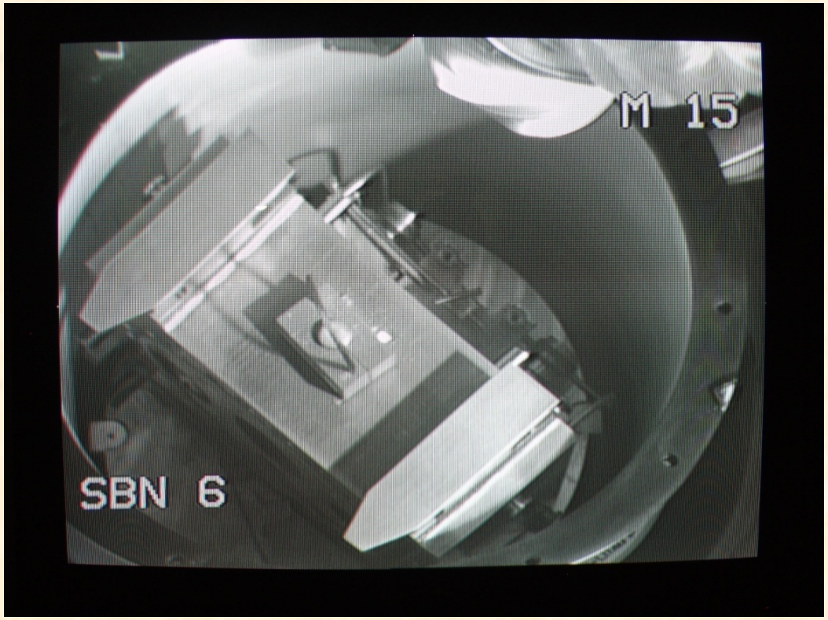
Target Disposition Operations

Target Disposition



Spent Adsorbers

- Carbon Adsorbers
- Gold Adsorbers

Gold Adsorber

- Al_2O_3 pellets containing a gold impregnant
- Sized for mercury that would exit into the off-gas during operational period
  - preliminary estimate is two target cycles per year
- Two gold adsorbers
  - one located in the target service bay
  - one in the MOTS
- Contains ~110 g of mercury when it is spent
  - calculated using the mercury weight and the specific activity of the mercury based upon the known irradiation history

Gold Adsorber in Target Service Bay

Gold Adsorber

Spent Gold Adsorber
Activity Inventory*

Isotope		Half life (s)	shutdown+30 min (Ci/1 cu m)	shutdown+30 min (Ci/g Hg)	Ci/Adsorber (30 m) (Ci)	Ci/Adsorber (30 m) Ci/m3	Ci/Adsorber (90 d) 90 d decay	Ci/Adsorber (90 d) Ci/m3
Hg	187	1.44E+02	0.285	2.11E-08	2.31E-06	1.29E-04	0.00E+00	0.00E+00
Hg	188	1.95E+02	5.46	4.04E-07	4.43E-05	2.46E-03	0.00E+00	0.00E+00
Hg	189	4.56E+02	277	2.05E-05	2.25E-03	1.25E-01	0.00E+00	0.00E+00
Hg	190	1.20E+03	2650	1.96E-04	2.15E-02	1.20E+00	0.00E+00	0.00E+00
Hg	191	2.90E+03	6000	4.44E-04	4.87E-02	2.71E+00	0.00E+00	0.00E+00
Hg	192	1.75E+04	8900	6.59E-04	7.22E-02	4.01E+00	1.25E-135	6.97E-134
Hg	193	1.37E+04	15200	1.13E-03	1.23E-01	6.86E+00	1.70E-172	9.42E-171
Hg	193*	4.25E+04	120	8.89E-06	9.74E-04	5.41E-02	8.14E-59	4.52E-57
Hg	194	1.64E+10	709	5.25E-05	5.75E-03	3.20E-01	5.75E-03	3.20E-01
Hg	195	3.56E+04	33300	2.47E-03	2.70E-01	1.50E+01	4.77E-67	2.65E-65
Hg	195*	1.50E+05	1210	8.96E-05	9.82E-03	5.46E-01	2.44E-18	1.35E-16
Hg	197	2.31E+05	115000	8.52E-03	9.33E-01	5.19E+01	6.87E-11	3.82E-09
Hg	197*	8.57E+04	18100	1.34E-03	1.47E-01	8.16E+00	7.13E-29	3.96E-27
Hg	199*	2.56E+03	70400	5.21E-03	5.71E-01	3.18E+01	0.00E+00	0.00E+00
Hg	203	4.03E+06	179000	1.33E-02	1.45E+00	8.07E+01	3.81E-01	2.12E+01
Hg	205	3.12E+02	60.1	4.45E-06	4.88E-04	2.71E-02	0.00E+00	0.00E+00
					Total	2.03E+02	3.87E-01	2.15E+01

Spent gold adsorber is a class A waste immediately upon generation.
Since the mercury in the adsorber may only be deposited by evaporation, no spallation product isotopes present; and only mercury isotopes included.

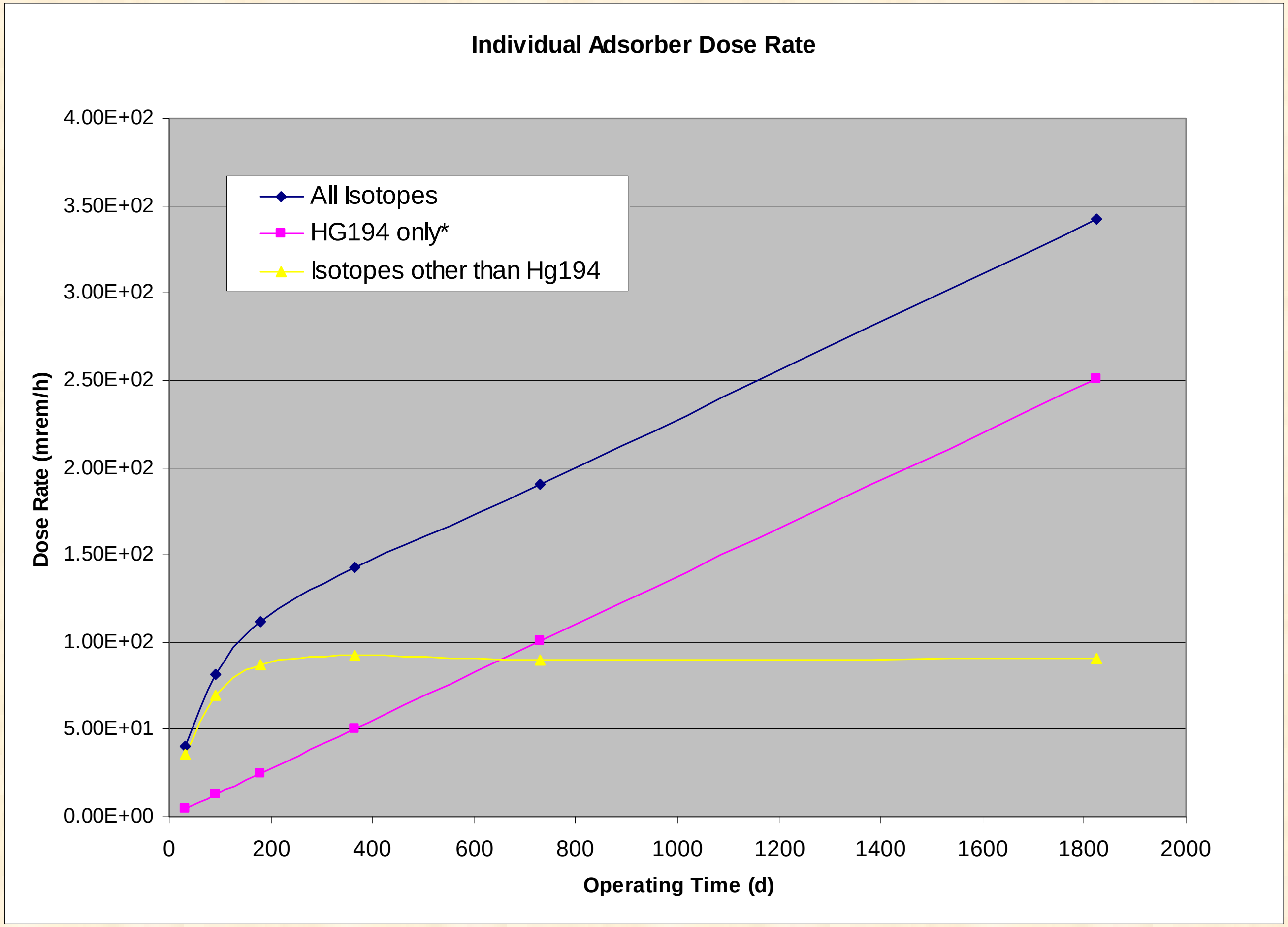
Packaging

- Removed from the installed position and capped.
- Inserted into a 85-gal drum with other in-cell materials
- Drum is inserted in the TN-RAM liner and removed from the hot cell through the bottom loading port

Carbon Adsorbers

- Sulfur impregnated charcoal
  - Nucon Mersorb 1.5 mm
- 1750 lb weight (total)
- Mercury content is about 2 kg
- measured by mercury content of air stream and flowrate
- Also measured by monitoring surface dose
  - Surface dose is <200 mrem/h
  - Known specific activity yields mercury content

Dose Rate Buildup on Carbon Adsorbers



Misc Service Bay Wastes

- How much mercury is possible to have in an 85-gal drum before a class A limit is exceeded?
- ~79 g Hg (40 year irradiation basis)
- in an 85 gal drum
- No visible mercury policy should eliminate exceeding this quantity

		ClassA						
	Value	Limit	Fraction					
C-14	9.35E-03	8.00E-01	1.17E-02					
Ni-59	5.71E-03	2.20E+01	2.60E-04					
Nb-94	5.79E-02	2.00E-02	2.89E+00	Class C, <2E-1				
Tc-99	1.13E-02	3.00E-01	3.77E-02					
I-129	1.62E-05	8.00E-03	2.02E-03					
Alpha emitters with half life >5 years								
	1.37E-03	Ci/m3						
	1.01E-01	1.00E+02	nCi/g					
Pu-241	1.18E+00	3.50E+03	nCi/g					
Cm-242	6.74E-02	2.00E+04	nCi/g					
H-3	5.54E+04	4.00E+01	1.38E+03					
Co-60	4.56E+01	7.00E+02	6.51E-02					
Ni-63	1.77E+01	3.50E+00	5.05E+00					
Sr-90	2.20E+01	4.00E-02	5.49E+02					
Cs-137	5.83E-01	1.00E+00	5.83E-01					
Nuclides with half life < 5 years								
	2.66E+04	Ci/m3	7.00E+03					
In an	85	gal container =		0.32	m3			
	When is the waste class A?							
	E.g, what activity is permitted before Class A is exceeded							
	Ci/m3	Ci/package*		m3 Hg	kg Hg			
C-14	8.00E-01	2.57E-03		2.75E-01	3.72E+03			
Ni-59	2.20E+01	7.08E-02		1.24E+01	1.67E+05			
Nb-94	2.00E-02	6.43E-05		1.11E-03	1.50E+01			
Tc-99	3.00E-01	9.65E-04		8.54E-02	1.15E+03			
I-129	8.00E-03	2.57E-05		1.59E+00	2.14E+04			
Alpha emitters with half life >5 years								
	1.00E+02	nCi/g						
H-3	4.00E+01	1.29E-01		2.32E-06	3.14E-02	> Class A		
Co-60	7.00E+02	2.25E+00		4.94E-02	6.67E+02			
Ni-63	3.50E+00	1.13E-02		6.37E-04	8.60E+00			
Sr-90	4.00E-02	1.29E-04		5.86E-06	7.91E-02	79.1 g hg per package		
Cs-137	1.00E+00	3.22E-03		5.51E-03	7.45E+01			
Nuclides with half life < 5 years								
	7.00E+03	2.25E+01		8.46E-04	1.14E+01			
		* to approach 1% of the limit						
	Sum of the fractions		1.61E-02					

All Hg together is a Class C waste

Class A limit for Sr-90 is exceeded at 79.1 g Hg

Conclusion

- **Science should drive selection of target!**
- **In the U.S., should mercury be selected as the target of choice, there is a path forward through the myriad regulations.**