NON-REACTOR ALTERNATIVES FOR PLUTONIUM DISPOSITION

Edwin S. Lyman
Senior Scientist
Union of Concerned Scientists

Presentation at the AAAS
Washington, DC June 10, 2014

SPENT FUEL STANDARD

- “Spent fuel standard” (SFS) concept for excess plutonium disposition
  - To render separated plutonium “roughly as inaccessible for weapons use as the much larger and growing stock of plutonium in civilian spent fuel”: National Academy of Sciences, 1994
  - Intrinsic properties of the waste form only
- Chief attributes:
  - Mass and bulk of disposition item
  - Plutonium chemical dilution
  - “Self-protecting” radiation barrier (e.g. cesium-137)
  - Plutonium isotopic composition much less important

PU DISPOSITION ALTERNATIVES

- Numerous technical alternatives to irradiation for plutonium disposition have been considered
  - Immobilization with vitrified (“glassified”) high-level waste and disposal in a mined repository (originally Yucca Mountain)
    - Homogeneous
    - “Can-in-Canister”
  - Immobilization without radiation barrier and
    - Co-disposal with spent fuel
    - Burial in deep boreholes
  - Mixture with chemically inert materials and burial in the Waste Isolation Pilot Plant (WIPP) (now called “Downblending and Disposal”)

CAN-IN-CANISTER IMMOBILIZATION

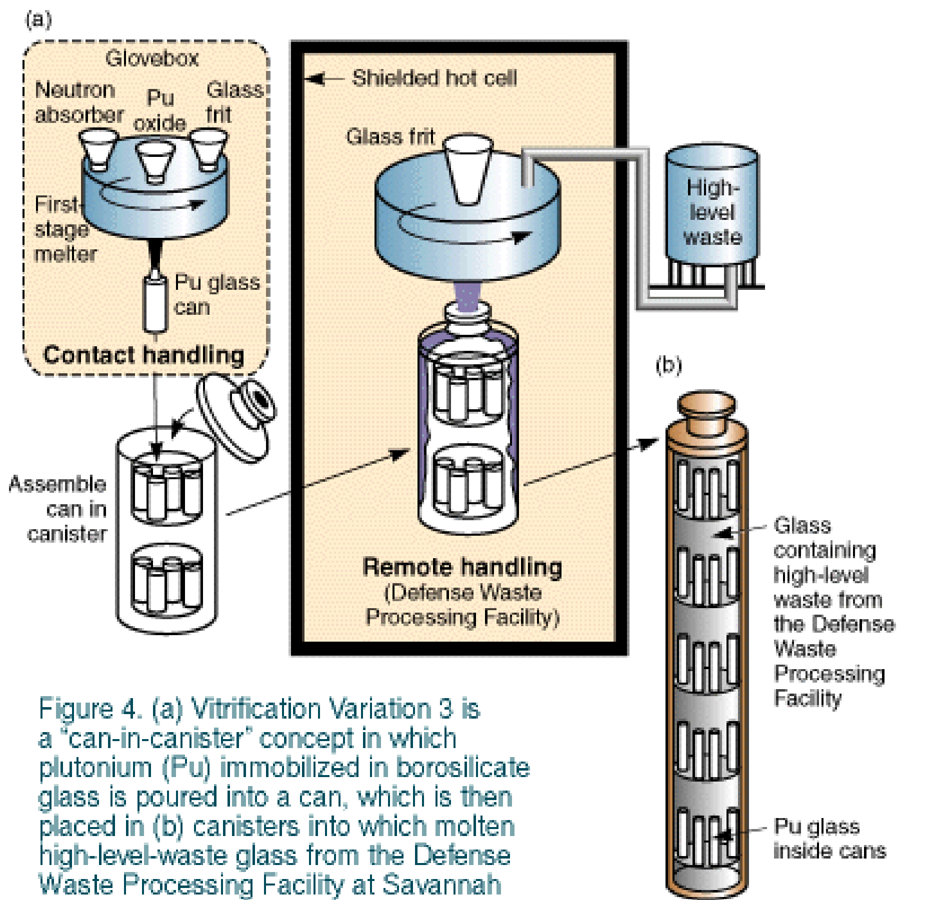

Figure 4. (a) Vitrification Variation 3 is a "can-in-canister" concept in which plutonium (Pu) immobilized in borosilicate glass is poured into a can, which is then placed in (b) canisters into which molten high-level-waste glass from the Defense Waste Processing Facility at Savannah River is poured. The outer canister provides an external radiation barrier.

ONE-TRACK PROGRAM

- DOE initially pursued a two-track approach: MOX and “can-in-canister” immobilization
  - DOE originally determined that both met the SFS
  - Considerable R&D on both MOX and immobilization options
  - Pilot ceramic immobilization plant was installed at Lawrence Livermore National Laboratory
- In 2002, DOE cancelled the immobilization program to focus exclusively on MOX
  - Although its analysis showed that immobilization was the lower-cost option, DOE asserted that Russia would never accept an all-immobilization option because it did not change the isotopic composition of the plutonium and hence was not irreversible
- This decision caused additional difficulties and delays
  - Complicated disposition pathway for impure, non-pit plutonium

ROLE OF RADIATION BARRIER

- The NAS judged that chemical dilution without a radiation barrier was not sufficient to meet SFS
  - Experienced chemists can recover plutonium from any form given sufficient time and resources
  - Radiation barrier should be high enough to preclude chemical processing in gloveboxes
- In 2000, NAS further refined the SFS
  - Judged that research and testing was needed to determine whether heterogeneous “can-in-canister” immobilization met the SFS

IS THE SPENT FUEL STANDARD STILL NECESSARY?

- Now that the current life-cycle cost of MOX is approaching $40 billion, NNSA is reconsidering MOX and, more generally, the costs and benefits of meeting the SFS
  - Would immobilization still be significantly cheaper and faster today than MOX? (Probably not, but not as expensive as NNSA Options Study)
  - What are the current security and non-proliferation objectives of plutonium disposition? Is the spent fuel standard still necessary?
  - Can more credit be given for dilution and other mechanical and chemical barriers to separation? Can more weight be given to extrinsic rather than intrinsic barriers?

DOWNBLENDING AND DISPOSAL: THE POSITIVES (as of 2/13/14)

- WIPP: an operating geologic repository for DOE transuranic (TRU) waste near Carlsbad, New Mexico
- DOE has already downblended and disposed of 4.8 MT of excess plutonium in WIPP
- Current cost of packaging plutonium for WIPP at the Savannah River Site is $100,000/kg – several times less than the cost of MOX fuel fabrication alone
- Savannah River Site reports that 1 MT Pu/year can be packaged for WIPP using existing infrastructure (compared to current commitment of 1.3 MT/yr)
- NNSA projected cost to dispose of 34 MT of Pu in WIPP as $8.8 billion --- 3-4 times cheaper than MOX

DOWNBLENDING AND DISPOSAL: THE NEGATIVES (as of 2/14/14)

THE WIPP OPTION

- Assuming the kitty litter fiasco eventually will be resolved, there are other considerations:
  - Statutory capacity (Land Withdrawal Act)
  - WIPP Waste Acceptance Criteria
  - EPA requirements in 10 CFR 191, 194
  - security objectives of Pu disposition (transparency, irreversibility)

WIPP CAPACITY

- Land Withdrawal Act limits the WIPP capacity to 175,600 m^3 of TRU waste
  - Contact-handled: surface dose rate < 200 mrem/hr
  - Remote-handled: 200 mrem/hr ≤ SDR < 100 rem/hr
- 1988 DOE-NM agreement limits the total volume of remote-handled TRU waste to 7,080 m^3
- April 2014 Options Study says that the Land Withdrawal Act will have to be amended to accommodate an additional 34 MT of plutonium: but is this correct?

WIPP CAPACITY

- As of the end of 2012
  - Total TRU volume in WIPP: 85,200 m^3
  - Total TRU volume not yet in WIPP: 66,200 m^3
  - Total committed waste volume: 151,400 m^3
  - Volume available: 24,200 m^3

WIPP PLUTONIUM DISPOSAL CONFIGURATION

- Pipe overpack container: 208-liter drum containing a stainless steel inner container
- Criticality considerations limit the amount of plutonium in each pipe overpack container to approximately 200 grams of Pu-239

CRITICALITY CONTROL OVERPACK

- WIPP has certified a “criticality control overpack” that can nearly double the maximum plutonium content of a 208-liter waste drum to 380 grams of Pu-239
- NRC approved the package in 2013
- Excess volume could accommodate 44 MT of plutonium if packed in criticality control overpacks
  - May compete with other waste streams proposed for disposal in WIPP (e.g. non-defense TRU waste)
- With other modifications, even greater quantities of plutonium could be loaded in each drum

OTHER CONSTRAINTS

- 40 CFR 191, 194 impose performance requirements on WIPP for 10,000 years
  - Limit cumulative releases, receptor doses, groundwater contamination
  - Both natural processes and human intrusion must be considered
- An additional 34 MT of plutonium in WIPP will increase the amount of Pu-239 by several times
  - May affect dose consequences of human intrusion scenarios

SECURITY CONCERNS

- Even if the excess plutonium inventory could be buried in WIPP, is that desirable?
- Security aspects:
  - DOE graded safeguards policy
  - Spent fuel standard
  - PMDA commitments
  - International monitoring/verification
- The relevant standards are different and not necessarily consistent

DOMESTIC SAFEGUARDS

- DOE requires termination of safeguards on materials prior to shipment to WIPP
  - WIPP is a “property protection area”
- Generally requires Attractiveness Level E designation
  - DOE-STD-1194-2011: solid Pu item with < 0.1- 1 wt% Pu or “highly irradiated” (no specific dose rate)
- DOE allows termination of safeguards on Attractiveness Level D items if security analysis shows no significant increase in risk of theft of a Category II quantity of SNM (16 kg for Pu)

ROCKY FLATS VARIANCE

- In 1998, Kaiser-Hill (Rocky Flats contractor) requested a variance from DOE to allow termination of safeguards on several tons of plutonium-rich residues
- Proposed blending to Attractiveness Level D (Pu < 10 wt-%), packing in POCs, and conducting a security assessment
- Asserted the approach met the SFS even though there was no radiation barrier
  - To acquire a comparable amount of plutonium would require theft or diversion of 127-160 drums weighing 19 to 40 MT and having a volume of 2,000 to 33,300 liters

STARDUST

- Some RF Pu residues required down-blending to below 10 wt-% with a special diluent called “stardust” in order to effectively reduce attractiveness level to D
  - “A mixture of cementing, gelling, thickening and foaming agents” that made it “more difficult and complex to recover, concentrate and purify the plutonium”
- Similar “termination of safeguards” materials (a misnomer) are now being used at SRS to down-blend non-pit Pu authorized for WIPP disposal

SFS EQUIVALENCE?

- Presumably, security assessments have determined that the additional time and resources needed to recover a Category II quantity of Pu from these waste forms justifies termination of safeguards
- TOS actually exceeds SFS because safeguards must be maintained on irradiated fuel
- Does this support a conclusion the SFS can be exceeded through dilution with TOS materials?
- Other options also available for further reducing accessibility of Pu in WIPP disposal drums
  - Dilution below 1% in cement grout
  - Immobilization in refractory materials

GEOLOGIC VERSUS INTRINSIC BARRIERS

- Inherent to the SFS was the understanding that disposition forms would all be in the same boat with civilian spent fuel with regard to final geologic disposal
- Assuming operations eventually resume, a large amount of excess plutonium in could be buried in WIPP faster than irradiated forms awaiting a spent fuel repository
- The geologic barrier is formidable and potentially can further compensate for lack of a radiation barrier
- Radiation barrier will decline over time for disposition forms and spent fuel in above-ground interim storage
- International monitoring easier for a repository than for multiple above-ground storage sites

CONCLUSIONS

- Disposal of excess plutonium in WIPP is proven
- Assuming WIPP resumes operations within several years, it could used for disposing of > 34 MT of Pu far more cheaply than MOX
- Near-term burial of plutonium in a repository is attractive compared to indefinite above-ground storage of highly irradiated disposition forms
- Security analyses should address the additional risks and whether further intrinsic or extrinsic compensatory measures are needed