HANFORD-THE COLD WAR LEGACY

HANFORD TANK WASTE

The United States of America has embarked on a multi-decade, many hundred billion dollar program to remediate the radioactive waste problem resulting from the production of nuclear weapons fissile material by reprocessing “low burn-up” fuel irradiated in production reactors. A significant component of the waste problem exists at the Hanford a where hundreds of large tanks store hundreds of thousands of cubic meters of radioactive solids and liquids. The current plan is to separate this material into high-level and low-level components and then subsequently vitrify both streams for ultimate disposal. The U.S. Government estimate of the radioactive waste to be vitrified at the Hanford reservation is shown below. The DOE requested a proposal for an LVPP Demonstration project.

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	LIQUID	SOLID	TOTALS	% OF TOTAL	
Total Mass (MT)	7.26E+05	1.97E+04	7.46E+05		
Volume (L)	5.86E+08				
Specific Gravity	1.24				
Radionuclides (Ci)					Mass (kg)
Am-241	7.91E+03	9.65E+04	1.04E+05	0.06%	29.47
C-14	3.22E+03	2.12E+03	5.34E+03	0.00%	1.17
Cs-137	3.18E+07	3.01E+06	3.48E+07	19.86%	392.58
Ba-137	3.02E+07	2.86E+06	3.31E+07	18.86%	0.00
Np-237	6.97E+00	6.27E+01	6.97E+01	0.00%	95.93
Pu-239	1.65E+03	2.53E+04	2.70E+04	0.02%	415.58
Pu-240	4.31E+02	6.28E+03	6.71E+03	0.00%	28.65
Pu-241	4.80E+03	7.01E+04	7.49E+04	0.04%	0.72
Sr-90	1.88E+06	5.17E+07	5.36E+07	30.57%	380.73
Y-90	1.88E+06	5.17E+07	5.36E+07	30.57%	0.10
Tc-99	2.27E+04	9.32E+03	3.20E+04	0.02%	1842.17
TOTAL	6.58E+07	1.09E+08	1.75E+08	100.00%	3187.10
Chemicals (MT)					
O (in Oxides, compounds)			5.74E+05	76.894%	
Na+	6.80E+04	7.77E+02	6.88E+04	9.213%	
H (in OH, H2O compounds)			5.80E+04	7.770%	
N (in NOx)			2.73E+04	3.657%	
Cancrinite		2.71E+03	2.71E+03	0.363%	
Al+3		2.31E+03	2.31E+03	0.309%	
Al			1.99E+03	0.267%	
P (in PO4)			1.65E+03	0.221%	
U (in UO2+2)			1.45E+03	0.194%	
F-	1.14E+03	6.89E+01	1.21E+03	0.162%	
organic carbon	1.06E+03	8.73E+01	1.15E+03	0.154%	
Fe+3	3.44E+01	7.62E+02	7.96E+02	0.107%	
K+	7.07E+02	2.96E+01	7.37E+02	0.099%	
Cl-	6.78E+02	9.00E+00	6.87E+02	0.092%	
S (in SO4)			6.82E+02	0.091%	
C (carbonate)			6.42E+02	0.086%	
Zn (in ZnO2:2H2O)			5.90E+02	0.079%	
Bi+3	1.18E+01	2.52E+02	2.64E+02	0.035%	
Si+4	1.59E+01	2.32E+02	2.48E+02	0.033%	
Ce+3	2.36E+00	2.35E+02	2.37E+02	0.032%	
Ni+3	8.21E+00	2.06E+02	2.14E+02	0.029%	
Cr (hydroxide)			1.93E+02	0.026%	
Mn+4	1.08E+01	1.80E+02	1.91E+02	0.026%	

The U.S. and all other nations use “wet chemical” techniques to separate the waste stream into high and low level components. This approach substantially adds to the mass of the material eventually to be disposed and is very complex, adding the risk of system failure sometime during the 30 to 50 year remediation schedule. Of course, such risk can be mitigated by systems redundancy but will come at a still higher cost (and further increase the material ultimately to be disposed).

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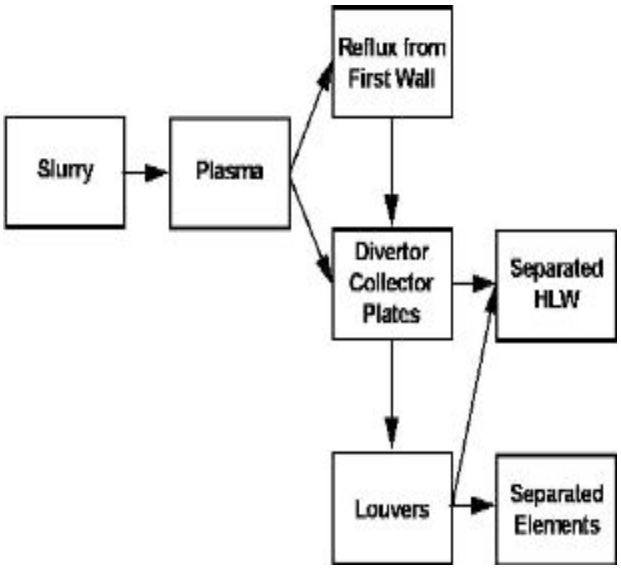
The LVPP offers a separation science based on plasma processing, a technology that has already contributed significantly to progress in the microelectronics industry by replacing “wet chemistry” manufacturing steps. Our estimates indicate that the LVPP process will result in much lower cost weapons waste disposal, will eliminate the need to characterize tank materials, will reduce the radioactive inventory in process flow streams and will eliminate most of the low level waste.

This robust technology incorporates systems initially developed for fusion research and development. In particular, the “Tokamak” technology has been incorporated in this invention because of its ability, without electrodes, to routinely produce plasma temperatures and densities high enough to ionize solids and to confine these ions while they diffuse to the collection system in the plasma chamber and along specially designed magnetic field paths to deposition stages (divertors and downstream collectors).

A second version of the LVPP incorporates electron beams to efficiently ionize solids in a linear magnetic geometry.

A key element of the LVPP concept is to ionize and separate the solids in less than a millisecond. This is to avoid radiation losses from high Z ions. (A single oxygen ion can radiate up to 1 million electron volts in a microsecond.) The Tokamak version used in the concept has "poor" confinement time in fusion reactor terms, but adequate for sufficient mixing to allow separation via the thermal differentiation technique employed in the concept.

A block diagram of the key LVPP subsystems involved in the waste separation process is shown on the right (other subsystems such as magnets,



current drive, remote handling, etc. are omitted for clarity). After de-watering (in the case of weapons waste) or another head-end process (in the case of Spent nuclear fuel), the process feed is injected as pellets or streams into a toroidal “tokamak” plasma with an initial plasma average “temperature” of about 10,000,000 C. The pellets ablate and all of the constituent atoms are ionized to states corresponding to a resultant average temperature of about 1,000,000 C. During the ionization step, additional power is injected into the toroidal plasma to maintain the tokamak electromagnetic configuration and confine the elemental ions while they diffuse towards the walls of the chamber, where they 1) strike the collection system in the plasma chamber and either stick, or 2) are returned to the plasma or 3) are swept along the specially designed magnetic guiding fields and are collected on the “divertor.” Gases. such as hydrogen, oxygen and nitrogen are primarily collected on cryogenic louvers located downstream of the divertor deposition.

A mathematical model of the separation process has been developed to predict the deposition of selected materials in specific subsystems. The Table below presents the results of calculations for a configuration in which the collection system in the plasma chamber and on the divertor plate are maintained at a temperature of 900C. The model assumes a maximum ion confinement time of 10 milliseconds (the time it takes for the density of the ionized pellet ions to be reduced to a factor of $1/\varepsilon$, or 0.368). It is also assumed that one pellet is injected every seven (7) confinement times. (The degree of separation becomes increasingly better as the number of confinement times increases.) The calculation results in the are presented in metric tons of each species and are representative of the results of processing all the Hanford tank waste via this method. The different louvers (LV1...etc) collect different elements.

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SPECIES	WALLS	DIVERTOR	LV1	LV2	LV3	LV4	LV5	TOTALS
STABLE (MT)								
Hydrogen	0	0	0	0	0	0	5.80E+04	5.80E+04
Oxygen	0	0	0	0	0	5.74E+05	0	5.74E+05
Nitrogen	0	0	0	0	2.73E+04	0	0	2.73E+04
Sodium	0	0	6.88E+04	0	0	0	0	6.88E+04
Carbon	1.15E+01	1.14E+03	0	0	0	0	0	1.15E+03
Calcium	1.46E+00	1.43E+02	0	0	0	0	0	1.44E+02
Aluminum	4.29E+01	4.25E+03	0	0	0	0	0	4.29E+03
Cesium-133	0	0	0	2.09E+00	0	0	0	2.09E+00
TOTALS	5.59E+01	5.53E+03	6.88E+04	2.09E+00	2.73E+04	5.74E+05	5.80E+04	7.34E+05
RADIOACTIVE (MT)								
Am-241	2.17E-05	2.86E-02	0	0	0	0	0	2.86E-02
C-14	1.70E-05	1.68E-03	0	0	0	0	0	1.70E-03
Cs-137	0	0	0	3.92E-01	0	0	0	3.92E-01
Pu-239	4.00E-03	4.10E-01	0	0	0	0	0	4.14E-01
Sr-90	3.70E-03	3.76E-01	0	0	0	0	0	3.80E-01
Tc-99	1.80E-02	1.82E+00	0	0	0	0	0	1.84E+00
TOTALS	2.57E-02	2.64E+00	0	3.92E-01	0	0	0	3.05E+00

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