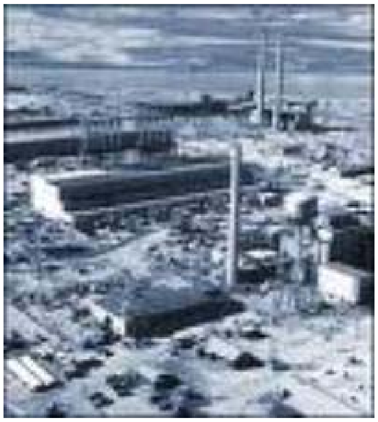


Proposal for a Prototype Fusion Torch/Large Volume Plasma Processor for Radioactive Tank Waste Remediation May, 1999

INTRODUCTION

“Dry” plasma chemistry has replaced many “wet” chemical stages in microchip production with environmental, cost, and quality benefits. The “Fusion Torch/Large Volume Plasma Processor” approach to radioactive waste separation is to apply robust plasmas developed in Fusion Energy Research to replace many “wet” chemical steps for tank waste cleanup and to simplify and increase the separations efficiency of the needed pyrochemical separation techniques for accelerator transmutation of waste. The proposal describes a 5 year program whose goal is to begin operations on-site with a 250 to 1000 kg/day pilot plant. The pilot plant is illustrated schematically in Figure 1. An article about this proposal appeared in the Economist magazine.

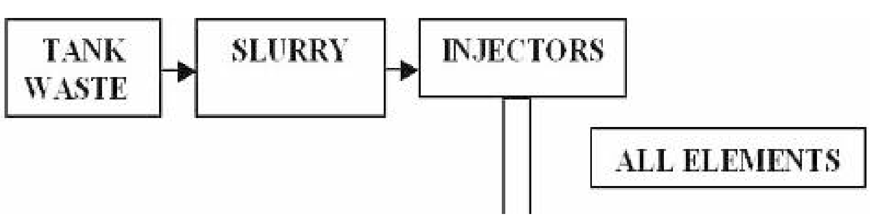
The tank waste would be converted into a slurry and injected directly into the plasma. The plasma would convert the slurry into separated elements by ionizing the slurry with a heat flux of over 5 million watts/cm2. (This is well beyond the capability of conventional plasmas such as the Westinghouse plasma torch.) Elements are separated one from the other with methods described in a series of three (3) method and apparatus patents 1,2,3 that have been recently awarded for the process. The plasma ionizes all the elements and collects them on different surfaces. Representative elements will be separated as shown in figure 1. Pu-239, AM-241, TC-99, C, Ca, Al and Fe are collected on “Levilor” slats and heated collector plates (900□C). Downstream, Sr-90, Cs-137, and sodium are collected on separate louvers at appropriate temperatures. Finally, the benign gases N2, O2, and H2 are released to the atmosphere. BNFL has referred to this process as a “single pot” system.

Small plasma experiments have shown promising results in the past for separation of tank waste However, in 1995, DOE declined further research in this area because of uncertainties in the ability to engineer large systems with appropriate economics in a timely fashion.

The Prototype Fusion Torch/LVPP is based on technology that is already well developed and understood in the Fusion Research area. In fact, validation experiments will be performed in an existing device. The program integrates aggressive programs to model the slurry process and to develop techniques for daily removal and handling of the separated radioactive species.

The advantages of this “single pot” approach compared with present Tank Waste Remediation System (TWRS) planning are:

- Much lower processing cost,
- No need to characterize the tank contents,
- Lower radioactive inventory in the process flow stream,
- Impressive simplification of the system “plumbing,”
- No additional materials added to the process, and
- Elimination of most low level waste



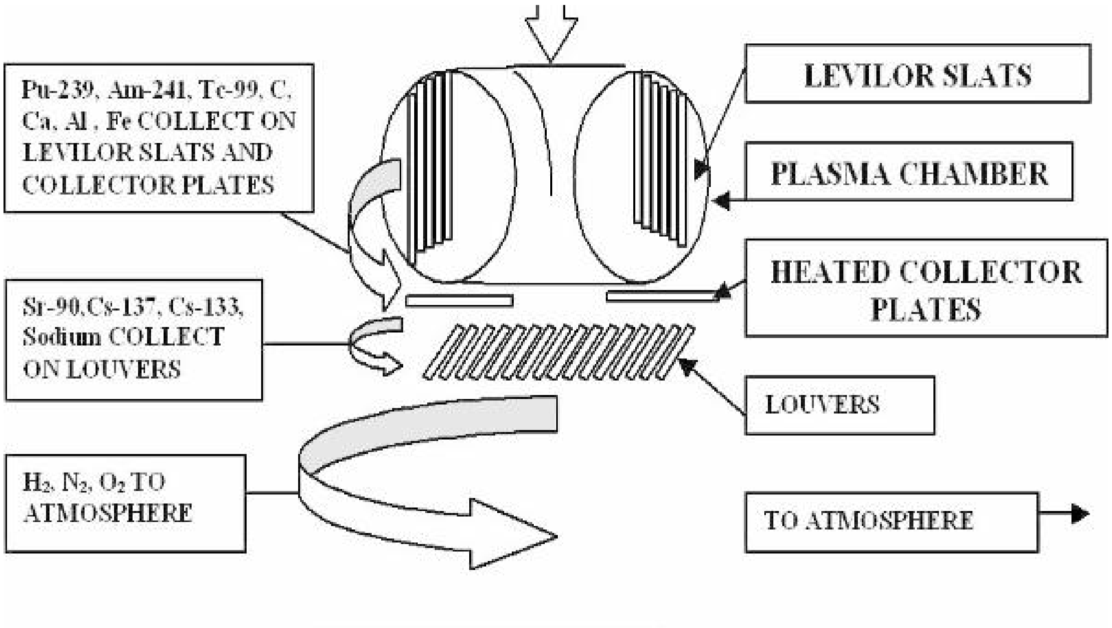


FIGURE 1
MATERIAL FLOW

The proposal is basically an outline of what would become a formal, unsolicited proposal, providing that there is sufficient interest on the part of the DOE. Our proposed subcontractors are: the University of Texas at Austin (Ken Gentle) and the Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University (John Plodinec).

II. Prototype Program Elements

A. The Prototype

The prototype device will include the plasma processor which, in a toroidal version, would be about 7 feet in diameter, with a height of about 3 feet.. The power supplies would be about the size of a 10 foot cube. The slurry injectors would occupy a space of about a 3 foot cube. Access for removal of separated species would be provided. (It is assumed the separated species are taken to a separate site for final disposition.) Options could include glass matrix isolation or commercial sale of some of the products. The TEXT Tokamak (valued at about $15,000,000) at the University of Texas would be dedicated to this project.

B. Validation Requirements - Operating Density

Plasmas with temperatures on the order of 5,000,000 degrees and electron heat flux of over 5,000,000 watts/cm2 were developed in the early 1980’s. This hot plasma represents a unique new medium, which can ionize any solid or liquid material within a few hundred millionths of a second after being injected in the plasma. Complete ionization of solid pellets and streams have been performed in such fusion research devices since 1982. In fact, pellets have been ionized to perform chores such as coating the inside walls of the devices with gettering materials such as silicon, boron, and carbon. Over 200 pellet ionization experiments have been performed world wide. It is this ability to ionize any substance that the Fusion Torch/LVPP uses for tank waste separation. The waste does not have to be characterized, just converted into a slurry.

The final maximum plasma density in solid ionization experiments is about 5 x 1014/cm3.

The pilot plant requires that the maximum plasma density be raised a factor of ten, to 5 x 1015/cm3. Stabilization techniques are included in the above mentioned patents to allow achievement of those conditions. Experiments are required to validate operation in this higher density regime as part of the prototype design effort. The Tokamak facility at the University of Texas would be used for these validation experiments.

C. Validation Requirements - Separation Efficiency

Theoretical analysis indicates a high degree of separation of species. Assuming the initial species concentration of Hanford Tank Waste is represented by the average chemical composition (see references 2 and 3) Experiments are required to validate separation at the maximum operating densities of 5 x 1015/cm3. For these experiments, “surrogate” (benign) isotopes of the targeted species will be used. The Tokamak facility at the University of Texas would be used for these separation experiments.

D. Validation Requirements - Thruput (Repetition Rate)

Each pellet or stream ionization event is for a relatively small pellet (about 1 mm in radius). The prototype will be designed to process at a 60 Hz rate. At 60 Hz, the throughput for a 2 MW system with the dimensions described above would be about 250 kg/day (assuming an average atomic weight of about 10.) Experiments at a repetition rate of 60 Hz will be performed in the Tokamak device at the University of Texas.

E. Validation Requirements-Energy Consumption

At 250 kg/day and for an electricity cost of .06/kWhr, the energy cost is between $7 and $10/kg. In comparison, the present DOE TWRS program estimates a cost of about $77/kg over 25 years to eliminate the tank waste Validation of these cost estimates will be done with the above mentioned Tokamak.

F. Validation Requirements-Material Balance

Conversion of the waste to a plasma state inherently allows a complete determination of each of the separated species. When in the ionized plasma state, each species emits particular radiation lines that can be monitored to determine their inventory. This would be taken advantage of early in the experimental program to perform an initial material balance. DIAL has the instrumentation and the personnel necessary to carry out this task.

G. Conversion of Tank Waste to Slurry

The DOE already supports a number of programs for conversion of tank waste to slurry. DIAL is already modeling such processes, as well as developing basic thermodynamic data to support waste retrieval decisions. DIAL will perform modeling and experimental slurry stability studies to integrate the tank waste slurry operation with the prototype operation. Perhaps the most important result of this program will be confirmation that a slurry can be produced which is compatible with the rest of the process.

III. Prototype Design

In contrast to previous plasma device design, the point of departure for the FT/LVPP Prototype is Reliability, Availability, and Maintainability (“RAM”). This requirement is driven by:

1. The presence of large quantities of hazardous and volatile radioactive materials,
2. The need to continuously remove these materials in a continuous or repetitive batch mode,
3. The need to perform the material removal completely remotely,
4. The need to completely and remotely maintain the plasma system for very long periods (years) of time, and
5. The need to accomplish the mission of tank waste remediation.

While the prototype is not a production machine, its objective is to establish the basis for the design and fabrication of production machines. Thus, it will satisfy the requirements stated above.

The most stringent of these requirements is remote material handling. There are two components to this:

1. Machine system and subsystem maintenance (demonstrated to some degree for the very large International Thermonuclear Experimental Reactor design), and
2. Radioactive material handling, particularly those that are deposited as solids on the interior surfaces of the machine.

With few exceptions, machines and facilities built to handle radioactive materials are designed for vertical lifts (most fission reactors, reprocessing canyons, etc.) as the simplest and safest handling approach. Plasma devices, being either toroidal or linear, don’t obviously lend themselves to this maintenance approach. These devices, having been experimental in the past and focused on low duty-cycle physics objectives, did not require significant remote maintenance. However, designs of “Engineering Test Reactors” over the past decade have addressed these issues and will be used as a significant resource for Prototype design. Additionally, recent private work in special magnet and plasma environment subsystem design (“first wall” and “divertor”) will be incorporated in Pilot Plant design. Likewise, slurry feed systems developed at DIAL will be modified to be easily integrated with the Prototype. Finally, post-processing of the recovered material, a new requirement for a plasma device, will be similarly integrated into the Prototype design and RAM system. DIAL will be responsible for determining whether the products of the LVPP will satisfy DOE’s waste form specifications.

Conceptual Design will be started immediately for the overall Prototype and the subsystems unrelated to the confirmation of physics objectives. This effort will intensify at the beginning of the second year and a

Preliminary Design will be completed by mid-year. Engineering Design, a refinement of the Preliminary Design, will be completed at the end of the second year. Fabrication and installation is planned to take three years with initial operations at the end of the fifth year.

Program Elements And Estimated Costs Exclusive of Containment

Year 1 Validation Experimental Setup

First 6 months - TEXT Restart Planning & Conceptual Design		
Specification of control systems and other equipment	UTA	600,000
Control equipment, new vacuum pumps etc	UTA	350,000
Sludge Modeling	DIAL	100,000
Collection Technique Scoping	ESEC/DIAL	50,000
Pilot Plant Conceptual Design	ESEC	125,000
Program Management and Systems Studies	ESEC	250,000
Second 6 months - recommissioning of UT Tokamak		
Diagnostic development for material balance	UTA/DIAL	50,000
Initial Validation Experiments	UTA	600,000
Pilot Plant Conceptual Design	ESEC	125,000
Program Management and Systems Studies	ESEC	250,000
YEAR ONE TOTAL		2,275,000

Year 2 Further validation experiments, intense prototype design activity.

First 6 months – Preliminary Design & Initial Design Verification Tests		
Pilot Plant Preliminary Design	TEAM	5,000,000
Second 6 months – Engineering Design & Final Design Verification Tests		
Pilot Plant Engineering Design	TEAM	7,000,000
Year 3-5 Construction		
Construction	TEAM	60,000,000

TOTAL ESTIMATED COST

74,257,000

References:

1. **U. S. Patent 5,868,909, Feb. 9, 1999.**
2. **U. S. Patent 5,682,434, Oct. 28, 1997.**
3. **U. S. Patent 5,630,880, May 20, 1997.**
4. **Boomer et al. 1993, Tank Waste Technical Options Report. WHC-EP-0616, Rev. 0. Westinghouse Hanford Company, Richland, Washington. March, 1993**