A Practical Solution to Hanford’s Tank Waste Problem

Darryl D. Siemer
d.siemer@hotmail.com
(208) 524-2479
Updated 10 April 2013
A “Troubled” Project

• “Since 1988, roughly $2 billion per year has been spent on Hanford cleanup.”

• “Despite the big money and big employment figures (typ. 10,000)…, many feel that cleanup is off-track. Very little of the radionuclide and chemical inventory has been stabilized after thirty years of effort.”

• “GAO estimates that the final bill may be as much as $120 billion and may take another 50 to 60 years to complete.”

http://www.hanfordchallenge.org/the-big-issues/how-hanford-works/

A FEW EXAMPLES


...etc., etc. back to the early-90’s

Two yardsticks are useful in judging the EM program: progress toward cleanup goals and the costs incurred

The remediation program has accomplished far less than many wish. The Government Accounting Office[8], ... concluded that while "DOE has received about $23 billion for environmental management since 1989, .. little cleanup has resulted. “

One of the consequences of the troubles has been the enhancement of a syndrome common to large bureaucracies: risk aversion. It has a name: "the Hanford Syndrome." It has become widespread and severe in the EM program. Its symptoms are an unwillingness to alter familiar behavior patterns, to stick with unproductive or failing procedures, to enhance tendencies for excessive resource allocation and regulation, and to oppose innovation. It is an important element in sustaining unproductive patterns of work.”

The Tri-Party Agreement at Hanford, and similar ones elsewhere, have proven to constitute major constraints on remediation progress because, in many instances, they are unrealistic, not having had proper input from those experienced in actual cleanup. The milestones they incorporate, along with penalties for noncompliance, force continued activities, some of which are make-work and should be abandoned. Other activities should be delayed or modified so as to await more effective and less costly technologies. Virtually no one believes the timetables are achievable and DOE has already been forced into renegotiations...

There is a marked incapacity within the Department's EM program to evaluate current and prospective technologies in a wide-ranging and competent manner based on well-assessed risks.”
History of Hanford Tank Waste Treatment Project 1989-2010

Plan #1 - 1989
Hanford Waste Vitrification Project for Double-Shell Tank Waste
Terminated

Plan #2 - 1993
New technical strategy to retrieve and vitrify all waste
Terminated

Plan #3 - 1996
Privatization Concept adopted for tank waste treatment
Terminated

Plan #4 - 2000
Bechtel selected as new Waste Treatment Plant (WTP) contractor

Plan #4 - delay
WTP Construction Schedule Slip

10 Years with 3 project terminations

2007
Old Hot Start

2007 Full-Scale Operation Plan

2019 Hot Operations

Wasted 10 Years with Schedule Slip in 2003

Schedule Slip in 2005

Schedule Slip in 2007

20 Year delay in original hot operations

10 Years with 3 major delays adds 12 years to hot operations

Figure 1: WTP Waste Treatment Process

<table>
<thead>
<tr>
<th>Characterization</th>
<th>Retrieval</th>
<th>Pretreatment</th>
<th>Treatment</th>
<th>Final disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling and analyzing the waste throughout preparation for treatment</td>
<td>Retrieving waste from tanks and preparing for treatment</td>
<td>Mixing and separating waste constituents into high-level and low-activity waste streams</td>
<td>Vitrifying high-level waste and placing it into stainless-steel canisters</td>
<td>Storing high-level waste canisters temporarily on site until permanent repository opens</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Vitrifying low-activity waste and placing it into stainless-steel containers</td>
<td>Storing low-activity waste containers permanently on site in landfill</td>
</tr>
</tbody>
</table>

Sources: GAO and DOE.

from GAO-13-38, Dec 2012
Root Causes

The “technical” reason why WTP has proven to be a boondoggle* is that it is based upon two unrealistic assumptions

1. (most harmful) Hanford’s tank waste will/must be separated into “high” & “low” fractions so that the former can be dumped into someone else’s “back yard”\(^{\text{note1}}\) (politically & economically unrealistic)

2. Both fractions will/must eventually be converted to borosilicate-type glass\(^{\text{note2}}\) (renders vitrification unnecessarily difficult/expensive)

Recommended Approach

• Homogenize (not separate) Hanford’s tank wastes: i.e., simultaneously retrieve from multiple depths from multiple tanks

• Pug-mill mix with crude phosphoric acid & powdered iron ore, vitrify with a large stirrer-equipped melter, and make “aggregate”* of the resulting glass

• Slurry this aggregate with a MgO/KH₂PO₄ (“Ceramicrete”) - type grout & pump it back into Hanford’s best-condition waste tanks**

* Either glass marbles, “gems” or cullet
** this grout would serve to seal any existing leaks in those tanks
Background Slides*

*srnl.doe.gov/emsp/day1_overv/hanford-gaspl.pdf  (CH2MHiIl, 2005)
More background...
Current Hanford Tank Waste Volume

- 177 Storage Tanks
- Volume ~54 Million Gallons (December 1998)
- ~40 Inactive Miscellaneous Underground Storage Tanks
- 1933 Cs/Sr Capsules
- 340 Million Curies of Radionuclides
Hanford High-level Waste Radioactive
Underground Storage Tanks are Large

1 Million Gallon Capacity
Single-Shell Tanks

- 149 Tanks Constructed 1943-64
- ~210 m$^3$ to 3,800 m$^3$ Capacity (55 kgal to 1 Mgal)
- Bottom of Tanks at Least 50 m (150 Feet) Above Groundwater
- No Waste Added to Tanks Since 1980
- Tanks Currently Contain:
  - ~132,500 m$^3$ (35 Mgal) of Salt Cake, Sludge, and Liquid
  - $4.07 \times 10^{18}$ Bq (110 MCl)
- 67 Are Assumed to Have Leaked
  - ~3,800 m$^3$ (~1 Mgal)
Double-Shell Tanks

- 28 Tanks Constructed Between 1968-86
- \( \sim 3,800 \text{ m}^3 \) to \( 4,300 \text{ m}^3 \) (1 to 1.14 Mgal) Capacity
- Tanks Currently Contain
  - \( \sim 72,000 \text{ m}^3 \) (19 Mgal) of Mostly Liquids (Also Sludges and Solids)
  - \( 2.86 \times 10^{16} \text{ Bq} \) (80 MCI)
- None Have Leaked

note
Hanford Site Waste Tanks Estimated Inventories

Radionuclide Inventory Decayed to 12/31/96*

- $^{90}$Sr-$^{90}$Y (16 MCI) 60%
- $^{137}$Cs-$^{137}$Ba (72 MCI) 38%
- $^{151}$Sm (1.0 MCI) 1%
- Other (<1 MCI) 1%
- Total in All Tanks 190 MCI

Chemical Inventory**

- Water (123,000 MT) 42%
- Nitrate (52,000 MT) 18%
- Sodium (48,000 MT) 16%
- Other (60,000 MT) 24%
- Total Other MT %
  - Total Other 5,400 2%
  - Hydroxide 21,000 7%
  - Nitrate 12,000 4%
  - Aluminum 7,800 3%
  - Carbonate 9,000 3%
  - Sulfate 3,200 1%
  - Silicon 1,100 <1
  - Other 9,600 3%

*Data Source: DOE/RW-006, Rev. 13 1996 Integrated Data Base
**Tank Characterization Database, 9/97

Total in All Tanks 292,000 Metric Tons
Mass sum oxides halides \( \approx 107,000 \) tonnes (~70% of which is \( \text{Na}_2\text{O} \)) \( \sim 3.95\text{wt}\% \text{ SO}_3 \)

“Ash” mass fraction of everything other than \( \text{Na}_2\text{O}, \text{K}_2\text{O}, \text{Al}_2\text{O}_3 \text{ Fe}_2\text{O}_3 \), \( \text{P}_2\text{O}_5 \) & \( \text{SO}_3 \) \( \sim 5\% \)
Some facts we don’t hear so much about

• Hanford’s tank farm is a good geological repository site\footnote{1}
• Its radwaste is extremely dilute (not very “high”): ~90 tonnes\footnote{2} initial FP ended up in about 290,000 tonnes of waste (0.03 wt%)*
• Its waste is thermally “cold”: Current FP inventory includes 0.4 tonne (3.6E+7 Ci) of heat-generating $^{137}$Cs/Ba & 0.25 tonne (3.3E+7 Ci) $^{90}$Sr/Y or ~1.3 watts/tonne\footnote{3}
• It’s mainly comprised of sodium salts averaging about 10.4 moles/liter Na\footnote{4} which means that its conversion to a “salt stone” would roughly treble its volume.\footnote{5}
• It also contains lots of other stuff (aluminate, halides, chromate/chromite, sulfate, phosphate etc.) incompatible with high loading in borosilicate-type glasses (BSG)
• There’s lots of “orphan” radwastes outside of its tanks

*The estimate is very uncertain. The waste volume is widely considered to be uncertain by a factor of 2-5.

\footnotetext{1}{The site is in dry sediments with minimal cracking which is water-permeable and has a large capacity. It is deep (~300m) underground and isolated.}

\footnotetext{2}{Initial FP release rate (2021) of 370GCi/year.}

\footnotetext{3}{It is too small to be a significant source of heat in a repository.}

\footnotetext{4}{Around 64% NaCl.}

\footnotetext{5}{The estimate is very uncertain. It’s widely considered to be uncertain by a factor of 2-5.}
Hanford’s Tank Waste is a “Greater than Class C LLW” \(^*\)note

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Class C LLW Limits*</th>
<th>∑Hanford’s Waste**</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{90})Sr</td>
<td>4600 Ci/m³</td>
<td>219 Ci/m³</td>
</tr>
<tr>
<td>(^{137})Cs</td>
<td>7000 “</td>
<td>142 “</td>
</tr>
<tr>
<td>(^{63})Ni</td>
<td>700 “</td>
<td>0.38 “</td>
</tr>
<tr>
<td>(^{14})C</td>
<td>8 “</td>
<td>0.023 “</td>
</tr>
<tr>
<td>(^{99})Tc</td>
<td>3 ”</td>
<td>0.15 “</td>
</tr>
<tr>
<td>(^{129})I</td>
<td>0.08 ”</td>
<td>0.0003 “</td>
</tr>
<tr>
<td>All (\alpha &gt; 5) yr (t^{1/2})</td>
<td>100 nCi/g</td>
<td>441 nCi/g</td>
</tr>
</tbody>
</table>

\((why\ it’s\ “greater\ than”)\)

\(sum\ fractions\ save\ TRU = 0.125\)

*Upper Class C limits: Tables 1 & 2, 10 CFR\$61.55 (from NRC website)

**assumes 19 yr decayed ”global” figures of Table ES-2 HNF-SD-WM-TI-740 Rev OB, 1998 & a total of 322,000 tonnes (dry basis) or 55 million gallons of waste
Why Iron Phosphate Glass (Fe-P)?

- More leach resistant than BSG glasses\textsuperscript{1}
- Easier to make - lower melting point/viscosity
- Accommodates much higher concentrations of “problematic” (for BSG) waste constituents – translates to having to making much less glass\textsuperscript{2}
- Already thoroughly studied/characterized for application to many DOE radwastes\textsuperscript{1-4}
- Compatible with “mag phosphate” grout

Why Iron Phosphate... cont.

Phosphate Glass Loading Estimates*

- Insufficient data to refine loading estimates, however, based on preliminary assessments:
  - 20 wt% ≤ Na_2O ≤ 26 wt% → most likely 22 wt%
  - 3 wt% ≤ SO_3 ≤ 6 wt% → most likely 4.5 wt%
  - No halide, phosphate, or chromate limits

Ball park calculations

- 22 wt% Na$_2$O waste loading* into Fe-P puts 54,200 tonnes of Na (100% of Hanford's tank waste) into ~330,000 tonnes of Fe-P glass
- Assuming 2.9 g/cc & 3785 cc/gallon, this translates to ~30 million gallons of glass
- Assuming 36% void volume$^{\text{note1}}$ for randomly dumped sphere "aggregate", this translates to a repository space requirement of 47 million gallons
- The total volume of Hanford's already-paid-for "canisters" (tanks) is ~172 million gallons$^{\text{note2}}$

Why not borosilicate glass?

The problem with bsg is that Hanford’s waste contains enough sulfate (and halides too) to render their manufacture both more problematic & more expensive.

Ignoring halide effects, this curve (WTP’s basis) & current “global” SO₃/Na₂O tank waste inventories translates to making 688,000 tonnes of bsg if the waste is blended & 697,000 tonnes if it isn’t.

* Excerpted from Vienna et al., “Impacts of Feed Composition and Recycle on Hanford LAW Glass Mass” (http://energy.gov/sites/prod/files/em/112010Meeting/04-Vienna_ViennaRecycleComplImpactsonLAWAmount%2811-15-10%29.pdf)
What about “Advanced” bsgs?

Both sulfate and halides ($H = Cl + 0.3F$) strongly affect (reduce) bsg waste loadings. Their effects upon bsg vitrification of the waste in each of Hanford’s tanks can be derived from data/formulae in PNNL/CSU reports (see figs. below)*

Bottom line: Even with today’s “advanced” formulations, implementing this proposal with bsg would require the manufacture of ~50% more glass.

*plots excerpted from slide 4, Vienna et al. 2010, “Effect of Feed Composition...”
**Tonnes Glass Generated From All Hanford Tank Waste**

with different vitrification scenarios**

Glass tonnes produced from all Hanford tank waste

<table>
<thead>
<tr>
<th></th>
<th>No Halide adjustment</th>
<th></th>
<th>Halide adjustment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WTP basis B-Si Glass</td>
<td>Advanced B-Si Glass</td>
<td>WTP basis B-Si Glass</td>
<td>Advanced B-Si Glass</td>
<td>Fe-P Glass</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unblended 697,000</td>
<td>Blended 688,000</td>
<td>Unblended 382,000</td>
<td>Blended 352,000</td>
<td>Unblended 722,000</td>
<td>Blended 717,000</td>
<td>Unblended 524,000</td>
</tr>
</tbody>
</table>

* No separations – the waste in each tank either goes directly into the melter (unblended) or is combined with everything in all other tanks & that combination fed to the melter (blended).

** Figures based upon, a) "Tank Waste Information Network System" (TWINS) queried 09/08/03) (note ("Best Basis Summary Report"))
http://twins.pnl.gov/twins.htm, updated to reflect current total global Na & SO4 estimates (54,200 & 5000 tonnes), & b) loading limits derived from data/equations in Vienna et. als, “Impacts of Feed Comp…”
In light of what’s actually in Hanford’s tanks, borosilicate glass’s intrinsic waste loading limitations would turn what should be a relatively quick / simple / cheap / certain vitrification campaign into a slow / difficult / expensive / uncertain “Chinese Fire Drill”
WHY “STIRRED” MELTER

• Mechanical mixing is apt to lessen semivolatile (e.g. Tc, Cs, & I) loss relative to bubbler mixing (WTP basis plan)

• Mechanical stirring greatly accelerates the melting process (smaller/cheaper melters could be used)

• They readily handle multiphasic (“chunky” or “stringy”) feeds – non-stirred melters can’t (simplifies feed preparation)

• They have already been utilized/proven for several DOE/SRS projects\(^1,2\)

• This project would not require high temperature melters or “advanced” glasses

Why “Ceramicrete”

Putting the glass back into Hanford’s tanks will require that it be rendered “pumpable” – a practical way to do this would be to make “aggregate” (marbles¹, “gems”², or cullet) which could be slurried with a suitable “grout” (cement + water + clay?) & pumped with conventional equipment.

Fe-P glass is compatible³ with magnesium phosphate based grouts because they share a common chemistry (components, pH, etc).

Ceramicrete has already been extensively studied as a stand-alone waste form⁴

¹ Germany’s PAMELA (‘Vitromet’) process would have embedded HLW phosphate glass marbles in a molten lead “grout”


³ Borosilicate glasses are incompatible with the OPC/flyash-based grouts usually specified for EM work

⁴ for example, Cantrell & Westsik, ”Secondary Waste Form Down Selection... CERAMICRETE”, PNNL-20681, August 2011.
Glass Aggregate Examples

1995 report ("Vitrification and Privatization Success")
describing the conversion of 670,000 gallons of "mixed" DOE radwaste to glass “gems” for $13.9 M

http://sti.srs.gov/fulltext/ms2000305r1/ms2000305r1.html

Another 1995 report comparing cullet, “gem”, marble & monolithic options for DWPF's HLW glass*


*since it was assumed that DWPF’s glass would be shipped off to YM, the simpler-to-produce & ~35% less voluminous monolith option was deemed "best"
WHY REUSE HANFORD’S TANKS?

• Its tanks are not evil
• They’ve already been paid for.\(^{\text{note1}}\)
• Steel-lined reinforced concrete “canisters” (tanks) are apt to much more durable than ORP’s basis plastic-lined LAW disposal pits.\(^{\text{note2}}\)
• This waste management scenario would simultaneously “remediate” them.\(^{\text{note3}}\)
• No “interim” storage, packaging, or offsite transportation costs
Real World Glass Costs

- Current cost of glass "gems" or marbles, any size, is $2.49/# - free shipping! http://www.mcgillswarehouse.com/c/119/38
- Fiber glass is also made with electric melters
  The USA made 3.04 million tons of fiber glass for $4.8 billion in 1999*
  Average inflation rate between 1999 & 2012 was ~3%

Consequently, making 330,000 tons of glass should cost about ...

\[ $4.8 \times \left( \frac{330,000}{3,040,000} \right) \times 1.03^{(2012-1999)} \approx $0.77 \text{ billion} \]

ORP 11242 rev 6’s cost estimate is ~$61 billion

*http://www.nrel.gov/docs/fy02osti/32135.pdf
Additive Cost Ballparking

• A great deal of experience suggests that component ratios of 1.1 Na:1 P:0.6 (Fe+Al) would be OK for a sodium salt-based Fe-P. This means that vitrifying 100% of Hanford’s waste* would require ~314,000 tonnes of fertilizer grade phosphoric acid (~3% of annual US consumption) and ~54,000 tonnes of iron ore - at current bulk commodity prices (~$600 & $2/ton) that adds up to ~$180 million

• At $500/ton, enough “Ceramicrete” to grout those gems/marbles would add another $10-15 million to the “additive” cost
An Important Bonus

Implementation of this proposal with “just” Hanford’s tank wastes would utilize under 30% of the space in its disposal “canisters” (tanks).

Their headspace volumes should be filled with something that’s both physically strong & chemically durable before final closure.

Hanford has many miscellaneous radwastes (“crib” dirt, sludges*, etc.) for which no permanent solution has been implemented.

These wastes could/should be coprocessed with the salt wastes & that glass grouted into the tanks too.\footnote{e.g., Hanford’s much-studied \~38 m$^3$ of K basin sludge represents about 0.01% of its total waste – adding it to the rest of the stuff going into the melter/tanks would not upset the system}
Things Worth Studying

• The interaction of conventional “grouts” with Fe-P type glasses: BFS/OPC/flyash based grouts are cheaper and easier to use than is Ceramicrete & might be perfectly satisfactory note1

• Tc & I behavior under the proposed conditions (different glass, lower temperature, shorter in-melter residence time, and no bubblers) note2

• Secondary waste generation/treatment/disposal: how to best go about getting everything (e.g., I & Tc) that’s in the waste into the disposal tanks/canisters in a way/ways that it can’t get back out again note3
DOE EM/ORP should “study” this proposal because...

1) Nuclear power’s future prospects depend upon what today’s leaders do with existing reprocessing wastes & how much money they spend (the institution’s viability is at stake)

2) That’s important because the implementation of a sustainable* “nuclear renaissance” could head off otherwise almost inevitable environmental degradation

3) The USA can’t afford to continue to waste $billions on politically correct but technically unrealistic EM boondoggles

4) This proposal is simultaneously “doable”, quick, affordable, and both technically & environmentally correct

* “sustainable” means breeder reactors which means more reprocessing waste
Extra slides
ORP Advanced Silicate Glass Formulation

Data points from scaled melter tests

Table 3-1. Tank Waste Remediation System Processing Inventory  
(December 31, 1999, Decay Date).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Tank Waste Remediation System Processing*</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inventory, MCl</td>
<td>Soluble</td>
<td>Insoluble</td>
<td>Total</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td></td>
<td>34.1</td>
<td>3.01</td>
<td>37.1</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td></td>
<td>1.89</td>
<td>52.5</td>
<td>54.4</td>
</tr>
<tr>
<td>Transuranics</td>
<td></td>
<td>0.00961</td>
<td>0.121</td>
<td>0.131</td>
</tr>
<tr>
<td>$^{99}$Tc</td>
<td></td>
<td>0.0228</td>
<td>0.0093</td>
<td>0.032</td>
</tr>
<tr>
<td>$^{79}$Se</td>
<td></td>
<td>0.00103</td>
<td></td>
<td>0.00103</td>
</tr>
<tr>
<td>$^{14}$C</td>
<td></td>
<td>0.0053</td>
<td></td>
<td>0.0053</td>
</tr>
<tr>
<td>$^{129}$I</td>
<td></td>
<td>0.000051</td>
<td></td>
<td>0.000051</td>
</tr>
<tr>
<td>$^3$H</td>
<td></td>
<td>0.01</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>$^{126}$Sn</td>
<td></td>
<td>0.0016</td>
<td></td>
<td>0.0016</td>
</tr>
<tr>
<td>Uranium</td>
<td></td>
<td>0.00006</td>
<td>0.00094</td>
<td>0.001</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>36.0</td>
<td>55.6</td>
<td>91.6</td>
</tr>
</tbody>
</table>

*aThe inventories of $^3$H, $^{14}$C, and $^{129}$I are given in Colby (1994). The inventory for $^{79}$Se and uranium is given in Mann et al. (1995). The inventory for $^{126}$Sn is given in Schmittroth et al. (1995). The primary source of tank waste inventories are given in Orme (1995) for $^{137}$Cs, $^{90}$Sr, and TRU because additional detail is given for fractions of soluble and insoluble radionuclides. The values for $^{137}$Cs, $^{90}$Sr, and TRU are consistent with the Integrated Data Base Report-1994. See Appendix C for source of TWRS processing inventory.

bRound-off error can result in $\pm 0.2$ MCl.
Table C-2. Estimated Discharges from Tanks to the Soil Column (December 31, 1999, Decay Date).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>MCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{137}$Cs</td>
<td>0.0131</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>0.0108</td>
</tr>
<tr>
<td>$^{99}$Tc</td>
<td>0.0009</td>
</tr>
<tr>
<td>Transuranics</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

Table C-3. Estimated Unplanned Releases to the Soil Column (December 31, 1999, Decay Date).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>MCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{90}$Sr</td>
<td>0.0</td>
</tr>
<tr>
<td>$^{99}$Tc</td>
<td>0.00014</td>
</tr>
<tr>
<td>$^{129}$I</td>
<td>0.0000004</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>0.290 to 1.090</td>
</tr>
<tr>
<td>Transuranics</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Table C-5. Tank Inventory (December 31, 1999, Decay Date).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Tank waste inventory, MCl</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soluble</td>
<td>Insoluble</td>
<td>Total</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>1.89</td>
<td>52.2</td>
<td>54.1</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>31.4</td>
<td>3.01</td>
<td>34.4</td>
</tr>
<tr>
<td>TRU</td>
<td>0.00961</td>
<td>0.121</td>
<td>0.131</td>
</tr>
<tr>
<td>$^{99}$Tc</td>
<td>0.0228</td>
<td>0.00930</td>
<td>0.0321</td>
</tr>
<tr>
<td>Total</td>
<td>33.3</td>
<td>55.3</td>
<td>88.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank total including daughters ($^{137}$Ba, $^{90}$Y)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>65.0</td>
<td>110.0</td>
</tr>
</tbody>
</table>

WHC-SD-WM-TI-699, Rev. 1
Current Reclassification Basis of ILAW

- Current approach for Immobilized Low-Activity Waste (that allows the High-Level Waste to be disposed in near surface facilities, rather than a deep geologic repository licensed by NRC) comes from a series of technical letters between USDOE and the NRC in the 1980’s and 1990’s.

- In 1993, NRC spelled out three criteria in a letter to USDOE:
  1. Tank wastes have been processed (or be further processed) to remove key radionuclides to maximum extent technically and economically practical.
  2. Wastes will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C [low-level waste] as set out in 10 CFR Part 61.
  3. Wastes are to be managed so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61 Subpart C are satisfied.
Table 6.2-2. Simplified Hanford Site Underground Tank Cesium-137 and Strontium-90 Material Balance.

<table>
<thead>
<tr>
<th>Material balance component</th>
<th>MCi&lt;sup&gt;a&lt;/sup&gt;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$^{137}$Cs</td>
<td>$^{90}$Sr</td>
</tr>
<tr>
<td>Generated in Hanford Site reactors</td>
<td>119.1</td>
<td>101.3</td>
</tr>
<tr>
<td>In fuel not reprocessed at the Hanford Site&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.5</td>
<td>11.2</td>
</tr>
<tr>
<td>In fuel input to Hanford reprocessing plants</td>
<td>104.6</td>
<td>90.1</td>
</tr>
<tr>
<td>Output to capsules&lt;sup&gt;d&lt;/sup&gt;</td>
<td>56.7</td>
<td>22.3</td>
</tr>
<tr>
<td>Output to other DOE facilities&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.5</td>
<td>3.9 to 4.6</td>
</tr>
<tr>
<td>Output to solid waste disposal&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>Output to facility contamination&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.7 to 3.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Output in releases to soil&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.8</td>
<td>0.44</td>
</tr>
<tr>
<td>Total tank inventory remaining&lt;sup&gt;f&lt;/sup&gt;</td>
<td>39.4 to 40.4</td>
<td>61.4 to 62.1</td>
</tr>
<tr>
<td>Inventory in double-shell tanks&lt;sup&gt;e&lt;/sup&gt;</td>
<td>25.4</td>
<td>11.4</td>
</tr>
<tr>
<td>Inventory in single-shell tanks&lt;sup&gt;f&lt;/sup&gt;</td>
<td>14.0 to 15.0</td>
<td>50.0 to 50.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>As of January 1, 2000
Figure 3-1. Estimated Hanford Site Tank Waste Radionuclide Inventory.\textsuperscript{c,d}

\textsuperscript{c}Curie values are based on the Integrated Data Base Report-1994, Rev. 11, Table 2.11 decayed to December 31, 1999.