

# Savannah River Site (SRS) Special Exposure Cohort Petition Evaluation Report Addendum #3 – Thorium (post 1972)

**Timothy D. Taulbee, Ph.D., CHP**

**Research Health Scientist**

**National Institute for Occupational Safety and Health**

**Division of Compensation Analysis and Support**

**December 2012**

**Knoxville, TN**

# Petition Overview

- **November 2007: Petition received**
- **December 2008: Evaluation Report presented to the Advisory Board**
- **May 2010: Evaluation Report Addendum #1 – Thorium presented to SRS Work Group**
- **January 2011: Work Group/Sanford Cohen & Associates comments received**
  - **Significant Work Group finding: Potential thorium work in other areas not discussed in the Evaluation Report Addendum**

# Petition Overview—cont.

- February 2011: SRS status update presented to the Advisory Board
- August 2011: In SRS Addendum #2, NIOSH recommended adding a class of thorium exposed workers in the 773-A and TNX to the SEC from January 1953 to October 1972 and proposed identifying the class based on dosimeter badge location
- August 2011: NIOSH indicated more research was needed for the post-Oct 1972 time period

# Petition Overview—cont.

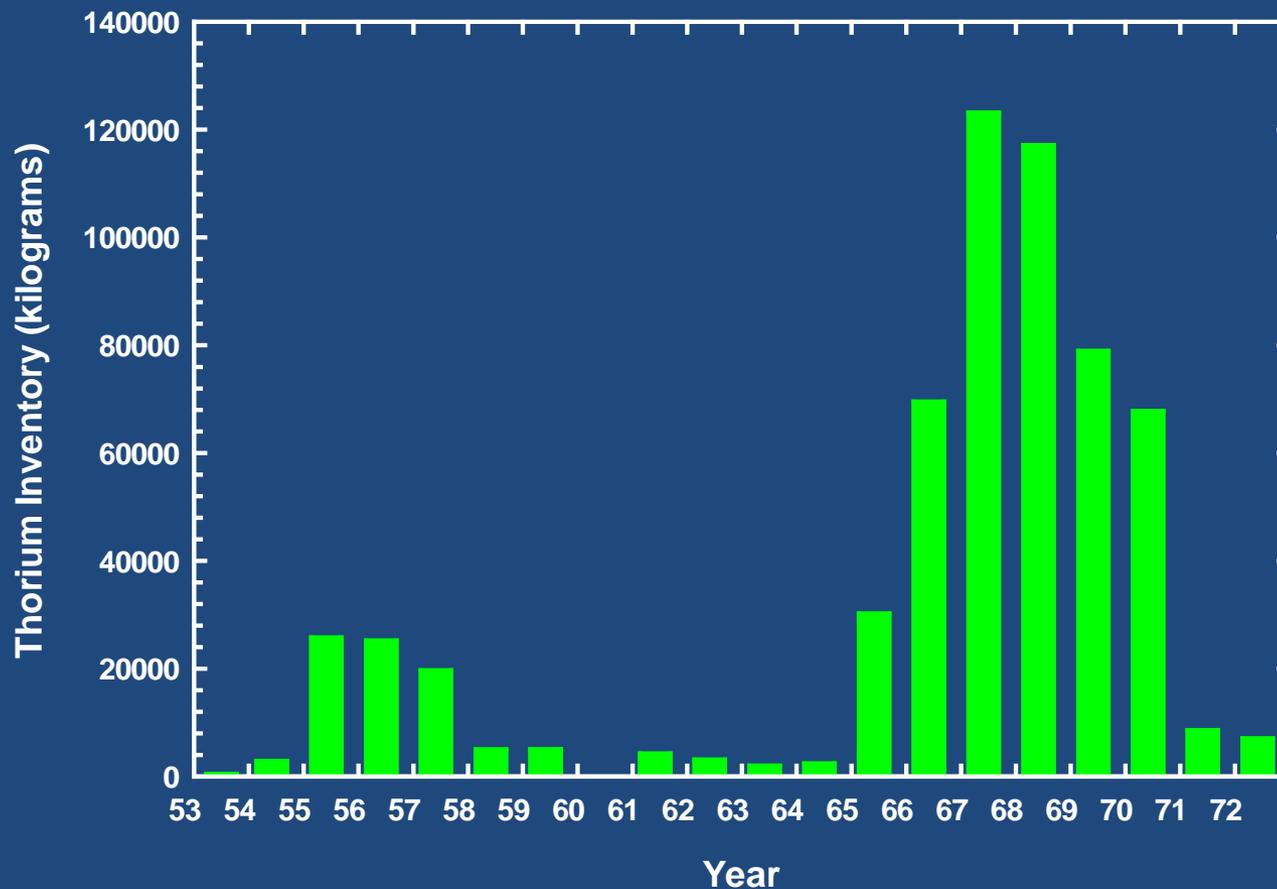
- **December 2011: Advisory Board partially concurred with NIOSH recommendation; however, recommended expansion of the class to include all workers at SRS**
- **March 2012: HHS Secretary added a class of all workers at SRS from January 1953 to October 1972 to the SEC**
- **November 2012: NIOSH issued third addendum to the SEC petition evaluation report regarding thorium (to cover the time period October 1972 through December 2007)**

# Recommendation to the Advisory Board

- NIOSH believes reconstruction of thorium exposures is feasible and that doses can be reconstructed with sufficient accuracy for compensation purposes from October 1972 through December 2007
- How NIOSH reached this conclusion
  - Very low inventory (source term)
  - Minimal use in certain defined locations
  - Knowledge of the processes
  - Radiological controls
  - Alternate bioassay data

# Thorium Inventory

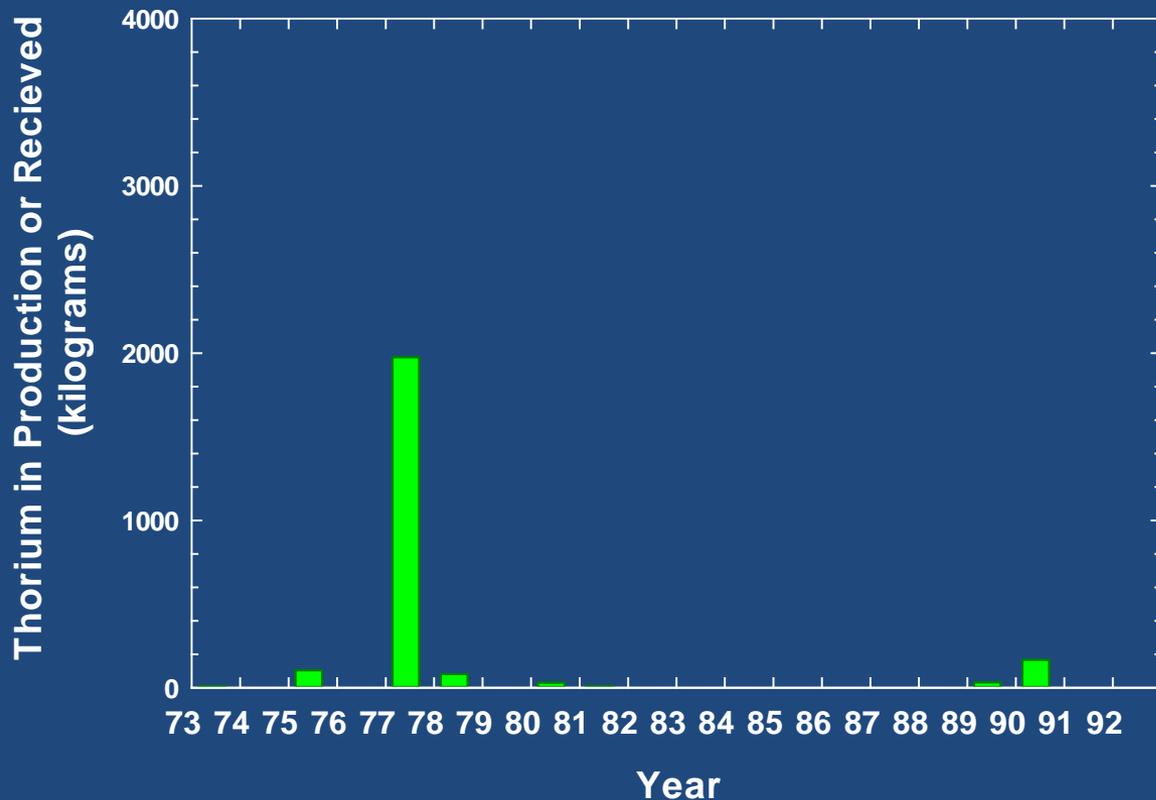
(Presented in August 2011—Addendum #2)



# Additional SEC End Date Research

(Presented in August 2011—Addendum #2)

- Inventories indicate some small thorium work in later years

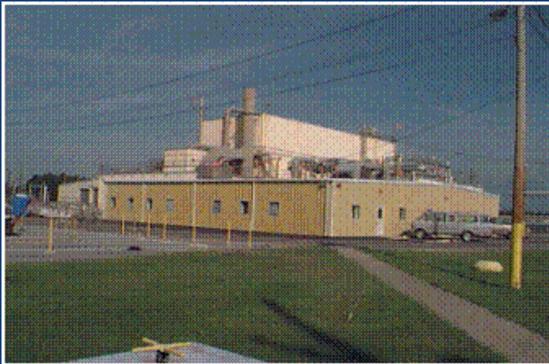


# Additional NIOSH Research

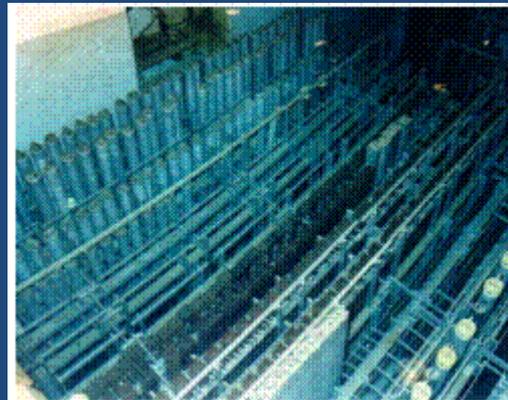
- Reviewed
  - Inventory reports (1972-2007)
  - SRL and Works monthly technical reports
  - Radiological surveys
- Evaluated
  - Whole body count data
  - Other bioassay methods
- Learned
  - Large spike of thorium work in 1977 that was reported in August 2011 was the receipt of spent thorium fuel in the receiving basin for offsite fuels (Receiving Basin for Offsite Fuels - RBOF)

# Receiving Basin for Offsite Fuels (RBOF)

- Encapsulated spent nuclear fuels
- Fuels repackaged underwater
- Fuels stored underwater



**RBOF Building**



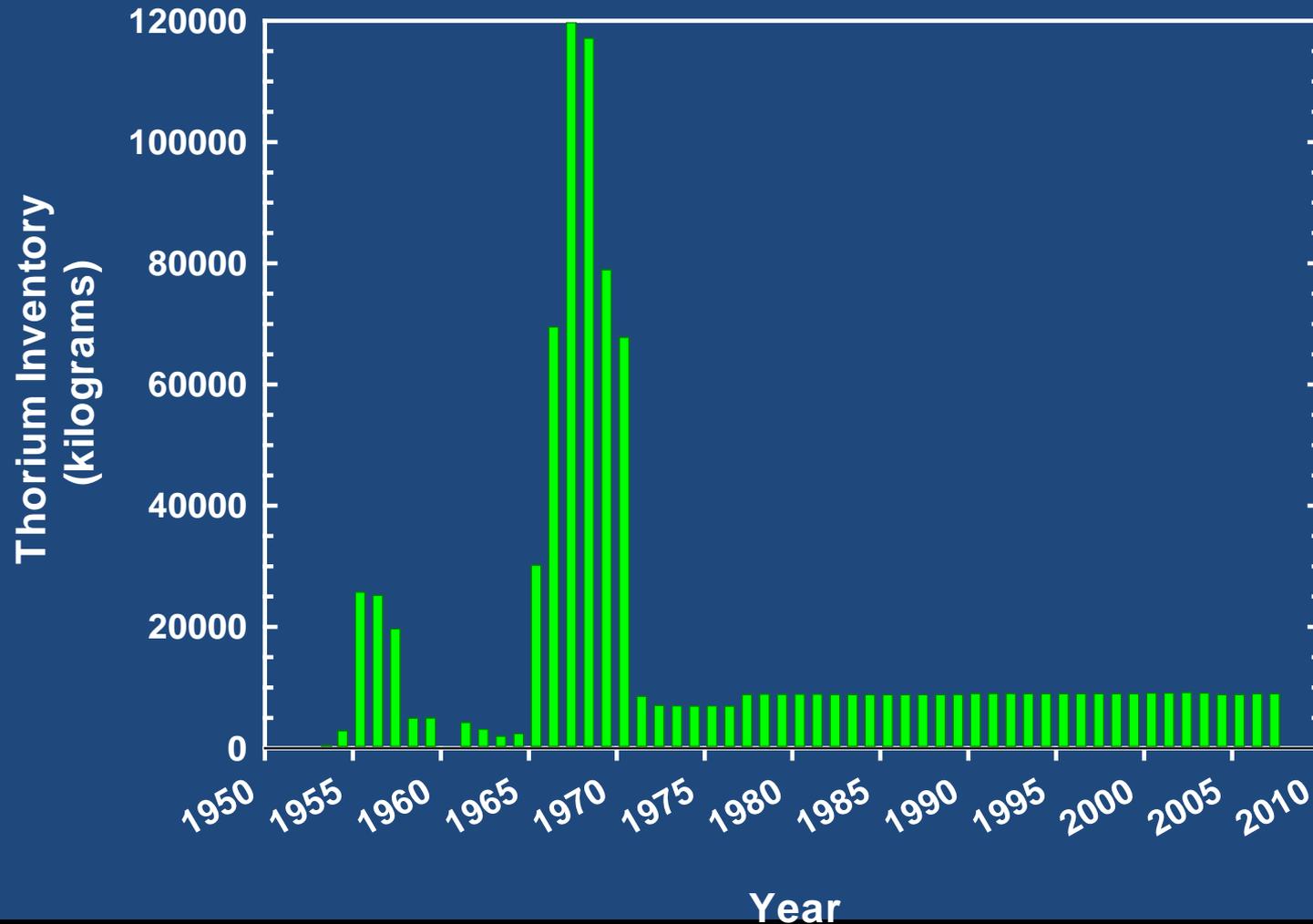
**Stored spent fuel**



**Repackaging basin**

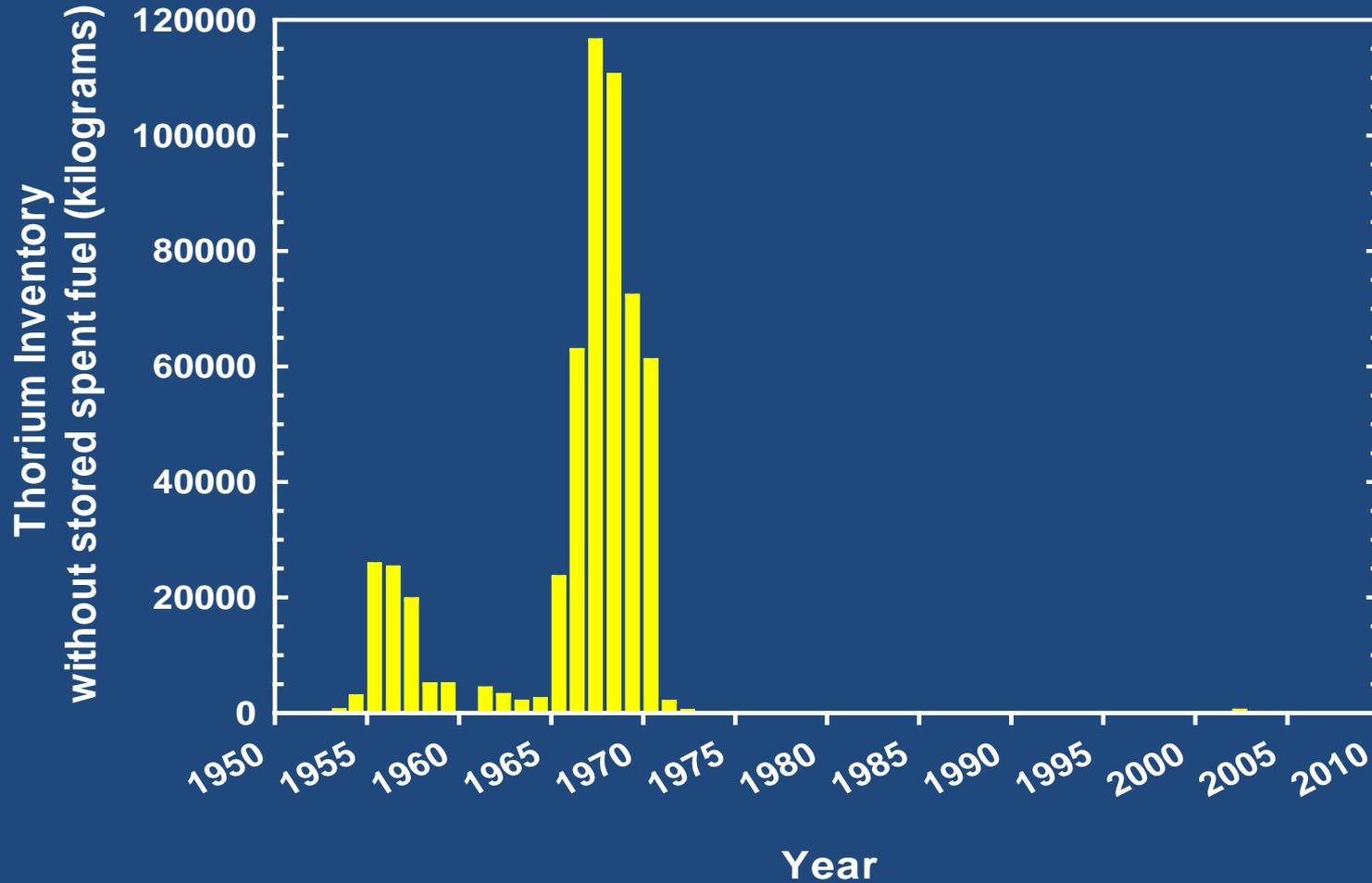
*Photos from WSRC-MS-99-00678 accessed via public internet at <http://sti.srs.gov/fulltext/ms9900678/ms9900678.html>*

# After Additional Review of Records



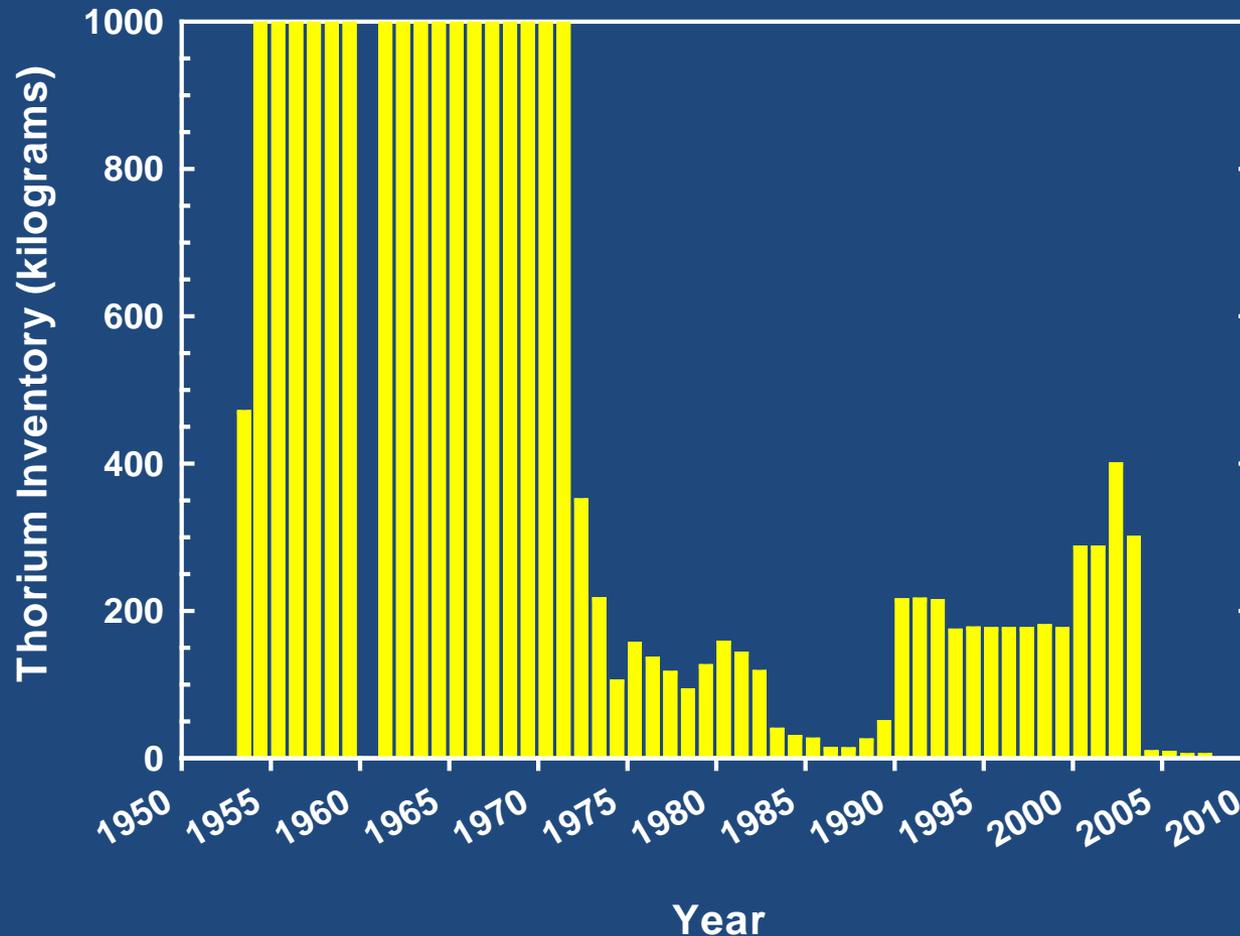
# Thorium Inventory

w/o water stored, encapsulated spent fuel



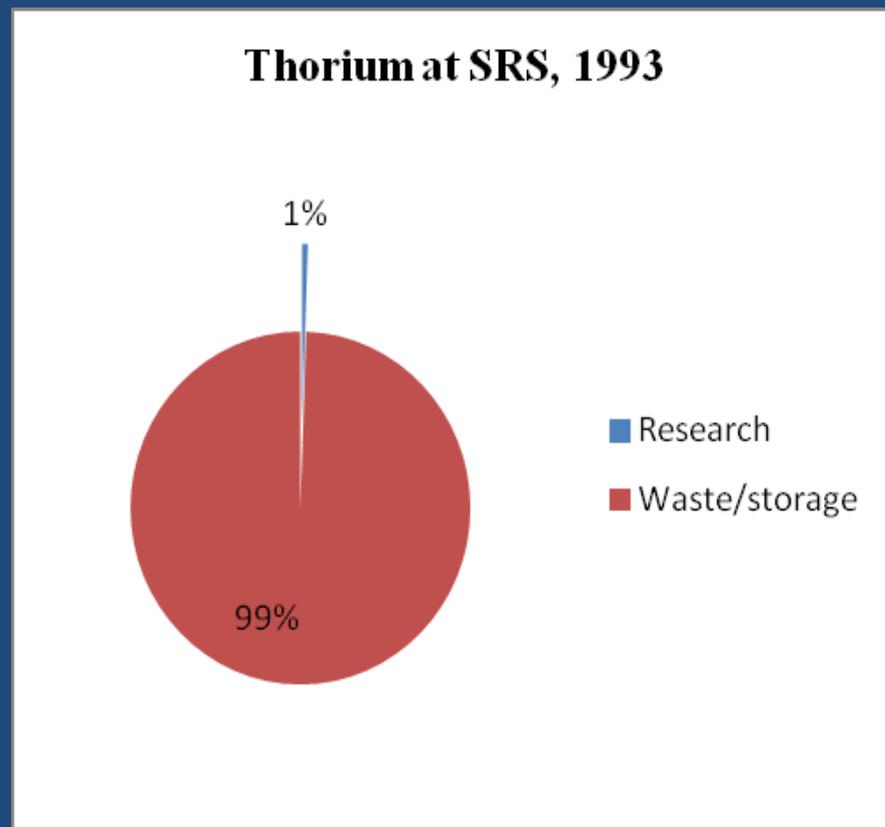
# Expanded Scale of Previous Graph

- Inventories indicate very small thorium inventory 1972 - 2007



# Research vs. Waste and Storage

- Most of the thorium inventory was waste and storage
- Less than 1% of the thorium on site was available for potential exposure

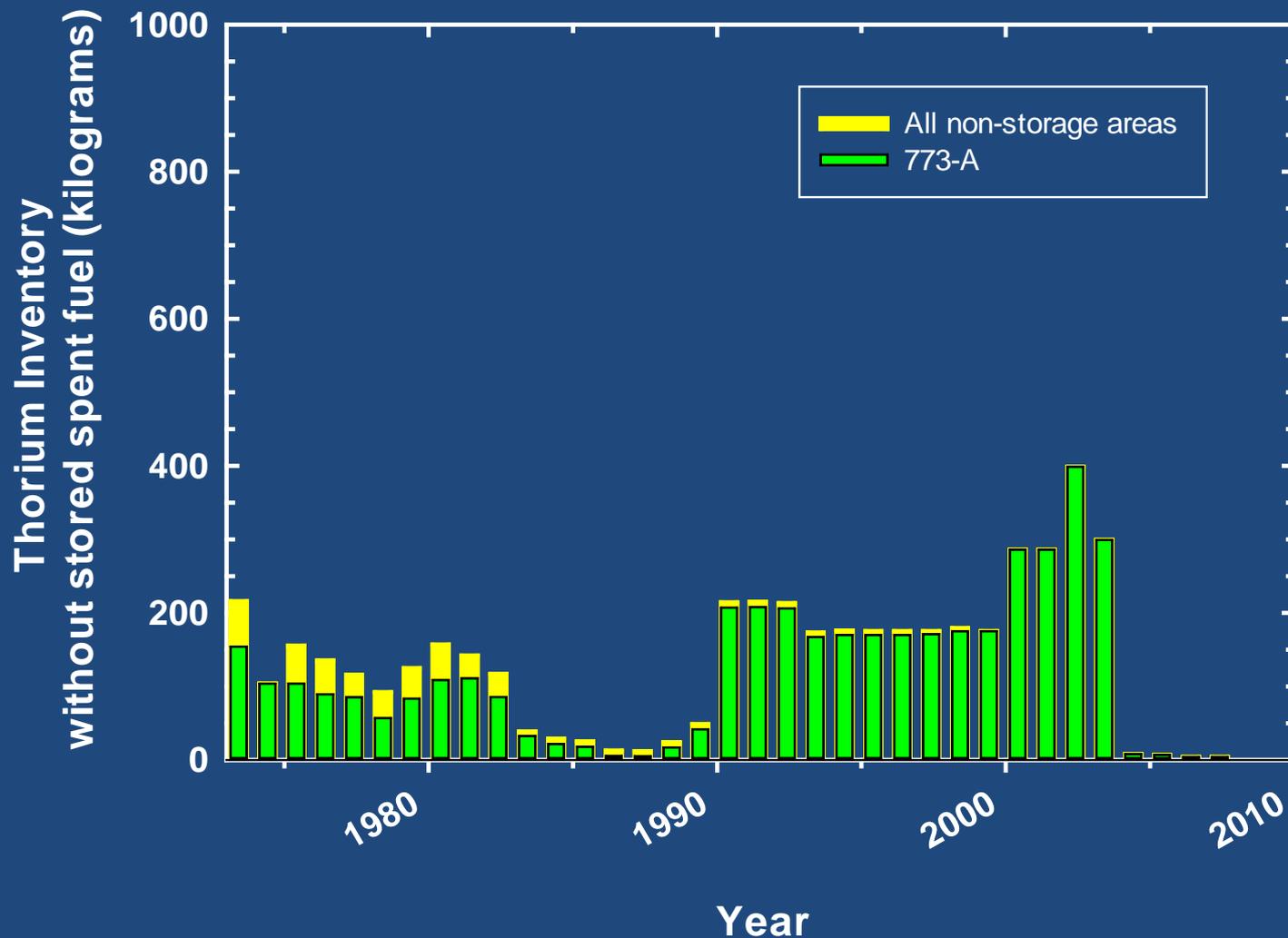


# Minimal Locations

Table 5-2: SRS Thorium Inventory, 1972-2007 (kg) (partial)

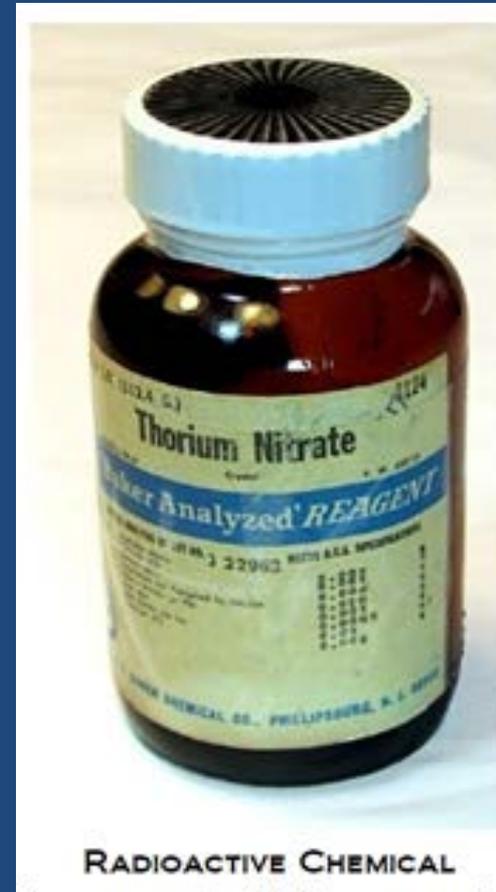
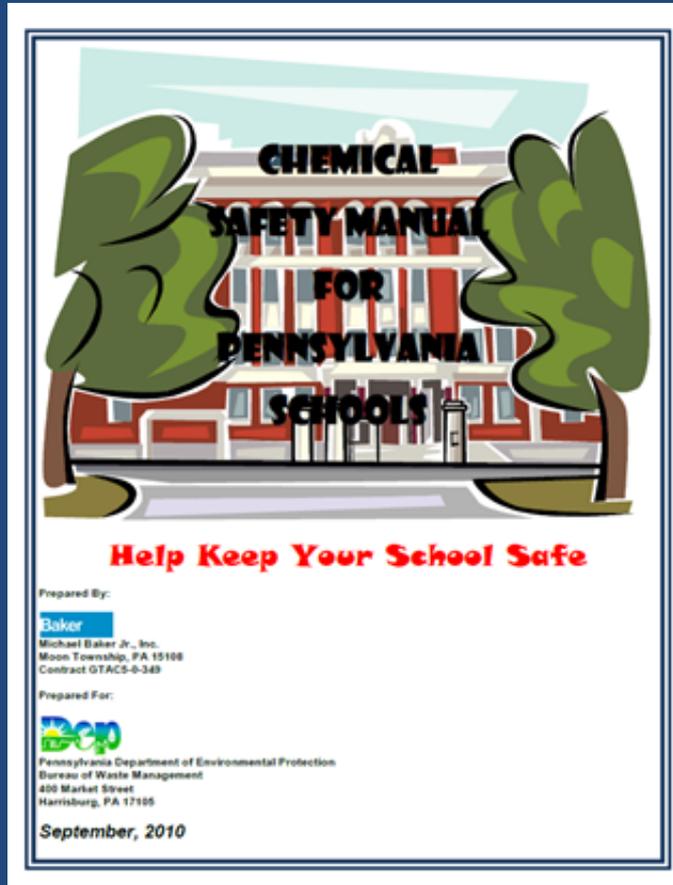
Year	773A	723A	235-F	772-F Lab	M Area	777 M	217-A Storage	100-K Basin	100-L Basin	RBOF
1973	154.0 <sup>1</sup>	--- <sup>2</sup>	0.0 <sup>3</sup>	---	57.2	6.4	0.0 <sup>3</sup>	52.0	---	6679 <sup>1</sup>
1974	104.0	---	---	---	---	---	---	52.0	---	
1975	104.0	0.5	1.1	1.1	43.2	5.4	---	52.0	---	6757
1976	89.4	1.1	0.9	0.9	40.7	2.0	0.0	52.0	---	6757
1977	85.4	1.1	0.9	0.9	25.4	2.0	0.0	52.0	---	8329
1978	56.6	---	4.0	4.0	25.2	2.1	0.0	52.0	---	8729
1979	83.4	---	4.0	4.0	31.1	2.1	0.0	52.0	---	8729
1980	108.6	---	4.5	4.5	31.1	---	8.0	52.0	3.1	8726

# Minimal Locations—cont.



# Thorium Nitrate

- Use of thorium nitrate is common in chemistry labs



# Process Knowledge

## (Savannah River Laboratory 773A)

- **1972: Alpha Material Laboratory used thorium oxide as a surrogate for Pu-238 testing in glove boxes**
- **1973: Gram quantities of thorium dioxide shards were used in 773A hot cells to test vapor deposition**
- **1977-1980: Alternate Fuel Cycle Technology Program (AFCT) and Thorium Fuel Cycle Technology Program (TFCT)—several research projects**

# Process Knowledge—cont.

(Savannah River Laboratory 773A)

- **Multiple AFCT/TFCT studies**
  - Mechanical grinding of  $\text{ThO}_2$  in high level caves
  - Study on effects of heat treatment on thorium oxide
  - Testing on conceptual THOREX flowsheets of Elk River fuel in high level caves
  - Analysis of off gassing of spent thorium fuel (Elk River Fuel – high level caves)
  - Hanford prepared (encapsulated) 30 fuel rods with  $80\%\text{ThO}_2 - 20\%\text{UO}_2$  for irradiation at SRS. SRS received rods in 1979 and stored them in a cage in 773A. The program was cancelled in May 1980 before they could be irradiated.

# Process Knowledge

## (Other)

- **Pu-238 Fuel Form Facility (1980)**
  - Thorium used as a surrogate for some of the work performed in the hot cells of the PuFF. Also used as a doping agent of the iridium welding agents
- **Galileo Project (1987)**
  - Thorium used as a surrogate for plutonium during process testing
- **Defense Waste Stabilization (1995-2010)**
  - Thorium used as a surrogate for plutonium and other radionuclides to test methods for defense waste stabilization and immobilization

# Summary of Thorium Use

For more details please see Table 5-3

Year	Operation	Locations	Average Inventory (kg)	Activity (millicuries)
1972- 1975	Storage, Surrogate	773A, M Area (storage)	158	15.8
1976 -1981	alternative fuels program, tritium studies, storage, surrogate	773A, 235-F, M Area (storage)	127	12.7
1982-1989	welding agent studies, storage, surrogate	773A, 235-F, M Area (storage)	38	3.8
1990-2003	defense waste research, storage, surrogate	773A, 235-F	224	22.4
2004-2007	defense waste research, storage, surrogate, D&D	773A	5	0.5

# Radiological Controls (1972-1990)

- **DPSOP-40 Savannah River Plant Radiation and Contamination Control and DPST-RH Radiation Hazards Technical Standards covered:**
  1. **Work in regulated areas**
  2. **Investigating radiation and contamination incidents**
  3. **Protective clothing**
  4. **Injury in regulated areas**
  5. **Disposal of contaminated waste**
  6. **Fires in regulated areas**
  7. **Radiation exposure control**
  8. **Internal radiation exposure control**

# Radiological Controls (1991-2007)

- SRS implemented a new radiation control manual (WSRC-5Q) in 1991 to comply with DOE Order 5480.11, it was updated as follows to comply with:
  - 1992 DOE Radiological Control Manual DOE N 5480.6
  - 1994 DOE Radiological Control Manual DOE/EH-0256T
  - 1995 Occupational Radiation Protection 10CFR835

# Other Radiological Information

- NIOSH has collected samples of contamination surveys in 773-A, M Area, 235-F, and TNX from 1972 through 1988
- NIOSH has collected samples of air monitoring surveys from 773-A, 235F, and 244-F from 1972 through 1988
- More contamination surveys and air sample results are available in electronic form

# Radionuclide Activities (1994)

Table 5-4: Radionuclide Activities			
Isotope	Inventory (g)	SA (Ci/g)	Activity (Ci)
Th-232	4.12E+07	1.10E-07	4.5
Np-237	6.90E+04	6.90E-04	47.6
U-233	1.34E+04	9.50E-03	126.8
Cf-252	2.50E-01	5.40E+02	135.1
Pu-239	5.13E+05	6.20E-02	31806.0
Am-241	7.23E+04	3.20E+00	231360.0
Cm-244	1.12E+04	8.20E+01	915940.0
Pu-238	1.49E+05	1.70E+01	2533000.0

**Table includes waste that is not available for intake; in 1994 only 0.0176 Ci were non-waste.**

# Alternate Bioassay Data

- A large number of workers in 773-A were monitored for Am, Cm, and Cf
- Review of the bioassay method during development of the co-worker model for Am, Cm, and Cf revealed that thorium would come through in the analysis and the alpha emissions would be counted as if it were Am, Cf, or Cm

# Alternate Bioassay Data—cont.

FE Butler and RM Hall, Analytical Chemistry Vol 42, No 9  
pp. 1073-1076 (1970):

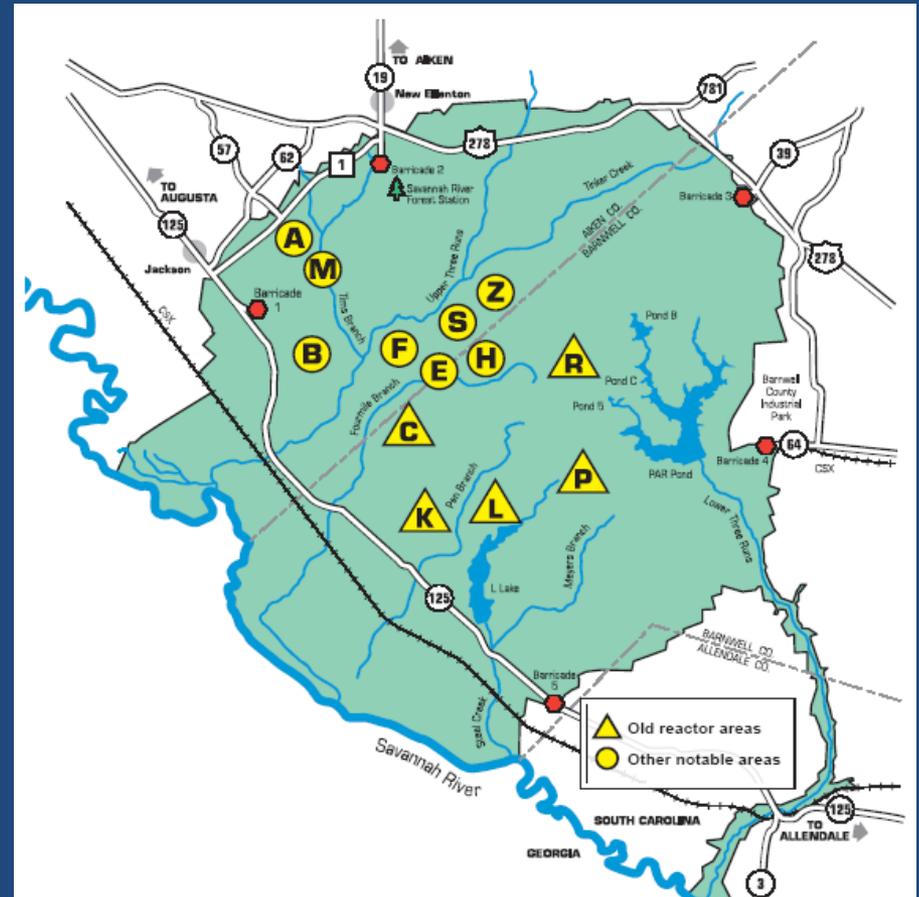
“A procedure was developed for sequential extraction of plutonium, neptunium, and uranium with tri-isooctylamine (TIOA), followed by extraction of thorium, americium, curium, berkelium, californium, and einsteinium with bidentate. Compared with previous methods, the new procedure is simpler, requires less analysis time, and gives better recovery. The recovery of Am-Cm-Cf from 250 ml of urine or 20 grams of feces was 90%.”

# Alternate Bioassay Data—cont.

**“All alpha emitting actinides from thorium through einsteinium extract, indicating an excellent gross alpha analytical procedure. The data show that in analysis of americium, curium, and californium any contaminating plutonium, neptunium, or uranium must be removed. At this laboratory, thorium, berkelium, and einsteinium are not present in biological samples in sufficient quantities to require separation or routine identification by alpha spectrometry.”**

# Thorium Volume and Activity

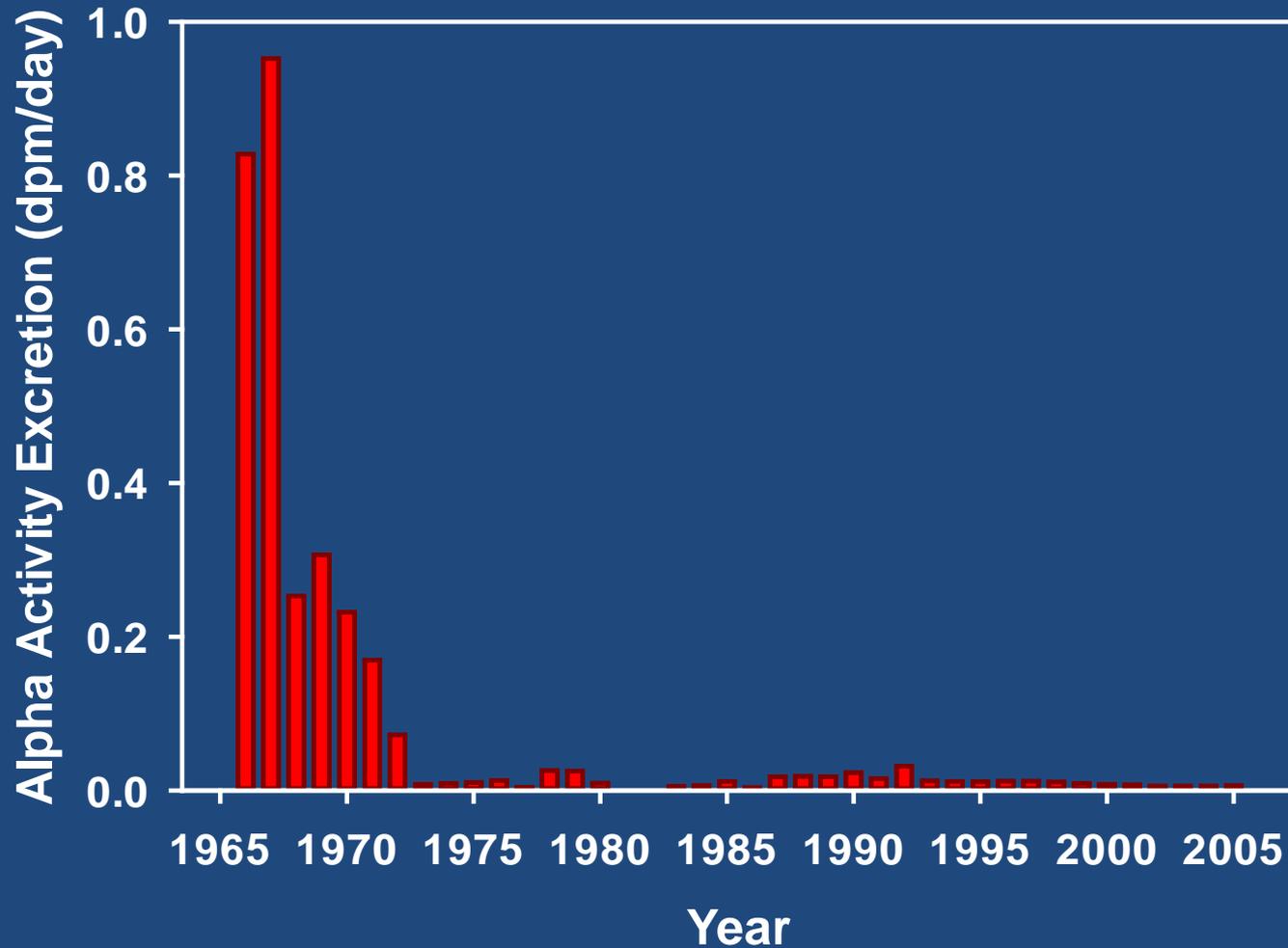
- Mass
  - 200 kg = 20.0 mCi
- Small volume
  - 200 kg = approximately ten 2L bottles of ThO<sub>2</sub>
- 773-A is a fairly large building
  - Small volumetric source term



# Alternate Bioassay Data

- No effort was made by the lab to remove the thorium contaminant from the urine sample
- Why
  - Activities were much lower
  - Not viewed as a significant contaminant
  - Thorium used as a surrogate because it was less hazardous than plutonium (i.e. safer to use)
- Effectively we have alpha urine bioassay sample that does not contain plutonium, uranium, or neptunium, but does contain Th, Am, Cm, Cf, Es, and Bk

# Alternate Bioassay Data—cont.



# Alternate Bioassay Data—cont.

- How high are the doses (1972-1994)?

Estimated Organ Dose from Thorium (Intake: 1973-1994)		
Material Type	Lung Dose (rem)	Bone Dose (rem)
Type M	2.60	18.66
Type S	79.92	23.34

# Whole Body Count Data

- In 1995, SRS started using Alpha Spectrometry (not gross alpha counts)
- Thorium was not one of the alpha energies evaluated
- Am, Cm, and Cf analysis only valid from 1972-1994
- Must use Whole Body Count Data
  - MDA for Th-232 = 0.15 nCi

# Dose from Whole Body Count Data

Estimated Organ Dose from Thorium (1995-2007)		
Material Type	Lung Dose (rem)	Bone Dose (rem)
Type M	56.94	174.3
Type S	15.40	1.75

During the Radiological Controls from 10CFR835

# Whole Body Count Data

- NIOSH has concluded that by this time period under 10 C.F.R. 835, people who should have been monitored were monitored
- NIOSH has also obtained lapel air sample data from 2004 when remediation work was conducted on a concrete pad that was contaminated with thorium

# Summary

- **Very low inventory (source-term)**
  - More thorium inventory in 1990s and 2000s than 1970s and 1980s
  - Most thorium on site was waste/storage
- **Minimal use in certain defined locations**
  - Mostly 773-A (especially post-1983)
- **Knowledge of the processes**
  - Mostly used as a surrogate
  - Except for AFCT/TFCT (1977-1980)

# Summary—cont.

- **Radiological controls**
  - Procedures in place
  - Routine monitoring of the workplace
  - Survey data available
  - Air monitoring data available
- **Alternate bioassay data**
  - Am, Cm, and Cf bioassay was effectively gross alpha analysis that included thorium
  - Doses are plausible

# Feasibility Summary

Feasibility Findings for Savannah River Site 1972-2007		
Source of Exposure	Dose Reconstruction Feasible	Dose Reconstruction NOT Feasible
<b>Internal</b>		
<b>- Thorium</b>	<b>X</b>	

# Recommendation

- For the period October 1, 1972 through December 31, 2007, NIOSH finds that radiation dose from exposure to thorium can be reconstructed for compensation purposes

Class	Feasibility	Health Endangerment
October 1, 1972 – December 31, 2007	Yes	Yes