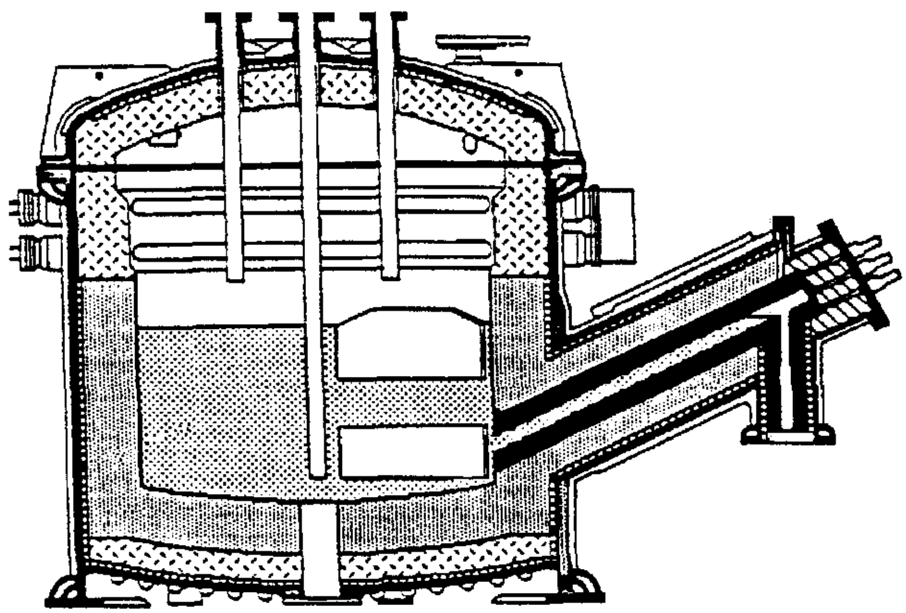
Cleaning Up Nuclear Waste:

Why Is DoE Five Years Behind And Billions Over Budget?



Savannah River Melter Which Will Turn Radioactive Waste Into Glass

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Executive Summary

The Department of Energy has spent billions on cleanup efforts which failed because the agency did not fully test a key technology. The French, by contrast, are way ahead of the U.S. because they have not only fully tested this key technology, but have implemented the process.

This technology is called vitrification or "glassification" of waste --- a process by which highly radioactive waste is mixed with molten glass and allowed to harden. This makes the nuclear waste relatively safe by solidifying it and avoiding leakage.

Ironically, both the U.S. and the French started their vitrification programs at roughly the same time. Unlike the French, the U.S. did not make it a high priority --- opting instead for an arguably more sophisticated vitrification process.

The result: millions of gallons of radioactive wastes continue to leak into the U.S. environment and endanger public health. Meanwhile DOE's failed cleanup efforts have cost the taxpayer billions. The French, by contrast, have effective vitrification operations at substantially less cost.

To fix this problem, the U.S. government needs to address two possible solutions: Either adopt the French process, or conduct full testing on the unproven American vitrification technology.

Since 1980, DoE's premier vitrification plant has run five years behind schedule, and will cost 82% more to construct than originally estimated[1]. Another DoE vitrification project will cost roughly one and a half billion dollars - three times as much as expected[2]. In the meantime, France has used thorough testing to bring three new low-cost vitrification plants on-line.

Whether or not French designs are the best choice for the U.S. vitrification program, they offer an example of how extensive, detailed research, testing and design can lead to success. DoE has often argued, *in public reports*, that the uniqueness of U.S. waste and the superiority of U.S. vitrification technology make any discussion of French vitrification technology unnecessary. However, *in reports not made public*, DoE has extolled the virtues of thorough testing, and has estimated that *billions of dollars might be saved by the adoption of French vitrification technology*[3].

None of these reports evaluate foreign technologies in sufficient detail to change the course of U.S. vitrification efforts. While such a thorough evaluation might be expensive in the short term, and might not lead to the adoption of the French vitrification system, it would likely pay large dividends in the long-run by highlighting the importance of testing in large technology development programs. **Because the commencement of construction on the new Hanford vitrification plant may be indefinitely delayed, DoE now has an opportunity to conduct such an evaluation.**

France's vitrification program is not perfect, and has experienced delays and cost overruns in its three newest plants. **But U.S. vitrification plants of comparable size will cost 75% more to construct[4], and will take seven years more time to complete construction[5]:**

DoE's approach to vitrification has failed in the following areas:

- **No U.S. vitrification facility on-line until 1993 at the earliest.** Earlier estimates called for both the Savannah River plant and the West Valley plant to become operational in 1988[6].

- **Cost overruns of 80% to 200% on the two vitrification plants close to completion[7].**

This performance is in stark contrast relative to that achieved by French-designed plants. While the French vitrification plants are in some ways technologically inferior to American plants, they are demonstrably superior in several important ways:

- **French vitrification plants have operated successfully on a small scale since 1978. Full scale production began in 1989[8].** The U.S. has never operated a full-scale vitrification plant.

- **France has a full-scale pilot plant available for testing new waste compositions[9].** This plant was used to demonstrate the French process for the British, when they were evaluating vitrification alternatives. As a result, the British chose the French system. The same plant might be used to test U.S. waste.

- **All French designs are based on full-scale testing[10].** U.S. designs, rather than relying on extensive full-scale testing, are built so that they may be easily modified. While the American approach is more flexible, it greatly increases the cost of these facilities[11].

The French emphasis on testing likely contributes to the superior performance of their vitrification plants, detailed in the above graph. In 1987, an *internal* DoE study team concluded that the French emphasis on testing *was* important:

> **Basic intelligence, gathered through years of testing and small-scale operations, are used to design plants that are easier to operate and maintain.[12]**

This ease of operation contributes directly to operating costs. That same unpublicized study group estimated that by using a French design at Hanford, ***the U.S. might save nearly $4 billion*** in operating costs over a 40-year operating period[13]. Savings of this magnitude would dwarf any costs of properly evaluating the French technology, or of changing the designs of future U.S. plants.

Ironically, the emphasis DoE placed on rapid development seems to discourage full-scale testing. This, in turn, appears to have contributed to further schedule slips. Progress on DoE's first two vitrification facilities is as follows:

- **The West Valley Demonstration Project is $1 billion over budget, and eight years behind schedule[14].** The West Valley, New York plant was originally scheduled to vitrify wastes from 1988 to 1990, at a total cost of $436 million[15]. It is now scheduled to operate from 1996 to 1998 at a total cost of $1.4 billion[16].

- **The Savannah River Defense Waste Processing Facility could be as much as $3.9 billion over budget, and five years behind schedule[17].** The Savannah River, South Carolina plant, originally scheduled to open in 1988, is now scheduled to open in 1993. Some Savannah River documents indicate that the plant was expected to cost a total of $1.1 billion. The General Accounting Office now expects the plant to cost a total of $5 billion --- thus a potential $3.9 billion overrun.

  DOE Waste Chief Leo Duffy disputes that the original $1.1 billion figure was the projected total cost of the project. Rather, Duffy argues, it's just the construction cost, so the estimated $3.9 billion cost overrun could be much lower. However, to date Duffy has failed to provide alternative estimates of the original total cost of the project --- and therefore an alternative cost overrun figure. Thus, we are forced to rely upon other Savannah River documentation.

  (It is interesting to note that Westinghouse, which operates both of these facilities, posted a 35% increase in profits from DoE contracts last year, despite these overruns[18].)

These delays have potentially serious implications for the environment, as well as worker and public health. *Nearly one hundred million gallons of high-level waste is now stored in large, expensive, unreliable tanks.* According to DoE's original plan, much of these should have already been vitrified. The longer it takes to bring U.S. vitrification plants on-line, the longer U.S. high level waste will have to be stored in this dangerous manner.

- **Roughly a million gallons of radioactive liquid have already leaked from DoE's waste tanks.** Westinghouse earlier estimated that 750,000 gallons of waste had leaked from the tanks at Hanford. More recently, the GAO reported that this figure does not include contaminated cooling water that likely also leaked from these tanks. *A single tank may have leaked 800,000 gallons of this radioactive water*[19].

- **Scientists believe that there is a 2% chance every year that one of these tanks will explode**[20]. Such an explosion could release thousands of gallons of high-level waste into the environment.

The French have achieved remarkable success with vitrification, in large part due to their thorough testing program. We believe that the material cited in this paper strongly suggests that the Department of Energy still does not recognize the importance of testing. DoE still has opportunities to save money through increased testing:

- **Recent delays in commencement of construction of the Hanford Waste Vitrification Plant renew the opportunity to consider alternative approaches**[21]. DoE's principle objection to switching to a French design for Hanford was that it would delay completion of the Hanford plant. (DoE estimates that a French plant could be built at minimal extra cost.) Since disagreements between DoE, EPA and state agencies over facility safety standards may delay the commencement of construction for several years anyway, there is a real opportunity to explore French alternatives.

- **Waste treatment options for Idaho National Engineering Laboratories have not yet been defined, offering an opportunity for rigorous testing of a variety of potential solutions.** Design work for an Idaho treatment plant is not scheduled to begin until 2002[22]. This would give ample time to develop and test more refined designs, based either on preceding U.S. designs, or present French ones.

In summary, we believe available literature on vitrification strongly suggests a correlation between full-scale testing and positive results. The French have accomplished a great deal of full-scale testing as well as actual operations. DoE acknowledges that the French designs that have resulted from this process may be suitable for U.S. waste vitrification[23]. **The United States Department of Energy should carefully analyze the French strategy of full-scale testing, as well as the inexpensive, reliable plant designs this testing has produced.** While this reevaluation will take time and money, it may lead to future savings of much larger magnitude.

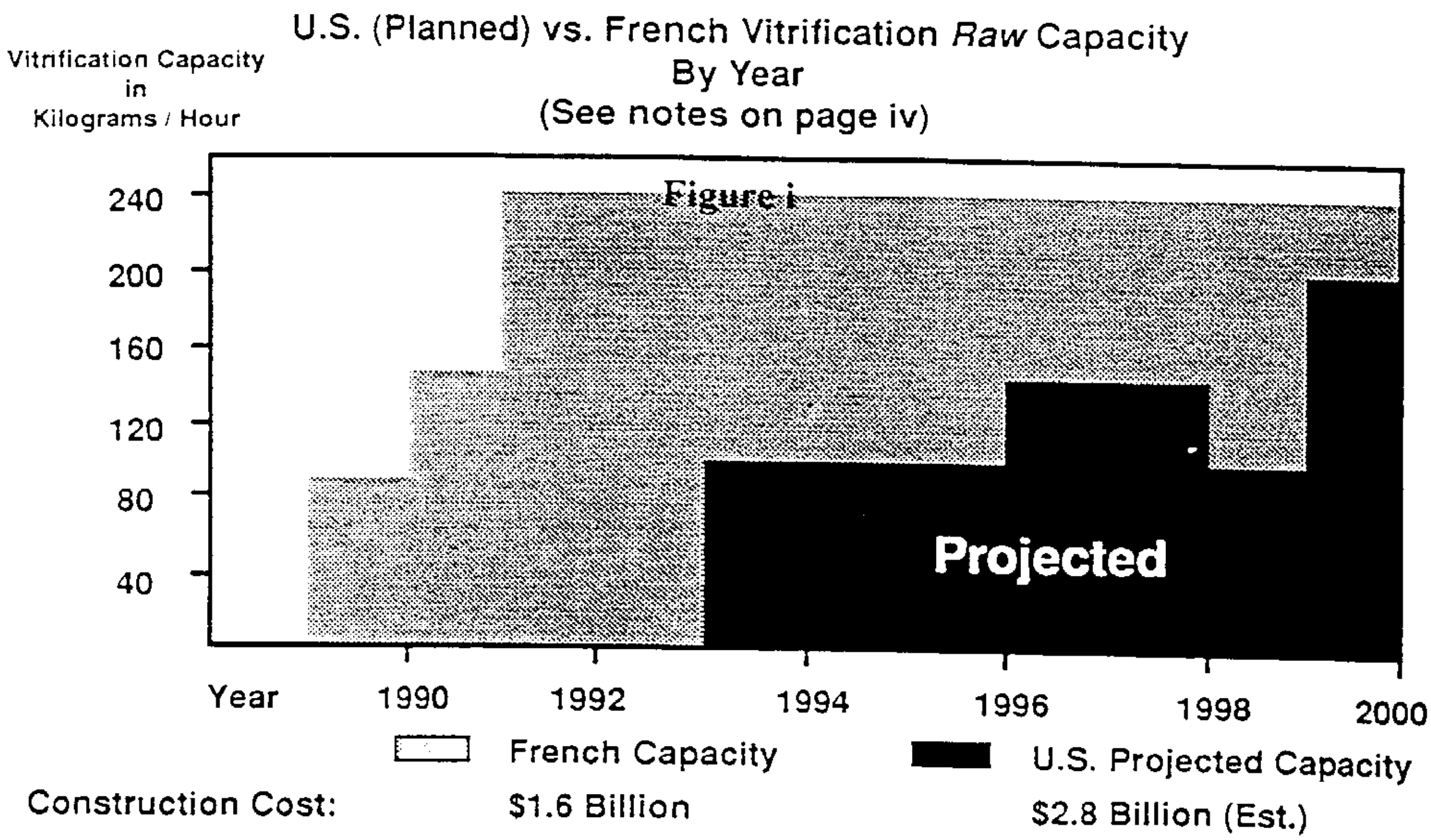

Figure i

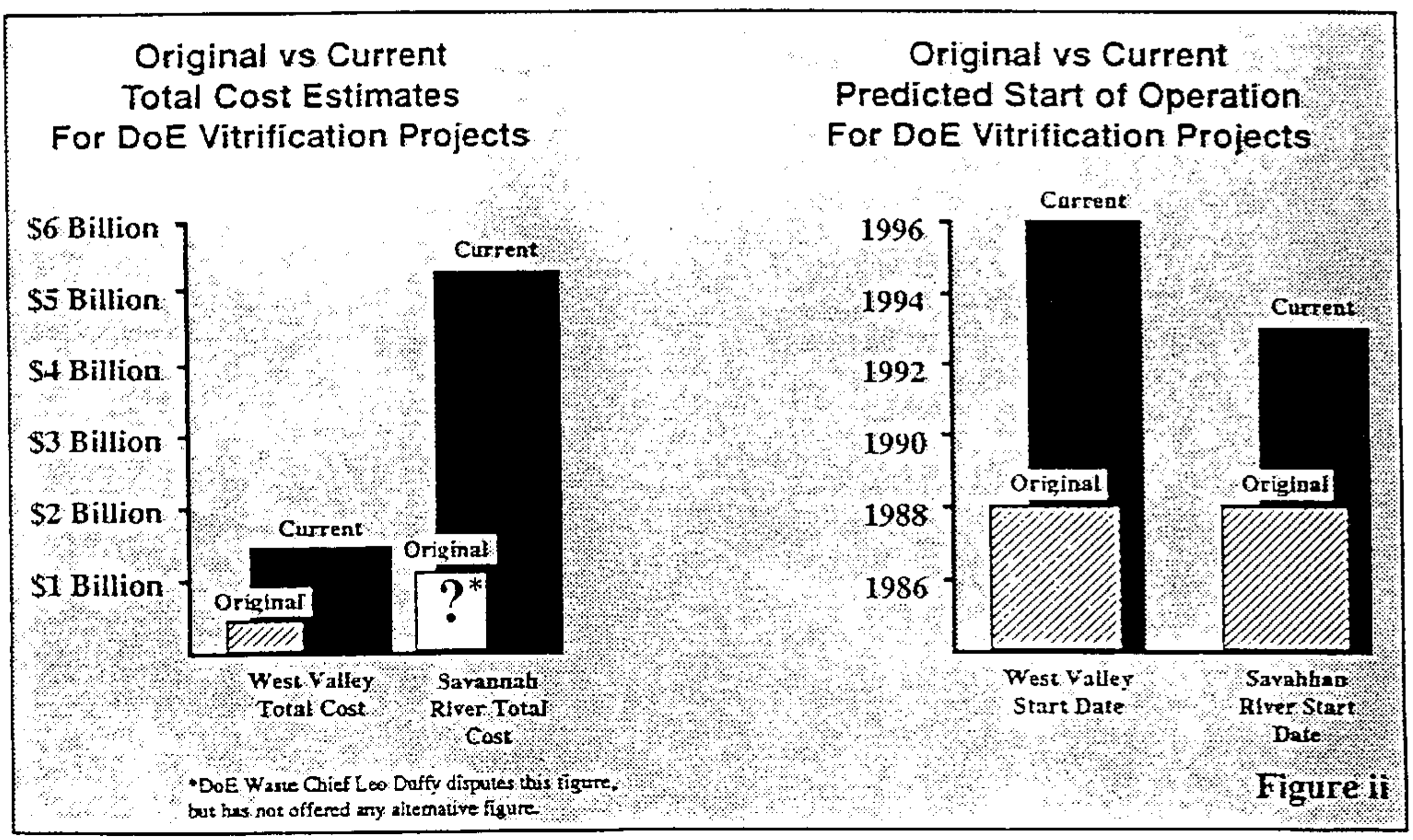

Figure ii

An Important Note on Statistics

When making comparisons between different vitrification plants, one must be careful to use meaningful, accurate statistics. This is often made difficult due to the highly speculative nature of many of the statistics used by the Department of Energy to describe their plants. In particular, the through-put capacity of vitrification plants is entirely dependent on how often they are predicted to be available for use.

According to DoE technical personnel, U.S. vitrification plant availability rates have been revised from 60% to 66%, and finally to 83% for Savannah River and Hanford[24]. Leo P. Duffy, Director of Waste Management & Environmental Restoration at DoE, has claimed that U.S. plants are "expected to attain production capacity approaching 100%"[25]. *This statement is contrary to more recent statements of DoE technical personnel, and totally without basis in any DoE written information we have ever seen.* Furthermore, DoE personnel acknowledge that their availability rates are estimates, and actual performance may vary.

The only availability figure verified by actual operations is the 67% claimed for French plants[26]. While the French claim no great increase in availability since the mid 1980s, *they have brought their plants on-line.* Meanwhile, U.S. plants have struggled with technical difficulties, and nonetheless claimed that *(if and) when they bring their plants on line*, they will have increased their availability rates by 50%.

We have included Figure iv to illustrate the potential implications of DoE claimed plant availability rates. This chart shows the effective through-put capacity of French and American plants, based on a French availability rate of 67% and an American availability rate of 83% (66% for West Valley). In this paper, plant capacity is defined by the following terms:

Raw Capacity - The amount of glass that a melter can produce in an hour when running at full speed. This is measured in kilograms per hour or kg/hr.

Availability - The fraction of time that the melter is actually used. It is expressed as a decimal, or a percent.

Effective Capacity - This is the **raw capacity** times the **availability rate**. It describes how much glass is produced on average by a plant.

100 kg/hr	X	.67	=	66 kg/hr
raw capacity		availability		effective capacity

U.S. (Planned) vs. French Vitrification *Effective* Capacity
By Year

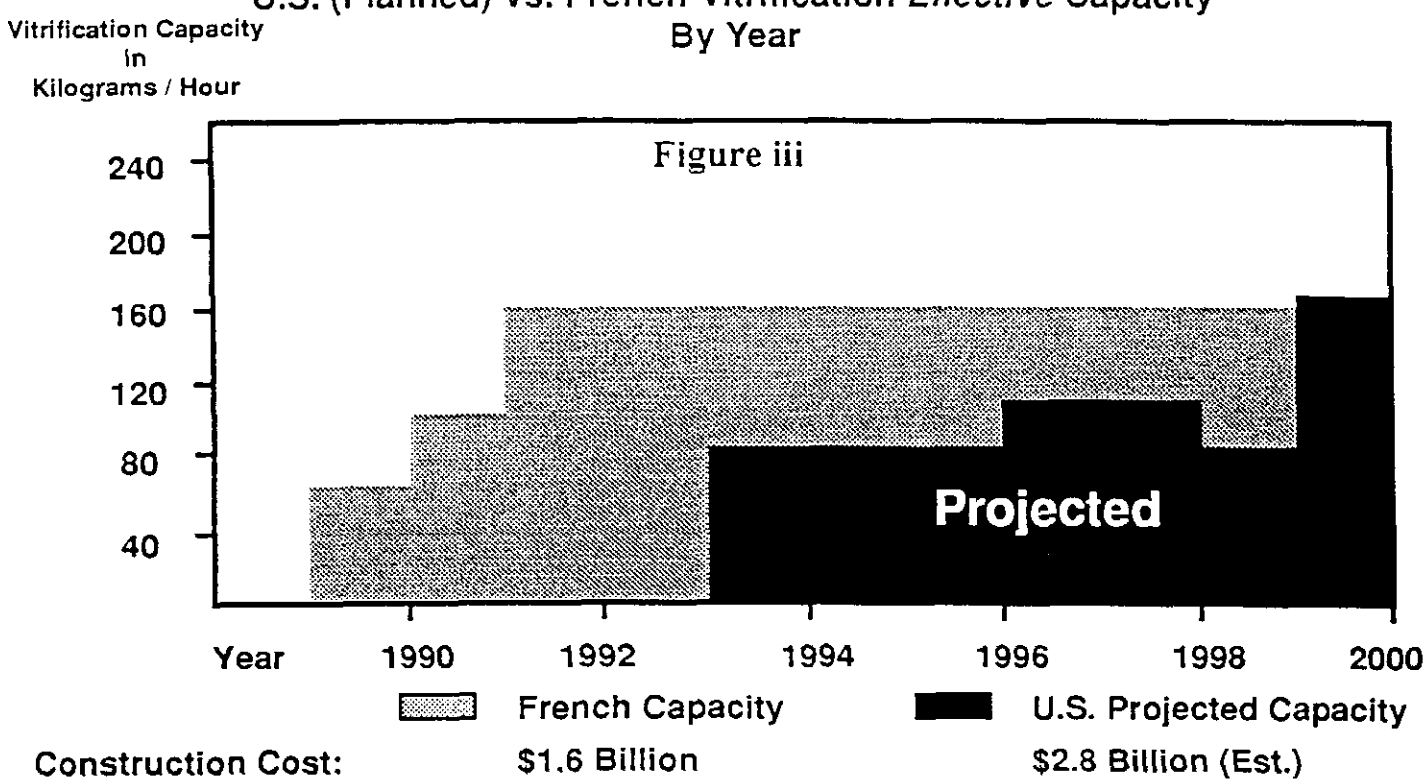

Table of Contents

Introduction to High-Level Waste and Vitrification

This paper discusses the U.S. Department of Energy program to immobilize radioactive waste by vitrification. Vitrification is a process in which hazardous waste is mixed with molten glass and allowed to harden. This is advantageous because, as a solid, the waste can no longer leak. Vitrification has the additional advantage of reducing the volume of the waste.

In vitrification, radioactive waste is combined with crushed glass in a large furnace, called a melter. These melters, as well as their associated equipment and buildings, vary greatly in design and operation, but the glass they produce is typically quite similar. The borosilicate glass most often used is similar to Pyrex glass, used in home kitchenware. In both the French and American systems, the vitrified waste is cast in stainless steel canisters, which provide additional protection. Once vitrified, the waste is still radioactive, and must be stored for millions of years before it is rendered harmless. The Energy Department plans to store vitrified waste canisters in deep shafts at Yucca Mountain, Nevada, although this site has not met final approval.

Where Nuclear Waste Comes From

Poisonous and/or radioactive waste are generated at every step of the process by which nuclear fuels are produced and used. When uranium is mined from the ground, large amounts of radioactive by-products, called tailings, are left behind at the mining site. These are much like the enormous heaps left at iron mines, only uranium tailings are radioactive. The uranium ore is then chemically treated to make civilian-grade uranium fuel. This process involves large volumes of toxic chemicals, some of which must be disposed of as waste. The resulting uranium fuel can then be used in a fission reactor. Fission reactors are used both by civilian electrical power utilities, and by the Navy to power submarines, aircraft carriers.

After uranium fuel is "burned" in a reactor, it is referred to as *spent fuel*. Spent fuel is a mixture of *enriched uranium*, *plutonium*, and useless *fission products*. In the United States, the enriched uranium and plutonium are chemically extracted and used to make nuclear weapons. This extraction is known as *reprocessing*. Reprocessing removes the valuable uranium and plutonium, and leaves behind the toxic, acidic, radioactive fission product solution, which must be disposed of carefully.

Historically, the Department of Energy has chosen a form of storage that is not conducive to retrieval, monitoring or future treatment of the waste. Rather than construct corrosion-resistant stainless steel tanks, the Department of Energy has stored its high-level waste in cheap carbon steel tanks. As a result, the corrosive acidic waste must be neutralized before it is sent to the tanks for storage. As a result of the neutralization process, the waste is converted to a thick, multilayered sludge. This sludge is allowed to settle on the bottom of large storage tanks, and becomes very difficult to move or sample accurately. Indeed, while the Energy Department has confirmed that at least 750,000 gallons of this waste has leaked from its tanks, it acknowledges that as much as 800,000 gallons could have leaked from a single tank[1]. The neutralized waste also releases potentially explosive hydrogen and ferrocyanide gasses. Thus, DoE's storage policies have made it difficult and dangerous to examine this waste, let alone move or treat it.

As a result of this lax management, U.S. nuclear weapons waste must be expensively "pretreated" before it can be vitrified. The heterogeneous sludge must be remixed, so that it can be pumped, and excess water and other relatively harmless materials removed. As a result, costly preprocessing facilities must be built adjacent to U.S. vitrification plants.

Many European countries reprocess their spent uranium fuel, but they use the resulting

[1]U.S. GAO/RCED-91-177, Nuclear Waste: Hanford Single-Shell Tank Leaks Greater Than Estimated, 8/5/91, pp.1-2.

plutonium and uranium to fuel civilian reactors, as well as nuclear weapons. A leader in nuclear power development, France reprocesses most of its spent fuel, and since 1978 has been vitrifying it in large, industrial-scale facilities. France stores its reprocessing waste in its original homogenous, acidic form, so that it can be easily pumped and sampled. It is stored in stainless steel tanks to prevent corrosion. Because they store their waste this way, the French have an accurate inventory of their waste, and can easily pump it directly to adjacent vitrification plants.

During the 1970s, the United States experimented briefly with reprocessing civilian nuclear fuel at a privately-owned site in West Valley, New York. While this project was a technical success, it was abandoned in the late 1970s for a variety of economic and political reasons. West Valley is now the site of one of DoE's vitrification plants.

Background

In the late 1970s, the Department of Energy decided that vitrification was the best available means of preparing high-level waste for final disposal. At this point, the French had been vitrifying high-level waste *for fifteen years*, and were prepared to offer fairly complete plant designs, as well as full-scale pilot facilities in which to test them. The Energy Department rejected not only the French design, *but also the French concept of full-scale process testing.*

In 1983, the Department of Energy opted to proceed immediately with its first vitrification "Demonstration Project", located in West Valley, New York. This facility would use a new, untested type of melter considered superior to that used by the French. When DoE decided to develope this new billion-dollar technology, it acknowledged that the existing French technology was adequate, but dismissed the significance of French experience and testing:

> **With some adaptation either approach could be made to work at West Valley. ... [But] It is believed [the U.S. melter's technical] advantages are of greater importance for the West Valley wastes than the radioactive operational experience advantages of the [French] process...**[2]

The same DoE committee said that it foresaw "no substantial cost or schedule advantage for either [the French or the American design]"[3], an assumption that has since proven incorrect.

The Energy Department felt confident in its ability to proceed with the vitrification project, <u>without waiting for thorough testing</u>. The West Valley project was put on a "fast track" program in which construction was begun before design work, let alone testing, was complete. And in 1983, with the West Valley Demonstration Project barely begun, DoE started construction on an even larger facility at Savannah River, South Carolina, using the same basic design. The General Accounting Office explained:

> **DoE officials told us that, under the fast-track strategy, construction was initiated on certain activities before design work was sufficiently completed. This was done in part because DoE Officials believed that the technology for waste solidification was sufficiently developed and could be applied at West Valley without feasibility and design work. *However, the fast-track approach did not work.***[4](emphasis added)

The "Fast Track" approach can be contrasted with the more pragmatic approach used not only by France, but by Belgium, Germany and other countries. A 1987 DoE report, which until recently was not made public, had high praise for these programs:

> **Basic plant operations and maintenance concepts seem to be thoroughly developed prior to designing the production plant. These concepts are developed at the pilot plants, demonstration plants, equipment development centers, and full-scale mockup facilities. Basic intelligence, gathered through years of testing and small-scale operations, are used to design plants that are easier to operate and maintain**[5]**.**

While the Energy Department's decision to proceed with a new, theoretically superior melter is debatable, its decision to ignore France's experience, *and* to forego full-scale operational testing seems inexplicable. The potential shortcomings of the French process, when applied to

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[2]DoE vitrification evaluation committee quoted in Michael Knapik, "DoE Rejects SGN's Vitrification Process But Will Use French Firm at West Valley", <u>Nuclear Fuel</u>, 11/7/83, p.5.

[3]Ibid.

[4]U.S. GAO/RCED-90-46FS, Op. Cit.,p.25.

[5]Paul Felise et al, <u>Alternative Design and Technology Study of Foreign Vitrification Programs</u>, U.S. DoE SD-HWV-ES-025, p.48.

U.S. waste, were not trivial. But these potential shortcomings could have been quickly tested, and possibly corrected, at France's full-scale pilot facility at Marcoule. In other words, the Department of Energy was faced with two technology options in the early 1980s:

Option 1	An operational French technology regarded as adequate, and for which any shortcomings could be conveniently tested at an existing pilot facility.
Factors:	**Costs and Technical Difficulties Could Be Quickly and Easily Defined**
Option 2	A theoretical American technology regarded as superior, for which no full-scale testing facility existed.
Factors:	**Costs and Technical Difficulties Unknown, and Not Easily Discovered**

While DoE's concerns regarding the French technology were serious, they might have been quickly eliminated through full scale testing. But the Energy Department chose not only to pass up the opportunity for testing the French technology in existing pilot facilities. DoE also chose to ignore entirely the potential benefit of building a large scale pilot facility to test the new U.S. technology.

DoE was unsure that the French process had the reliability and flexibility to consistently produce glass meeting U.S. Environmental standards. These questions, however, could have been answered by processing a test sample of U.S. waste at the full-scale pilot plant at Marcoule, France.

This is exactly what the British did when they were studying the possibility of vitrifying their radioactive waste. Since then, the British have successfully constructed and operated a full-size vitrification plant at a construction cost of $460 million[6]. While the British plant has two-thirds the capacity of Savannah River, it is only half as expensive as the (estimated) $930 million construction cost[7]. And since Savannah River is not yet operational, its cost may increase further.

The Department of Energy, however, chose a different course, fraught with risk. While the U.S. plant design may yet prove to be superior, U.S. plants so far have only proven to be more expensive, and more time consuming to build than the French designs. ***And no U.S. plant has yet been made to function satisfactorily. Furthermore, even by DoE's conservative estimates, French plants built to U.S. standards are likely to cost 12% less, per Kg/hour of capacity, than American designs[8].*** American plants are also more expensive to operate. Interestingly, DoE's public statements have not always been consistent with their internal studies:

1987 <u>Internal</u> Report:	For a 40-yr mission, the budget outlay differences [between a U.S. and a French designed plant] would be $3,925 million.[9]
1990 <u>Public</u> Report:	Both cost and schedule would be adversely affected [by adopting French designs]"[10].

This stark discrepancy seems hard to explain.

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[6]The Sellafield plant is reported to cost $460 million in Pearl Marshall, "BNFL Opens New Vitrification Plant", <u>Nuclear Fuel</u>, 3/4/91.

[7]According to Savannah River Operations Office, "Presentation to the Energy Systems Acquisition Advisory Board on the Status of the Defense Waste Processing Facility", 12/12/90, p.13, the construction cost of the Savannah River plant is estimated at $930 million. It will have a capacity of 100 Kg/hour.

[8]U.S. DoE Richland Vitrification Project Office, <u>Hanford Waste Vitrification Plant Foreign Alternatives Feasibility Study</u>, 5/90, p.3-17.

[9] Paul Felise et al, Op. Cit., p.50.

[10]Ibid., p.viii.

The Energy Department's Plan

The Energy Department's plan in 1982 was to simultaneously begin construction of two waste vitrification plants, both of which were once projected to operate before 1988[11]. These would include a large facility to vitrify nuclear weapons waste in Savannah River South Carolina, and a smaller plant to vitrify a small amount of spent commercial power plant fuel in West Valley New York. While some small scale testing would be conducted, full-scale radioactive testing would not precede either of these plants construction or design. And both plants would be built at the same time, effectively eliminating the possibility of one benefiting from the other's operating experiences. At the time, the French insisted that their process could solidify U.S. waste more cheaply[12]. DoE insisted otherwise.

In 1984, the Department of Energy was confident in its decision, and predicted that its first plant, at West Valley, would vitrify all of its waste by 1990 at a total cost of $436 million[13]. By 1987, the projected cost had nearly doubled to $800 million[14]. Now the projected total cost is $1.4 billion, *more three times the original estimate, and nearly $1 billion over budget*[15]. The opening date has also slipped by a total of eight years, to 1996[16]. West Valley has yet to begin vitrifying radioactive waste, and will not do so until 1996 at the earliest. By that time, *the smallest of the French plants built since 1980 will have vitrified more waste than West Valley will vitrify over its entire lifespan*[17].

Also in 1984, a larger vitrification plant at Savannah River was predicted to be opened by 1988[18]. The construction of this plant was originally estimated to cost no more than $550 million[19]. By 1990, this estimate had been increased to roughly $1 billion[20]. And the commencement of operations had been pushed back until 1992 -- ***a five year delay***[21]. In the most recent DoE budget request, the operational date is further delayed until 1993. With over a year of check-out testing to complete, this deadline may be revised again.

At both of these facilities, problems which might have been identified in full-scale testing have instead been identified late in the construction process, resulting in delays and large cost overruns. As the General Accounting Office commented on the West Valley project:

> **Lack of sufficient design work resulted in inaccurate cost estimates, numerous design changes during construction, and delays in other project activities.**[22]

At Savannah River, for instance, the melter has been redesigned several times. Unfortunately, instead of using a series of small-scale test melters to arrive at a final design, a series of full-scale melters were constructed as designs were changed[23]. Each of these is

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[11]R. Maher, E. I. du Pont de Numours, Solidification of Savannah River Plant High Level Waste, 11/81, p.1, and GAO/RCED-90-46FS, Op. Cit., p.24.

[12]"COGEMA Tells DoE It Will Save Money With AVM Vitrification At West Valley", Nuclear Fuel, 12/20/82, p.9.

[13]U.S. GAO\RCED-90-46FS, p.24.

[14]Ibid.

[15]John Chamberlain, Op. Cit..

[16]Ibid.

[17]Output of the French-designed Windscale plant is detailed in British Nuclear Fuels, "The Vitrification Plant and Vitrified Product Store", 1991, p.3. Output of West Valley is stated by John Chamberlain, Op.Cit..

[18]R. Maher et al, Op. Cit., p.1.

[19]Ibid.

[20]W.D. Pearson, Op. Cit. p.13. The original cost was estimated at $550 million. The current estimate is $930 million, or $1 billion depending on whether startup costs are included.

[21]GAO/RCED-90-46FS, Op. Cit., p.2.

[22]U.S. GAO/RCED-90-46FS, Op. Cit., p.25.

[23]D.F. Bickford et al, E.I. du Pont de Nemours, Noble Metal Accumulation and Recovery in DWPF Waste-Glass Melter, 4/10/89.

thought to be capable of operating satisfactorily, but the newer designs are expected to last longer. And even the most advanced of these melters may not perform well once it is actually put into use[24]. Operational experience from the smaller West Valley "demonstration" melter will not be available until it begins operating in 1996. So DoE has bought and paid for enough melters to last well into the 21st century, before it is known for sure that they will work.

Summary

In its effort to proceed as quickly as possible with the most promising technology, the Department of Energy incurred high costs and large schedule slips as a result of inadequate testing and design work. These risks might have been avoided by constructing and testing U.S. prototypes, or by studying and testing the foreign systems. DoE was presented with a working French technology, for which a full-scale facility was available to test U.S. waste. It instead chose to develop an experimental technology, without the aid of full-scale pilot facilities, or even detailed design work.

While DoE plants have been struggling towards operations in the mid to late 1990's, French-designed plants have been built and are operating at low costs. And while the DoE vitrification plants may eventually be excellent facilities, it will be several years and many millions of dollars before we know the outcome.

[24] D.F. Bickford et al, Op. Cit.

While it is too late to substantially change the $5.4 billion vitrification project at Savannah river, or the $1.4 billion effort at West Valley, the Department of Energy plans to build two more large vitrification facilities. The applicability and cost-effectiveness of existing technologies, including the French process, should be carefully examined before proceeding. Opportunities for greater testing and better planning are as follows:

- **Recent delays in commencement of construction of the Hanford Waste Vitrification Plant renew the opportunity to consider alternative approaches.**[25] DoE's principle objection to switching to a French design for Hanford was that it would delay completion of the Hanford plant. Since other problems may delay construction anyway, there is a real opportunity to explore French alternatives.

- **The vitrification plant planned for Idaho National Engineering Laboratories has not yet been designed, and offers an opportunity for rigorous testing of a variety of potential designs.** Design work for the Idaho plant is not scheduled to begin until 2002[26]. This would give ample time to develop more refined designs, based either on preceding experience with U.S. designs, or French ones.

Exploring Alternatives at Hanford

In 1989, Congress ordered DoE to evaluate foreign design alternatives for the planned vitrification plant at Hanford. While this public report acknowledged the applicability of the French process to U.S. waste, it was much more pessimistic than a 1987 DoE report on foreign vitrification technology, *which was not released to the public*[27]. The public report, written in 1990, rejected the French technology primarily on the basis of cost and schedule. This report was vague on several important points:

Principle DoE Objections to Use of French Design at Hanford	Important Factors Not Discussed In the Report
1. Restarting design work would cause costly schedule slips of three to five years.	The schedule for starting vitrification operations at Hanford is now delayed indefinitely anyway due to critical problems in preprocessing technology and facilities.[27] See Endnotes
2. The French design would cost $50 million more to build.	**This $50 million is entirely eclipsed by the $524 million to $3.9 billion an earlier, unreleased DoE report predicted would be saved in operating costs.**[28] See Endnotes
3. Testing would be required to verify modifications made to the French design to accommodate U.S. wastes.	France has a full-scale facility at which such tests could be accomplished. The U.S. will not have a full-scale, operational facility until 1993 at the earliest.

[25]GAO/RCED-90-46FS, Op. Cit., p.30, predicts construction starting in July 1991. U.S. DoE, Environmental Restoration & Waste Management 5-Year Plant: FY 1993-1997, estimates construction starting in 1992, subject to potential future delays.

[26]U.S. GAO/RCED-90-46FS, Op. Cit., p.35.

[27]Paul Felise et al, Op. Cit..

Indefinite Delays

The vitrification project at Hanford is currently stalled due to uncertainty regarding the proper location, technique and even possibility of pretreatment of Hanford waste. This waste cannot be vitrified without pretreatment. DoE had planned to use a dangerously outdated building for pretreatment, and has recently been confronted with opposition from EPA and Washington Department of Ecology. The Energy Department is also unsure that it will be able to safely remove the waste from its present location so that it can be pretreated. Construction has already been delayed by one year, and while start-up of the plant might still take place as planned in 1999, it cannot unless these two critical issues are resolved.

Incomplete Analysis of Alternatives at Hanford

In its recent report on alternatives for the Hanford vitrification plant, the Department of Energy acknowledges that it has never conducted a thorough evaluation of the French vitrification technique. DoE is now conducting a detailed reevaluation of pretreatment technologies for Hanford. Since this evaluation may cause indefinite delays, it may present an opportune time to reevaluate the basic vitrification process as well. A detailed analysis of the French process' application to Hanford might eliminate a variety of important uncertainties regarding the French design's cost and suitability for U.S. waste. The 1990 DoE report on this subject report plainly points out areas in which its analysis is highly speculative due to lack of information.

A particularly noteworthy example of the vagueness of DoE's 1990 public report is its estimation of the construction costs of the French design. The DoE report begins with a "base estimate" of $560 million for construction of a plant identical to those recently completed at La Hague, France. Seventy million dollars is then added for needed modifications. If the costs were totalled at this point, **the result would be a French plant costing $335 million less than the planned American design.** The earlier *internal* DoE report estimated that a French-type plant, complying with U.S. requirements, could be built at Hanford for $90 million *less* than the planned U.S. plant.

But public DoE report goes on to add $385 million in ill-defined "adjustments", thus bringing the total construction cost from 35% less than that of the American design, to 5% more. A large part of this increase was accounted for by "contingency", an arbitrary amount added to account for the uncertainty of the estimate. A more detailed analysis of the French technology might remove this uncertainty factor.

The "adjustments" also include money lost due to schedule slips associate with switching designs mid-stream. These costs may not be applicable if the plant is already delayed for other unrelated reasons. Thus, it is possible that, given some analysis, the estimated cost of a French plant at Hanford could be reduced to a cost substantially lower than the estimated cost of the U.S. design.

Table 3-2. Normalized Plant Cost. ($M)

Element	HWVP	La Hague
Base estimate	965	560[a]
HWVP features required of AVH facility	--	--
Feed and waste storage tanks and transfer pipelines	N/A	20
Feed concentration/liquid waste handling	N/A	40
Cell volume increment to accommodate U.S. canister size and feed concentration tankage (estimated)	N/A	10
Adjustments	N/A	385[b]
Total	965	1,015

[a] Estimated cost to replicate Ateliers Vitrification La Hague (AVH) plant in France (1988)
[b] Cost adjustment for escalation (HWVP schedule), labor rate differences, contingency, and U.S. requirements (e.g., capacity)--see Table 3-3.

HWVP = Hanford Waste Vitrification Plant
N/A = not applicable

Figure 1 - DoE 1990 Estimate of Plant Costs

Current DoE analysis of French vitrification options is not sufficiently current, detailed or frank, and should be updated. The uncertain situation at Hanford could delay the start-up of operations there indefinitely. This gives DoE an opportunity to more fully explore the possibility of capitalizing on French vitrification experience. This would put the Energy Department in a much better position to plan for future treatment of U.S. high-level waste.

Technical Differences Between U.S. and French Vitrification Processes

The Department of Energy has often argued that comparisons between the foreign and U.S. vitrification programs are irrelevant, because U.S. vitrification needs are unique. In fact, U.S. and French plant designs do differ remarkably. But these differences stem not only from different U.S. requirements, but also from DoE's unusual approach to technology development. So comparisons with foreign vitrification programs are not only relevant, but serve to illustrate important differences between U.S. and foreign design approaches.

While American plants are optimized for unique U.S. defense wastes, the Department of Energy acknowledges that French designs are likely to be adequate for treating U.S. waste[28]. Basic differences in design approaches apparently stem from the Energy Department's desire for "flexibility". In other words, whereas the French prefer to eliminate uncertainties through prior detailed testing, DoE prefers to build plants that are capable of adapting to unforseen problems. This was DoE's primary basis for rejecting French proposals in the early 1980's:

> **[While] with some adaptation either approach could be made to work at West Valley ... the [U.S.] slurry-fed ceramic melter does have some technical advantages, including: greater flexibility to handle variations in waste feed compositions or off-normal conditions...**[29]

DoE's decision seems to amount to buying the capability to operate under any conceivable conditions. It is analogous to buying a 50 bladed swiss army knife, when a good scalpel would do the job. While this approach has the obvious advantage of preparing for all conceivable situations, it is very difficult and expensive. A DoE study group estimated that the U.S. requirement for flexibility will add $95 million to $140 million to construction cost of the Hanford plant[30]. It is unclear why the Department of Energy did not first identify exactly the waste compositions it would have to deal with, and test them at a full-scale facility. DoE could then buy only what was necessary to do the vitrify the waste.

Introduction to Vitrification Plant Design

Generally, a waste vitrification facility is a factory, in which glass can be made in complete isolation. Because the waste and waste glass, are highly radioactive and poisonous, both workers and the outside world must be carefully shielded from them. Thus, the actual equipment used to mix the waste with crushed glass, melt it, and pour it into containers must be operable without direct human contact. Much of the complexity involved in vitrification plant design is a result of this need for *remote operation*. The vitrification plant must also be capable of ensuring that the radioactive glass produced conforms to a very precise formula or "recipe", so that it will be sufficiently durable to withstand storage for millions of years.

The Department of Energy chose to develop entirely new designs both for plant lay-out, and for the melter itself. This decision has meant that the U.S. has invested billions of dollars in developing these new technologies, and will reach full vitrification capacity at least seven years later than the French.

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[28] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

[29] DoE vitrification technology review committee quoted by Michael Knapik, "DoE Rejects SGN's Vitrification Process But Will Use French Firm at West Valley", Nuclear Fuel, 11/7/83, p.5.

[30] Paul Felise et at, Op. Cit., p.53.

Why Develope a New Melter?

The new melter developed by DoE is supposed to be superior to the French melter in the following respects:

- **Longer melting time in the U.S. melter may make the glass safer for the environment.**
  Because glass and waste remain in the American melter for an average of 40 hours instead of 4-8, more even mixture is encouraged[31]. If the glass is not evenly mixed, it may not be as safe. Nonetheless, testing on French waste suggests that the French melter is adequate in this respect[32].

- **Greater size and capacity is possible with U.S. melter designs.**
  While this is true, the French solution of having multiple, independent melters in each plant allows them to have plants with capacities as great or greater than ours. And individual melters can receive maintenance while others continue to operate. Smaller melters are also easier to test.

- **The U.S. melter will last longer than metallic French melters.**
  Because the ceramic material used in the American melter is fundamentally more resistant to heat and corrosion than the stainless steel of the French melter, it can be expected to last several years, instead of just one. However, critical metal parts inside the U.S. melter are made of stainless steel, which is vulnerable to heat, corrosion and failure[33].

Glass Consistency

The principle reason stated for developing the U.S. Liquid-Fed Ceramic Melter is that it offers longer melting time, and therefore greater product glass consistency[34]. It is undeniable that glass consistency is important. If the glass and waste are not mixed thoroughly, and pockets of waste remain unmixed with the glass, they will dissolve into the air and groundwater much more easily when the waste is put in final storage. Because the U.S. melter pours from the bottom of a large, continuously fed glass pool, the glass/waste mixture has, on average, been stirring in the melter for 40 hours before it is poured[35]. By contrast, when French glass is poured, it is only 4-8 hours old[36]. **This distinction may, however, be irrelevant**, because, according to DoE:

> **Testing [with French waste] of the product from the French AVH process *indicates acceptable performance*;**[37](emphasis added)

The glass also doesn't have to be *perfectly* consistent. It just has to be *adequately* consistent to ensure its durability over several million years. In this (very limited) sense, vitrification is like making cement for a dam: If you don't mix it long enough, the cement will crumble, and the dam will leak. Vitrifying U.S. waste, which is less consistent than French waste, is like making cement with extra gravel in the mix - This cement might have to be mixed longer to ensure that clumps of gravel don't form, leaving weak points in the dam. *But a smart construction contractor wouldn't go out and buy whole new cement mixer before trying out the gravel in the old one, and testing the cement that it produced.*

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[31] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

[32] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

[33] Ibid.

[34] DoE vitrification alternatives committee, cited in Michael Knapik, Op. Cit..

[35] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

[36] Ibid.

[37] Ibid.

Evidence suggests that the French process *would* provide adequate mixing for U.S. waste[38]. Testing could have been accomplished nearly ten years ago that would have settled this question, and perhaps eliminated the need for a multibillion dollar program to develop the U.S. melter. In 1982 France offered DoE this opportunity, and it was refused[39].

Melter Reliability

The American ceramic melter is also supposed to be substantially more durable than the French stainless steel melter. The ceramic material of which the U.S. melter is made is intrinsically more resistant to heat and corrosion than stainless steel. However, the American melter depends on three types of internal components which are made of stainless steel: the roof heater, the spout heater and the glass-heating electrodes. All of these are susceptible to failure long before the ceramic material wears out. In particular, the electrodes may be short-circuited by metal deposits left by the waste processed in the U.S. melter.

It is unclear how long these components will last before failure. A similar Belgian melter short-circuited after only eight months of operation[40]. It is also unclear how difficult these components will be to replace. French melters can be replaced within the span of an eight hour shift[41], whereas DoE predicts it will take *six weeks* to replace a U.S. melter[42]. And unlike French vitrification plants, which can remain running while one melter is replaced, American plants must shut down entirely when the melter is receiving maintenance. Indeed, an *internal* DoE study team expressed concern that reliability problems with U.S. melters might require the adoption of foreign designs:

> **Foreign technology may eliminate or reduce problems associated with conducting material buildup in the melter and the resulting short melter life. Both German and French development programs can provide a resolution to this problem. *Adopting foreign melter technology may be a requirement* for [Hanford] if noble metals become an issue[43].** (emphasis added)

Melter Size

The U.S. Liquid-Fed Ceramic melter is also desired for its potentially unlimited size. Because French melters transfer heat to the center of the molten glass pool by means of conduction, rather than direct electrical current, they must be relatively small to ensure that the glass in the center is adequately heated. Because this limits the size of the melter, its capacity is limited to 30 kg/hour. But this has not prevented the French from building vitrification plants of 90 Kg/hour capacity, nor, according to DoE, would it prevent them from building plants of 120 Kg/hour capacity[44]. (Our largest plant has a 100 Kg/hour capacity.) The French simply use more than one melter per plant, which has advantages of its own:

- **Plants can be scaled up or down in 30 Kg/hour increments without major redesign.**
  When the British needed a plant with a capacity of 60 Kg/hour, the French simply took their 90 Kg/hour design, and reduced the number of melters from three to two. Similarly, when the Department of Energy recently evaluated the French process for use at Hanford, it assumed that the 90 Kg/hour design could be easily upgraded to a four-melter 120 Kg/hour design.

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[38]Ibid.

[39]"COGEMA Tells DoE It Will Save Money With AVM Vitrification At West Valley", Nuclear Fuel, 12/20/82, p.9.

[40]Paul Felise et al, Op. Cit., p.18.

[41]Michel Lung et al, SGN, La Hague Vitrification Plants: A Status Report, 9/11/88, p.4.

[42]Leo P. Duffy, Director, Office of Environmental Restoration & Waste Management, U.S. DoE, written statement, 10/23/91, p.5.

[43]Paul Felise et al, Op. cit., p.19.

[44]U.S. DoE Richland Vitrification Project Office, Op. Cit., pp.vi, 3-18.

- **One melter can be shut down while others receive maintenance.**
  Even if major equipment, such as a melter, requires replacement, French plants do not have to cease operations. Two melter lines can operate while the third receives maintenance. American, designs by contrast, require the whole plant to be shut down for maintenance.

- **Spare parts can be shared between identical melters.**
  Because each plant houses several identical sets of vitrification equipment, spare parts can be bought and stored in more economical quantities[45].

- **Smaller melters can more easily be tested.**
  To perform a full-scale test of the French vitrification process, one must build only a 30 kg/hr plant, vs a 100 kg/hr plant to test the American system. To test at one-half-scale, only a 15kg/hr plant, such as the one at Marcoule, is required.

Vitrification Plant Design

Beyond the differences between U.S. and French melters, the overall designs of the plants in which they are used are dramatically different. To understand the fundamental differences in U.S. and French approaches to vitrification plant design, it is necessary to understand the basic requirements of a vitrification plant.

In designing a vitrification plant, engineers must consider the design of the necessary vitrification equipment, as well as how it is laid-out within the facility. Basic equipment in the vitrification plant includes:

Melter: The central part of the plant, the melter is the furnace in which crushed glass and radioactive waste are melted together. From here, the resulting molten radioactive glass "product" is poured into canisters for transportation and storage.

Waste Holding and Make-Up Tanks: Before waste is fed into the melter, it is mixed with additives to make sure the final glass product is of proper "recipe", ensuring compliance with environmental requirements. In American vitrification plants, crushed glass is also added during this step.

Canister Handling Equipment: After being melted in the melter, the glass product is poured into stainless steel canisters. These must be positioned under the melter spout, then removed, welded shut, decontaminated, and placed in temporary storage.

Calciner: In the French system, the radioactive waste is first dried in a rotating tubular oven to remove excess moisture. The American system does not use a calciner, and instead moisture is removed by evaporation inside the melter.

Off-Gas Equipment: Gases that evaporate from or are contaminated by the vitrification process must be filtered so that air leaving the facility complies with environmental requirements. Off-gas equipment usually includes a wide variety of staged filters connected to the above equipment.

The French and American plant designs differ both in equipment design, and in lay-out. The American plant lay-out is referred to as a "remote canyon" approach, which offers flexibility, but is more costly and takes up more space. The French plants use a "nested cell" lay-out, which emphasizes compactness, economy and efficiency. The glass melter used in DoE designs is a Liquid-Fed Ceramic Melter. The melter used by the French is a calcine-fed metallic

[45] D. Alexandre, et al, Vitrification of Fission Product Wastes: Industrial Experience and Construction of the New Vitrification Units at La Hague, Cogema, 8/23/87, p.9.

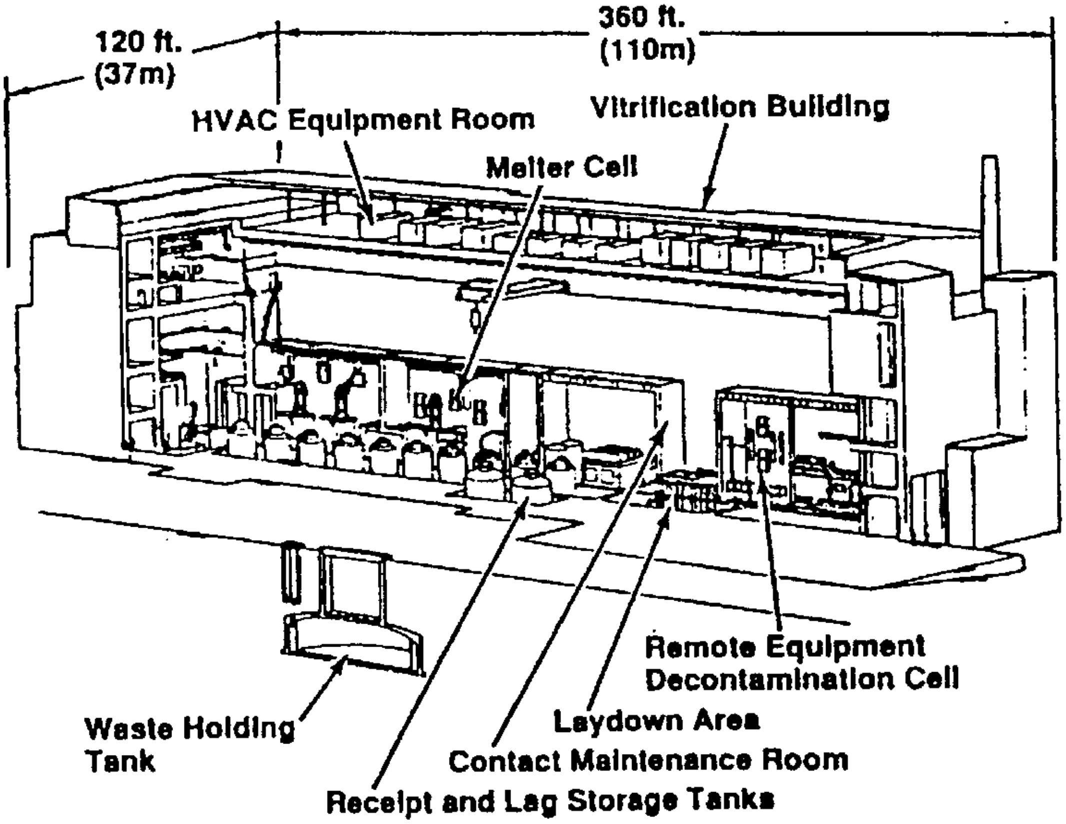

Figure 2 - Remote Canyon at DoE's Hanford Vitrification Plant

melter. In theory, either melter can be used with either lay-out. Both designs allow equipment to be operated remotely, and are capable of precisely controlling glass composition.

Plant Lay-Out

Both the remote canyon and nested cell approaches have been successfully applied to hazardous waste processes for many years. However, unlike the French nested cell lay-out, **the remote canyon design has never been successfully used in an industrial scale vitrification plant.** Remote canyons have been used in U.S. nuclear weapons making facilities. Both designs offer good protection for both workers and the environment. The principle stated advantage of the U.S. DoE "remote canyon" lay-out is that it allows plant equipment to be rearranged easily to accommodate changes in vitrification procedures. But, according to an *internal* DoE report, this approach "is a major contributor to higher [Hanford] plant costs."[46] The French nested cell lay-out, has the advantages of being cheaper to build and operate.

Although U.S. plants are unquestionably more flexible, it is unclear that they need to be. By thoroughly testing U.S. waste and U.S. vitrification procedures, DoE might have been able to better predict the requirements of a U.S. plant. Thus, the extreme flexibility of a remote canyon would be unnecessary.

The French nested cell lay-out is founded on this principle. Many years of testing allowed the French to arrive at a very compact, efficient design. French plants, as a result, require fewer

[46]Paul Felise et al, Op. Cit., p.38.

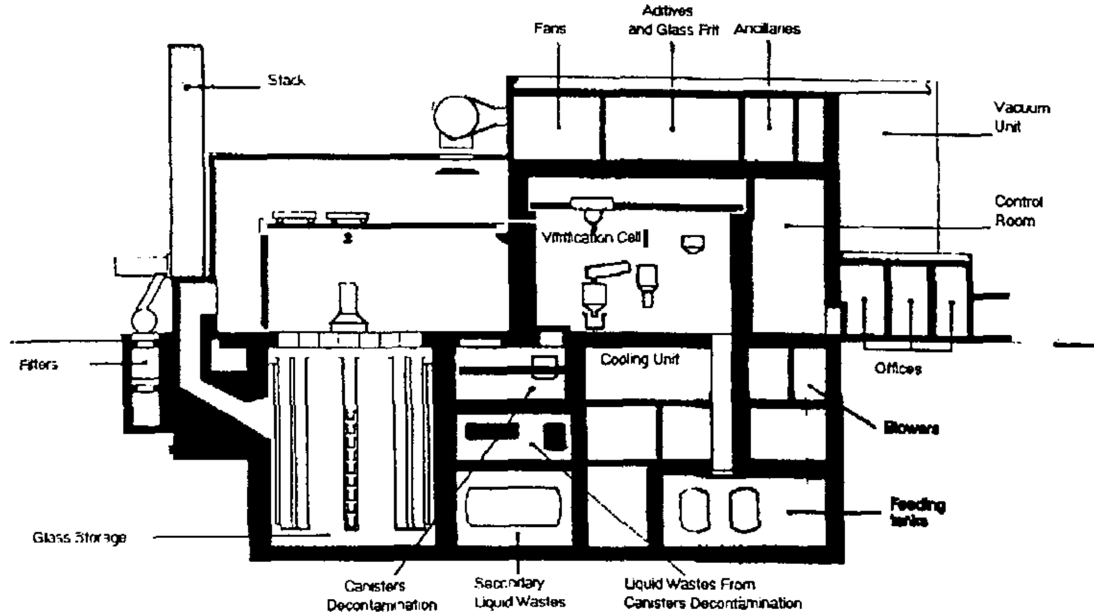

Figure 3 - Cross Section of French Nested Cell Plant

building materials[47], which contributes to lower cost. And because their process is so thoroughly refined and understood, it can be extensively automated. This, and high quality training allow for staffs as small as 82 for a French-type plant at Hanford, as opposed to a staff of 257 for a U.S. plant[48].

The purpose of DoE's remote canyon is to provide a sealed, shielded work area, in which nearly all operations, maintenance *and modifications* can be safely accomplished by remote control using an overhead crane. This crane is usually mounted near the ceiling on rails which run the length of the work area. Thus, the work area takes the form of a long, narrow vault, much like a natural canyon. In theory, all equipment should be operable, maintainable and removable by means of simple procedures performed by the crane.

In simpler canyons, such as the one at West Valley, all process equipment is arranged in a single room. In more complex canyons, such as the one planned for Hanford, there is a series of separate sealed operating rooms (cells) arranged on the floor the canyon. Each of these cells has a lid which can be removed by the crane. A key quality of all canyons is that all cells are on one level, with none stacked on top of each other. This would preclude access by the crane.

The French "nested cell" arrangement is fundamentally different. Cells are stacked on top of each other, as well as next to each other. Also, much equipment is permanently installed. This allows the designer of the vitrification facility to pack equipment much more tightly. This results in a more efficient, compact design that uses substantially less building material[49]. The 1987 internal DoE study team pointed out:

> **If cell heights were reduced to 25 ft and the canyon crane concept eliminated, building volume reductions could result in capitol cost reductions of $95 to $140 million [at Hanford][50].**

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[47]U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

[48]Paul Felise et al, Op. Cit., p.49.

[49]U.S. DoE Richland Vitrification Office, Op. Cit., p.3-4.

[50]Paul Felise et al, Op. Cit., p.53.

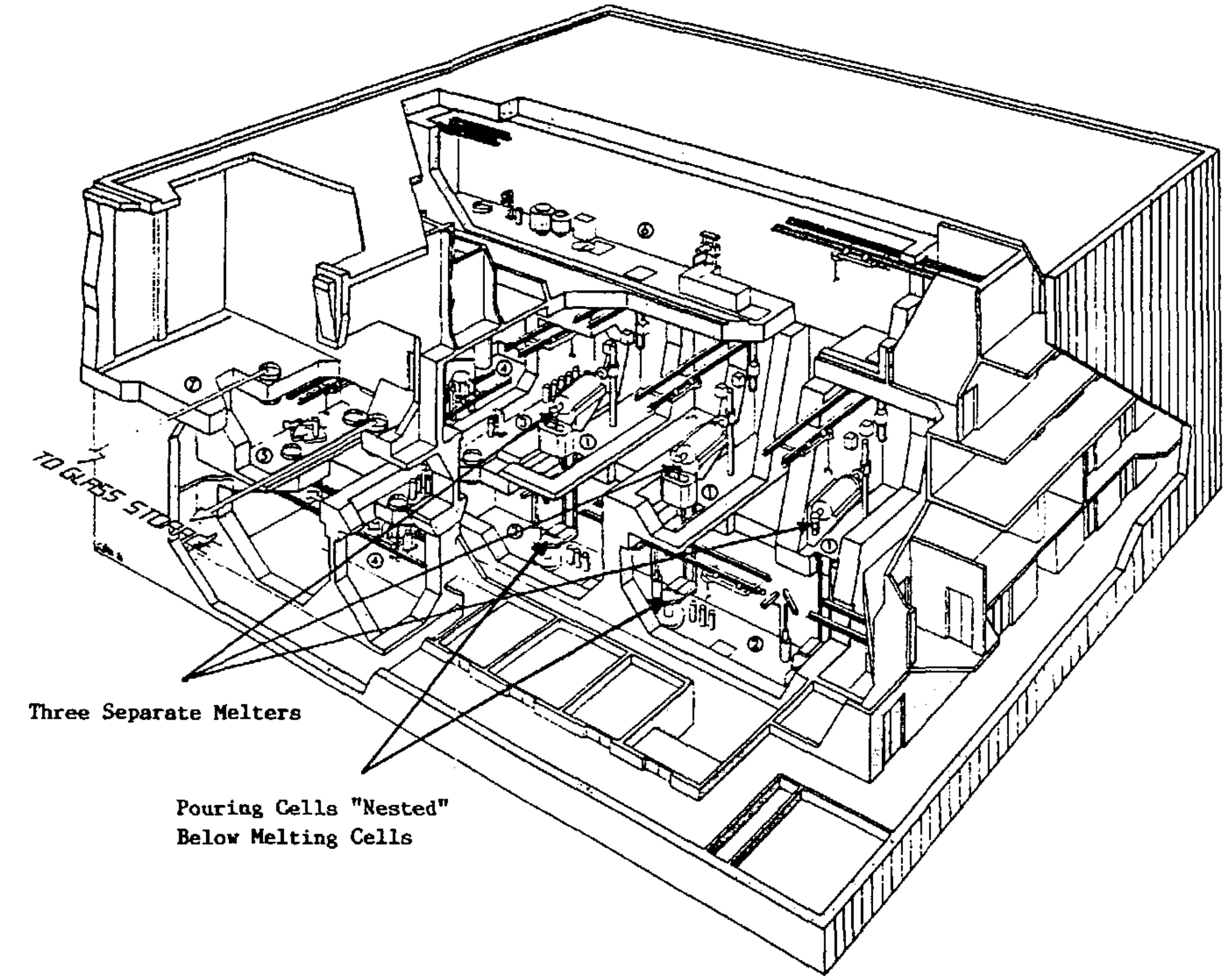

Figure 4 - French Nested Cell Plant Lay-Out

Because there is no requirement that all equipment be accessible by the crane, more complex conveyors and other equipment may be installed. Basically, the U.S. requirement that all equipment be removable by crane is like requiring that a VCR be operable and maintainable while wearing mittens: All the buttons have to be bigger, and all of the internal components must either be larger, or have special handles so that one could grab them without disturbing other components. Such a VCR would be enormous, and very expensive. Of course, if that VCR were covered with hazardous chemicals, such a requirement would not be unreasonable.

What the French have done is separate the plant components that are most contaminated, and required that they be handled remotely. Other less dangerous equipment does not have this requirement, and can thus be more elaborate and more compact. This makes both maintenance and operations easier. In the latest French plants, for instance, many operation are so automated that they can be accomplished at the touch of a button by preprogrammed robotic systems[51]. So, in effect, the French have required that only the most dangerous parts of their plants be operable "with mittens".

[51]Jean Maillet & Claude Sombret, Op. cit., p.10.

Because much equipment is permanently installed in French nested cell plants, it cannot be easily modified, and sometimes must be maintained by hand by human workers. Neither of these supposed shortcomings has so far proven significant with French-designed plants. Because only the melter and calciner need be accessible by the crane, other, more reliable equipment can be more effectively protected from contamination, in separate, sealed cells. According to DoE, these cells can be more easily decontaminated, making direct worker access safe[52].

DoE reports that worker exposure level in French plants is in fact substantially higher than those planned for the Hanford vitrification plant[53]. But DoE explains that vitrification plants in France actually have thicker shielding than do U.S. designs, but experience more radiation contamination because the waste they handle is *three times as radioactive as U.S. waste*[54]. French waste is vitrified shortly after it is produced, whereas U.S. waste has rested in tanks for decades, thus losing some of its radioactivity. The same report also points out that French exposure levels are comparable to those regularly experienced in other Hanford facilities[55]. If French-type plants were built in the U.S., the lower radioactivity of U.S. waste would likely result in worker exposure levels within U.S. limits[56].

The Department of Energy opted for the remote canyon design because it was unsure that the fixed French design could adapt to all the waste forms found at DoE facilities. The French, however, have been satisfied with their plant's capability to handle at least four different types of high-level waste[57], including at least some alkaline waste[58]. (U.S. waste is alkaline.) DoE is also more familiar with remote canyon operation, due to their use in nuclear weapons production. Nonetheless, in a 1990 report on vitrification technology alternatives, DoE indicated that it was likely that French nested cell process plants could be adapted to perform well with U.S. waste[59]. **Why this option was not fully explored before billions of dollars were spend developing U.S. designs is unclear.**

Melter Designs

The U.S. Liquid-Fed Ceramic Melter (LFCM) and the French calcine-fed metallic melter are very different in both design and use. They are both considered suitable for U.S. waste[60].

As its name suggests, the American Liquid-Fed Ceramic Melter (LFCM) is made of a ceramic material which is very resistant to heat and corrosion. The functioning of the melter, however, is dependent on metal electrodes and heating elements, which are susceptible to corrosion and other problems. If these fail, the melter is rendered inoperative.

Most of the heating in the U.S. Liquid-Fed Ceramic Melter is performed by electrodes. Electrodes are electrical power sources, such as the ones that heat the burners on a household electric stove. To make a stove work the way the U.S. melter works, you would remove the burner, and stick the electrodes in either end of a hot dog.

Because the electricity passes from one side of the melter, through the center of the glass pool, to the other side of the melter, large volumes of glass can be heated thoroughly. (As with the glass, the middle of the hot dog would be cooked, instead of just one side.) The

[52] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-5.

[53] Paul Felise et al, Op. Cit., pp.37-38.

[54] Ibid.

[55] Ibid.

[56] Ibid.

[57] Jean Maillet & Claude Sombret, SGN, Vitrification of High Level Waste: The French Experience, 9/28/87, Appendix.

[58] Paul Felise et al, Op. Cit., p.5.

[59] DoE vitrification technology review committee quoted by Michael Knapik, "DoE Rejects SGN's Vitrification Process But Will Use French Firm at West Valley", Nuclear Fuel, 11/7/83, p.5.

[60] U.S. DoE Richland Vitrification Project Office, Op. Cit., p.3-3.

electrodes in the American melter are supplemented by heating elements (like the ones in your stove), placed in the pour spout and roof of the melter. These heating elements heat the waste/glass mixture as it is fed into the melter, and prevent it from solidifying as it is poured through the spout.

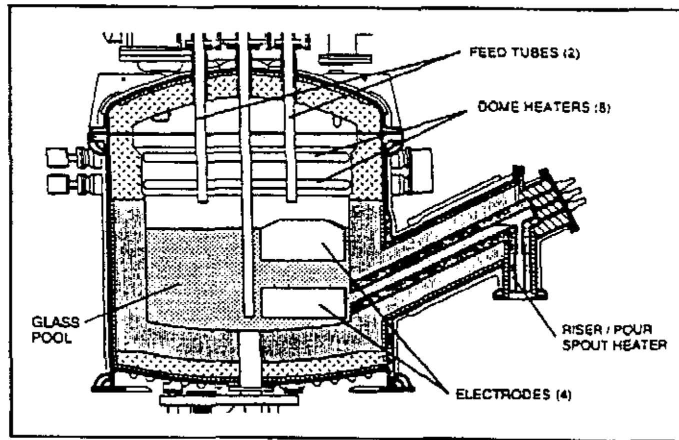

Figure 5 - Liquid-Fed Ceramic Melter

Premixed liquid waste and crushed glass are pumped into the melter, and deposited on top of the pool of molten glass. As water is evaporated from the waste, it begins to melt, and become part of the glass pool. The melter is shaped like a teakettle, with a pour spout that draws from the bottom of the glass pool (see figure 4). Rather than tipping the melter (as one would a teakettle) pressurized air is pumped into the top of the melter, forcing the molten glass through the spout. The melter is kept hot and full of glass at all times.

The French metallic melter is made of stainless steel, which is less durable than ceramics, but is a better conductor of heat. The French melter must conduct heat well, because no electrodes are used to heat the glass. All heating is done by heating elements, like those in a stove, which heat the melter wall, which in turn heats the glass. Waste is fed into the melter through a rotating oven, called a calciner, which removes water from the waste. This dried waste is fed directly into the melter. Crushed glass is added simultaneously (though separately). When the glass has melted, and mixed thoroughly with the waste (this takes about 8 hours), it is drained through a hole in the bottom of the melter.

Pouring is controlled by a separate heating element, which when turned off, allows a glass plug to form. When the heating element is turned on, the plug melts, and the glass is allowed to flow into a canister position below the melter. Unlike the American melter, the French melter is emptied during pouring.

U.S. vs French Vitrification Technologies - Summary

While U.S. vitrification plants have many theoretical advantages over French plants, these advantages are still unproven, and will have been bought at huge cost. There is so far no indication that French technology is incapable of meeting the demands of U.S. waste. When comparing U.S. and French vitrification techniques, the following points are important:

- **The greater flexibility offered by U.S. plants might have been rendered unnecessary by advanced testing of U.S. waste in French pilot plants.** By determining in advance what processes would be necessary to vitrify U.S. waste, DoE could have eliminated the need for expensive, remote canyon vitrification plants.

- **The possibly greater uniformity of product glass offered by U.S. plants may be unnecessary to ensure safe final disposal of U.S. waste.** While U.S. plants are likely to produce somewhat more uniform glass, testing could have been accomplished nearly ten years ago to determine if the French process were adequate for U.S. needs.

- **The larger capacity and longer life of the Liquid-Fed Ceramic Melter are of limited importance.** By using multiple small, easily replace melters, French plants can remain on-line constantly, whereas American plants require shut-down for maintenance.

In effect, there seem to be no credible arguments for having embarked upon a multibillion-dollar effort to develope a new American vitrification technology without having thoroughly evaluated the existing French technology. The suitability of the French process could have been easily tested ten years ago.

In summary, we believe available literature on vitrification strongly shows a correlation between full-scale testing, and positive results. The French have accomplished a great deal of full-scale testing, as well as actual operations. DoE acknowledges that the French designs that have resulted from this process may be suitable for U.S. waste vitrification. Therefore, the United States Department of Energy should carefully analyze the French strategy of full-scale testing, as well as the cheap, reliable plant designs this testing has produced before proceeding with new vitrification plants at Hanford and Idaho National Engineering Laboratory. Regardless of whether such study results in the adoption of the French vitrification process, it will teach us valuable lessons about the importance of testing when developing a new technology.

End Notes:

1. Defense Waste Processing Facility was predicted to commence operations in 1988 in R. Maher, E. I. du Pont de Numours, Solidification of Savannah River Plant High Level Waste, 11/81, p.1. For construction cost overrun, see R. Maher, et al, Op Cit, p.1 vs. W.D. Pearson, Presentation to the Energy Systems Acquisition Advisory Board on the Status of the Defense Waste Processing Facility, 12/12/1990, p.13.

2. U.S. GAO/RCED-90-46FS, Nuclear Waste: DoE's Program to Prepare High-Level Radioactive Waste for Final Disposal, 11/9/89, p.24, and John Chamberlain, Community And Environmental Affairs Specialist, West Valley Nuclear Services Co., letter dated 7/2/91.

3.Paul Felise et al, Alternative Design and TEchnology Study of Foreign Vitrification Programs, U.S. DoE SD-HWV-ES-025, 11/12/87, pp.48-50.

4. The construction cost of the Hanford facility is estimated at $965 million according to DoE Richland Vitrification Project Office, Op Cit, p.3-17. The construction cost of the Defense Waste Processing Facility is reported as $930 million by the Savannah River Operations Office in "Presentation to the Energy Systems Acquisition Advisory Board on the Status of the Defense Waste Processing Facility", 12/12/90, p.13. The total construction and operating cost of the West Valley Facility is reported as $1.41 billion by John D. Chamberlain, in his letter to the author of 7/2/91. This includes less than three years of operations. Given that Savannah River Operations Office, Op Cit, p.13, cites a yearly operating cost of $150 million for the much larger DWPF, a capitol cost of $900 million for West Valley may be conservatively estimated. While DoE estimates for the construction costs of West Valley are as low as $200 million, it seems unlikely that these included the associated testing and design work included in the construction effort.

The cost of the La Hague facilities is reported at $560 million each in DoE Richland Vitrification Project Office, Op Cit, p.3-17. The Sellafield plant is reported to cost $460 million in Pearl Marshall, "BNFL Opens New Vitrification Plant", Nuclear Fuel, 3/4/91.

5. The French-designed plant at Sellafield became operational in 1990, according to British Nuclear Fuels, The Vitrification Plant, 1991, p.3. U.S. DoE Richland Vitrification Project Office, Op. Cit., p.2-11.

6. Defense Waste Processing Facility was predicted to commence operations in 1988 in R. Maher, E. I. du Pont de Numours, Solidification of Savannah River Plant High Level Waste, 11/81, p.1.

7. For the Savannah River construction cost overrun, see R. Maher, et al, Op Cit, p.1 vs. W.D. Pearson, Op. Cit., p.13. For the West Valley total project overrun, see GAO/RCED-90-46FS, p.24, vs. John Chamberlain, Op. Cit..

8. Michel Lung et al, SGN, La Hague Vitrification Plants: A Status Report, September 11, 1988, p.4.

9. British Nuclear Fuels, The Vitrification Plant, 1991, p.4.

10. Michel Lung et al, Op. Cit., pp.1 - 8.

11. Paul Felise et al, Op. Cit., pp. 49, 50, 53.

12. Paul Felise et al, Alternative Design and Technology Study of Foreign Vitrification Programs, U.S. DoE SD-HWV-ES-025, 11/12/87, p.48.

13. Paul Felise et al, Alternative Design and Technology Study of Foreign Vitrification Programs, U.S. DoE SD-HWV-ES-025, p.50.

14. U.S. GAO\RCED-90-46FS, p.24, & John Chamberlain, Op. Cit..

15. GAO/RCED-90-46FS, Op. Cit., p.24.

16. John Chamberlain, Op. Cit..

17. For original cost and schedule estimates, see R. Maher et al, Op. Cit., p.1. For current estimates, see U.S. GAO/RCED-90-46FS, Op. Cit., p.2, and U.S. DoE Congressional Budget request, FY 1992, p.529.

18. Westinghouse Electric Corporation, 1990 Form 10-K, Securities and Exchange Commission, p. 17.

19. U.S. GAO/RCED-91-177, Nuclear Waste: Hanford Single-Shell Tank Leaks Greater Than Estimated, 8/5/91, p.1-2.

20. Dr. Arjun Makhijani, in Mathew Wald, "Carolina Plant to Encase Atomic Wastes in Glass", The New York Times, 11/28/90, p.B6.

21. GAO/RCED-90-46FS, Op. Cit., p.30, predicts construction starting in July 1991. U.S. DoE, Environmental Restoration & Waste Management 5-Year Plant: FY 1993-1997, estimates construction starting in 1992, subject to potential future delays.

22. U.S. GAO/RCED-90-46FS, Op. Cit., p.35.

23. Paul Felise et al, Op. Cit., and U.S DoE Richland Vitrification Project Office, Op. Cit..

24. Telephone conversation with DoE personnel, 11/5/91. See author for details.

25.Leo P. Duffy, Director, Environmental Restoration & Waste Management, U.S. DoE, Written response to questions submitted by the Project on Government Procurement, 10/23/91, p.4.

26. Michel Lung et al, SGN, La Hague Vitrification Plants: A Status Report, 9/11/88, p.4.

27. GAO/RCED-90-46FS, Op. Cit., p.30, predicts construction starting in July 1991. U.S. DoE, Environmental Restoration & Waste Management 5-Year Plant: FY 1993-1997, estimates construction starting in 1992, subject to potential future delays.

28. Paul Felise et al, Op. Cit., pp.49-50.