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Department of Energy
Washington, D.C. 20545

JUN 14 1983

In September 1982 the Department of Energy issued a Record of Decision for the West Valley Demonstration Project at the Western New York Nuclear Service Center, West Valley. The decision was to construct and operate the facilities necessary to solidify the liquid high-level radioactive wastes at the Center into a form suitable for transportation and disposal pursuant to the West Valley Demonstration Project Act of 1980 (Pub. L. 96-368). Publication of the Record of Decision completed the National Environmental Policy Act (NEPA) documentation required for the project to proceed. The decision was based on the "Final Environmental Impact Statement--Long Term Management of Liquid High-Level Radioactive Waste Stored at the Western New York Nuclear Service Center, West Valley" (DOE/EIS-0081) issued in July 1982.

As part of the decision it was stated that the radioactive components of the waste would be separated into a concentrated high-level radioactive waste form suitable for disposal in a Federal geologic repository and a low-level radioactive sodium salt by-product. It was also stated that selection of the waste form would be subject to subsequent environmental review. The Department has selected borosilicate glass as the waste form for the West Valley high-level waste. This selection was based on studies particular to the West Valley Project and on other existing environmental documentation prepared by the Department. The Department has determined, in accordance with Council on Environmental Quality regulations (40 CFR Parts 1500-1508) and Department of Energy implementing guidelines (45 FR 20694), that no supplement to the West Valley Environmental Impact Statement (DOE/EIS-0081) is required.

Enclosed for your information is a copy of a report discussing the basis for selection of borosilicate glass. Copies are being provided to members of Congress, state and local governments, and organizations and individuals known to have an interest in this project. Copies of the supporting documents are available for inspection through the Department's Project Office, Rock Springs Road, West Valley, New York, or for purchase through the Technical Information Center, Department of Energy, P.O. Box 62, Oak Ridge, Tennessee 37830. Additional copies of the enclosure are available from: Ted Adams, West Valley Demonstration Project Office, Department of Energy, Attn: Waste Form Selection, P.O. Box 191, West Valley, New York 14171.

Sincerely,

F E Coffman

Franklin E. Coffman, Director
Office of Terminal Waste Disposal
and Remedial Action
Office of Nuclear Energy

Enclosure

22498

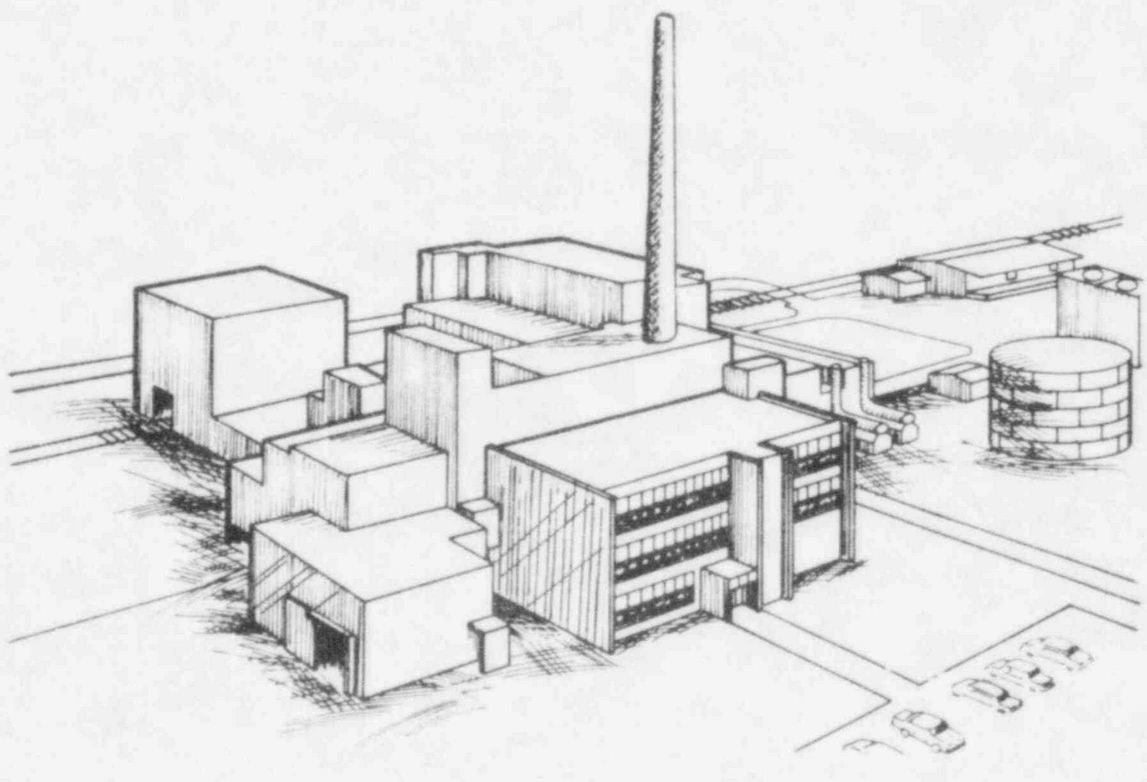
WVDP-100

ANALYSIS OF THE

TERMINAL WASTE FORM SELECTION

FOR THE

WEST VALLEY DEMONSTRATION PROJECT



West Valley Demonstration Project

West Valley, New York

DUPE 8306290626

WASTE FORM SELECTION
FOR THE WEST VALLEY DEMONSTRATION PROJECT

INTRODUCTION

Approximately 2 million liters (560,000 gallons) of liquid high-level radioactive waste are stored in large steel tanks situated in underground concrete vaults at the Western New York Nuclear Service Center located near West Valley, New York, approximately 50 km (30 miles) southeast of Buffalo. The wastes are the byproducts of chemical processing of nuclear reactor fuel from both Federal Government reactors and commercial power reactors during the period 1966-1972.

In October 1980, Congress enacted the West Valley Demonstration Project Act, Public Law 96-368 (Ref. 1), which directed the Department of Energy to carry out a high-level radioactive waste management project at the Center for the purpose of demonstrating solidification techniques which can be used for preparing high-level radioactive waste for disposal. Solidification of the wastes is consistent with the Federal government's policy and management objective to isolate existing and future wastes from the biosphere so they pose no significant risk to public health and safety. The Department of Energy is now the site administrator, and West Valley Nuclear Services Company, Inc. (a wholly owned subsidiary of the Westinghouse Electric Corporation) is the site operator.

A form for disposal of the waste has now been selected for the West Valley Demonstration Project. This paper summarizes the environmental considerations associated with the selection of borosilicate glass as the waste form.

BACKGROUND

Two different types of liquid high-level wastes are stored in the tanks at West Valley: (1) alkaline wastes, stored in one of the carbon-steel, 2.8 million liter tanks (8D-2) located in an underground concrete storage vault; and (2) acidic wastes, stored in one of the stainless steel, 57,000 liter tanks (8D-4) which is located in a separate underground concrete storage vault. The waste solution sent to tank 8D-2, initially highly acidic (in nitric acid), was made alkaline with sodium hydroxide before being transferred. This resulted in the precipitation of the iron, aluminum, and most of the heavy metals and radioactive elements. The waste now consists of an upper supernatant liquid layer, which has a high concentration of salts, and a bottom layer of sludge. The alkaline wastes are similar to liquid high-level waste at Department of Energy facilities at Savannah River and Hanford in that these latter wastes also consist of an alkaline supernate and an associated sludge. The acidic wastes in Tank 8D-4 are considered to be a single-phase solution.

The fuels reprocessed at West Valley will, by 1988, have a minimum "out-of-reactor" time of 18 years, with the average time for the entire inventory being somewhat over 20 years. In addition, many of the fuels processed had low reactor burn-up. The radioactive nuclides in both tanks continue to decay with time, thereby reducing the activity level of the wastes. The dominant radioactivities in Tanks 8D-2 and 8D-4 are due to Cesium-137, (Cs-137; half-life, 30.2 years) and Strontium-90, (Sr-90; half-life, 28.1 years). The cesium in 8D-2 is found dominantly in the supernatant; the strontium dominantly in the sludge.

In accordance with the National Environmental Policy Act (NEPA) (Ref. 2), the DOE published the Final Environmental Impact Statement--Long Term Management of Liquid-High-Level Radioactive Wastes Stored at the Western New York Nuclear Service Center, West Valley (DOE/EIS-0081) (Ref. 3). The action considered in the Environmental Impact Statement (EIS) was to construct and operate facilities necessary to solidify the liquid high-level waste stored at the Center, transport the solidified waste to an appropriate Federal repository for permanent disposal, decontaminate and decommission (D/D) the storage tanks, facilities, hardware, and material used in connection with the solidification, and dispose of low level and transuranic radioactive waste produced as a byproduct of solidifying the high-level waste and of carrying out the D/D program, in accordance with Pub. L. 96-368. Reasonable alternatives to implementing this action were analyzed in the EIS. Notice of the availability of the EIS was published in the Federal Register on July 16, 1982 (47 FR 31062).

Because of its advanced stage of development, borosilicate glass was utilized as the reference terminal waste form for solidifying the wastes for purposes of analysis in the West Valley EIS. The analysis was carried out using glass properties and characteristics that were believed to be reasonably attainable with near-term technology. The reference process for producing borosilicate glass consists of the pretreatment of waste to remove salts and vitrification of the remaining materials using a slurry-fed ceramic melter with an accompanying off-gas treatment system. The flow diagram for the process is shown in Figure 1. In this reference process the supernatant liquid would be treated to separate and concentrate the fission products Cs-137 and a trace amount of Sr-90, leaving a low level radioactive sodium salt by-product to be disposed of separately. The sludge then would be washed with water to reduce the sodium concentration. The rinse solution would be treated in the same manner as the supernatant. Then the washed sludge, fission products from the supernatant concentrate, acidic waste, and glass formers (host glass) would be blended and fed to an electric-heated, ceramic-lined melter. There the slurry would be melted at about 1150^{0} C and the molten glass poured into steel canisters 0.6m (2 ft.) in diameter and 3.0m (10 ft.) high in a continuous process. The molten glass solidifies into a chemically inert, insoluble, nondispersible, nonvolatile solid with low measured leachability in simulated groundwater. Although variations are being and will continue to be considered, the blended pretreated waste feed (without glass former) is expected to consist of approximately 75 weight percent alkaline waste (sludge) and 25 weight percent acidic waste. This waste would be blended with glass formers on a reference basis of 28 weight percent waste and 72 weight percent glass formers. The West Valley EIS addressed all aspects of waste solidification, including the environmental impacts of solidifying the high-level waste in a borosilicate glass waste form, temporarily storing the immobilized waste at West Valley until a geologic repository becomes available, transporting the waste to a geologic repository, and decontamination and decommissioning of the solidification equipment and facilities. Socioeconomic effects and resource consumption from processing the waste into borosilicate glass were found to be minimal, and radiological effects to the public were projected to be insignificant when compared to normal background levels. All operations were within regulatory limits. The EIS stated another waste form would not be chosen unless it had equal or better processing and product characteristics than assumed for borosilicate glass; consequently the EIS calculations were considered limiting for any waste form in that no greater impacts than those identified in the West Valley EIS would be expected.

In September 1982, the Department issued a Record of Decision (Ref. 4) to proceed with construction of facilities at the Center to solidify the liquid high-level radioactive wastes in accordance with the West Valley Demonstration Project Act of 1980 (Pub. L. 96-368). The Record of Decision stated that the radioactive components of the waste would be separated into a concentrated high-level radioactive waste form suitable for disposal in a Federal geologic repository and a low level radioactive sodium salt waste by-product. It was also stated that selection of a terminal waste form would be subject to subsequent environmental review to comply with the NEPA as provided for by Department environmental compliance guidelines.

DISCUSSION

Reference geologic repository designs for permanent disposal of radioactive high-level waste require that the waste form be one of the multiple barriers to the release of radionuclides, thus contributing to the isolation of waste from the accessible human environment, and that it meet product performance criteria. These criteria include:

- Leach resistance--the ability of the waste form to resist chemical attack and degradation in aqueous environments.

- Thermal stability--the ability of the waste form to resist chemical and physical degradation due to heating at elevated temperatures.

- Mechanical stability--the ability of the waste form to resist mechanically induced increases in surface area (cracking) and fines generation.

- Radiation stability--the ability of the waste form to resist chemical and structural degradation due to radionuclide decay.

- Mechanical strength--the ability of the waste form to resist thermal stress during processing and the stress from normal handling.

- Impact resistance--the ability of the waste form to minimize the quantity of dispersible and respirable particles produced by an impact accident.

- Fire resistance--the waste form's ability to prevent the release of radionuclides or gas when heated.

- Waste loading--the minimization of the number of canisters produced, packaged, shipped, and placed in the repository.

Several studies have been conducted analyzing alternative waste forms using the above mentioned properties as a basis for comparison. Most of these studies considered generic waste forms, and their conclusions are applicable. A list of waste forms studied and their developers is shown in Table 1. Early studies (Ref. 5 and 6) concluded that the first seven waste forms in Table 1 had the highest potential for success, and these were subjected to further review. Department of Energy evaluation of these seven forms considered both waste form product and waste form processibility. The evaluations (Ref. 7, 8, 9, 10, 11, 12, and 13) have consistently ranked borosilicate glass as the favored form for immobilizing high-level waste. The alternative waste form Peer Review Panel (Ref. 14), a group of engineers and scientists, has also ranked borosilicate glass as the preferred form. A crystalline ceramic waste form (e.g., Synroc) was considered as the leading alternate to borosilicate glass. A quantitative analysis performed by the Department of Energy determined that the product performance of borosilicate glass and ceramic forms was approximately the same (Ref. 15).

Much attention in the United States and abroad has been given to borosilicate glass as a waste form, which accounts for the relatively advanced status of its production technology. To produce borosilicate glass waste, a glass-forming granule, called frit, is blended with radioactive waste, and the two substances are then melted together. Borosilicate glass has gained support because it offers several advantages. The glass will accept a large variety of glass formers and waste compositions, and essentially all of the radionuclides and inert components normally found in liquid high-level wastes can be incorporated into the glass. About 25 to 35 weight percent of the nuclear waste oxides can be loaded into the molten glass. Large glass monoliths can be cast which are chemically compatible with most metal canister materials. These canistered monoliths are structurally strong and have relatively good impact resistance, high heat capacity, and good resistance to radiation damage, helium buildup from entrained alpha emitters, and water leaching at moderate temperatures. The properties of the finished glass are not critically dependent on small variations in waste and glass-former compositions or in processing conditions. The fact that incorporation of radioactive wastes into borosilicate glass is a currently proven technique was the chief reason for using this waste form as the reference terminal waste form for environmental analysis in the West Valley EIS (Ref. 3).

The West Valley high-level waste has many of the characteristics of high-level waste stored at the Department's Savannah River Plant (SRP). For example, most West Valley and SRP wastes were produced using similar reprocessing technology, and were then both made alkaline by adding sodium hydroxide. The resulting wastes have comparable constituents. Additionally, the pretreatment and vitrification process for the West Valley waste will be functionally similar to that being designed for SRP waste.

A detailed comparison of the composition of the West Valley waste with that of the SRP waste was performed (Ref. 16). It was found that none of the elements in the West Valley waste, except thorium, exceed the maximum concentration level found in SRP waste; that is, the West Valley waste constituents lie within the compositional range found in the SRP waste. These relationships are shown graphically in Figure 2.

During vitrification, thorium will be converted into its oxide, thoria (ThO_2). By blending the neutralized waste and acidic waste before feeding them to the glass melter, the thoria concentration in the final glass product will be controlled to about 4 weight percent. This is conservatively below its solubility limit (about 10 weight percent) in glass when the other waste constituents are also present. At the intended level of thorium additions to the glass, no adverse alteration of the glass properties is expected. The thoria will be fed to the glass fabrication process at a rate such that its solubility limit in borosilicate glass will not be exceeded. The thoria is expected to be fully integrated into the borosilicate glass and to behave like other actinide oxides (e.g., uranium oxide) in the glass matrix.

Some West Valley waste constituents occur in concentrations which are below the respective ranges in the SRP waste by an amount that is small relative to the variation expected during normal processing. Consequently, should it be subsequently determined that their concentration affects behavior of the waste form (i.e., borosilicate glass), additional amounts could be added before vitrification during the pretreatment operations. It was therefore concluded that the West Valley waste characteristics are comparable to those at SRP.

Like the West Valley EIS (Ref. 4), borosilicate glass was utilized as the reference terminal waste form in the SRP waste solidification EIS (Ref. 17). The Department recently assessed the potential environmental consequences of selecting borosilicate glass as the waste form for immobilizing the SRP waste (Ref. 15). That environmental assessment showed that the environmental effects of disposing of SRP waste as a crystalline ceramic form, the leading alternative to borosilicate glass, would not differ significantly from the projected effects for disposal as a borosilicate glass form, and both waste forms would be expected to meet regulations and repository acceptance criteria.

The goal of HLW solidification and emplacement in a geologic repository is to minimize the release of radioactive contaminants to the human environment for this and future generations. From a total system perspective (waste form, canister, overpack, host geologic media), the repository parameters (location, rock type, geohydrologic and geochemical conditions, design, etc.) have a much greater effect on release rates to the accessible environment than do the leach performance characteristics of the waste form (Ref. 15). This fact, therefore, tends to overshadow the minor differences in leach resistance between borosilicate glass and Synroc-D. (Synroc-D has slightly better leach resistance for uranium, slightly worse for strontium, and about the same for cesium.)

The comprehensive evaluation program led to the recommendation of borosilicate glass as the preferred waste form for SRP waste because process complexity, development requirements, and programmatic costs were determined to be less for borosilicate glass than for crystalline ceramic (Ref. 15). The utilization of the borosilicate glass is supported by waste form evaluation programs in other countries in which essentially all other nations are either using borosilicate glass or have selected borosilicate glass as the preferred waste form for disposing of high-level waste.

The process for manufacturing a ceramic waste form is considered more complex than the borosilicate glass process and would require a larger and more expensive processing facility. A process for producing the ceramic has been demonstrated on a laboratory scale, but extensive equipment development efforts are required for a production scale facility, including: (1) scale-up and demonstration of process equipment, unit operation tests, and integrated process tests, and (2) optimization of the ceramic form's phase chemistry. Hence the ceramic form process is not as developed as the borosilicate glass process.

The United States Environmental Protection Agency (EPA) sets generally applicable standards and Federal radiation protection guidelines for disposing of high-level radioactive wastes. EPA issued a draft of 40 CFR 191, "Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste", in December 1982 (Ref. 18). The disposal standards given in draft 40 CFR 191 place no specific requirements on the waste form, but restrict the amount of radioactivity that may enter the biosphere over a 10,000 year period. Total system analyses show that the environmental effects of disposing of borosilicate glass or Synroc-D generated by solidified SRP waste in a geologic repository would be within the draft EPA standards (Ref. 15).

The United States Nuclear Regulatory Commission (NRC) has licensing and regulatory authority over facilities authorized for the express purpose of long-term storage of high-level waste. The NRC disposal criteria and regulations, 10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories: Technical Criteria" were published in draft form in July 1981 (Ref. 19). The NRC draft regulations apply to the total waste package, including the waste form and overpacks. The regulations propose to prohibit radionuclide releases from the packaged waste form for the first 1,000 years and to restrict releases to no more than one part in 10^5 per year thereafter. A variety of packages can be designed for either waste form to assure compliance with the draft 10 CFR 60 requirements. The NRC was consulted in the selection of the West Valley waste form, and judged that a West Valley borosilicate glass form could be an acceptable waste form in a suitably engineered barrier system. NRC noted that additional development work remains to be completed.

The Department of Energy, through the Office of Nuclear Waste Isolation, is developing draft high-level waste acceptance criteria for geologic disposal which include waste form performance specifications and data requirements (Ref. 20). These performance criteria reflect all proposed

EPA and NRC criteria. The National Waste Terminal Storage Program has tentatively specified that the radionuclide release rate due to leaching be less than 1 part in 10^4 per year for the waste form. Both borosilicate glass and Synroc-D meet this proposed specification.

SUMMARY

Since the composition of the West Valley waste and the solidification process are substantially the same as those analyzed in Reference 15, that analysis is applicable for West Valley as well. That is, the environmental impacts of borosilicate glass and crystalline ceramic waste form are similar with the more developed borosilicate glass technology being relatively less complex and less expensive to implement at this time. The selection of borosilicate glass for the West Valley Demonstration Project is consistent with applicable draft Federal standards and regulations and draft DOE acceptance criteria relating to high-level waste disposal in a geologic repository.

Making the final waste form selection at this time allows design of the West Valley Demonstration Project to proceed, reduces the need to conduct alternative waste form studies, increases efficiency by concentrating research and development on a single waste form, and ensures the West Valley wastes will be solidified at the earliest possible date while minimizing costs. Analyses of borosilicate glass containing simulated West Valley waste have been performed and will continue to be performed to assure process and product performance meet operational and repository requirements. Key features of the reference West Valley Demonstration Project solidified waste and canister are shown in Table 2. The waste form verification program will be coordinated with the national waste repository program and the U.S. Nuclear Regulatory Commission to ensure the performance of the West Valley Demonstration Project borosilicate waste glass is demonstrated as being adequate within the multibarrier geologic waste disposal system to ensure isolation of the high-level waste from the human environment.

REFERENCES

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2. U.S. Congress, "National Environmental Policy Act of 1969, as amended." Public Law 91-190, January 1, 1970.

3. U.S. Department of Energy. Final Environmental Impact Statement, Long-Term Management of Liquid High-Level Radioactive Wastes Stored at the Western New York Nuclear Service Center, West Valley DOE/EIS-0081, Washington, D.C., June 1982.

4. U.S. Department of Energy. "Long-Term Management of Liquid High-Level Radioactive Waste at the Western New York Nuclear Service Center, West Valley; Record of Decision." Federal Register, Vol. 47, No. 179, pp. 40705-40706, Washington, D.C., September 15, 1982.

5. Alternative Waste Form Peer Review Panel, The Evaluation and Review of Alternate Waste Forms for Immobilization of High-Level Radioactive Wastes, DOE/TIC-10228, U.S. Department of Energy, Washington, D.C., August 1979.

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7. J. A. Stone, et. al., Preliminary Evaluation of Alternative Forms for Immobilization of Savannah River Plant High-Level Wastes, DP-1545, Savannah River Laboratory, Aiken, SC, December 1979.

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15. U.S. Department of Energy, Environmental Assessment, Waste Form Selection for SRP High-Level Waste, DOE/EA-0179, Washington, D.C., July 1982.

16. West Valley Nuclear Services Company, Inc., Comparison of High-Level Radioactive Wastes at the West Valley Demonstration Project and the Savannah River Plant, WVDP-0018, West Valley, NY, January 1983.

17. U.S. Department of Energy, Final Environmental Impact Statement, Defense Waste Processing Facility, Savannah River Plant, Aiken, S.C., DOE/EIS-0082, Washington, D.C., February 1982.

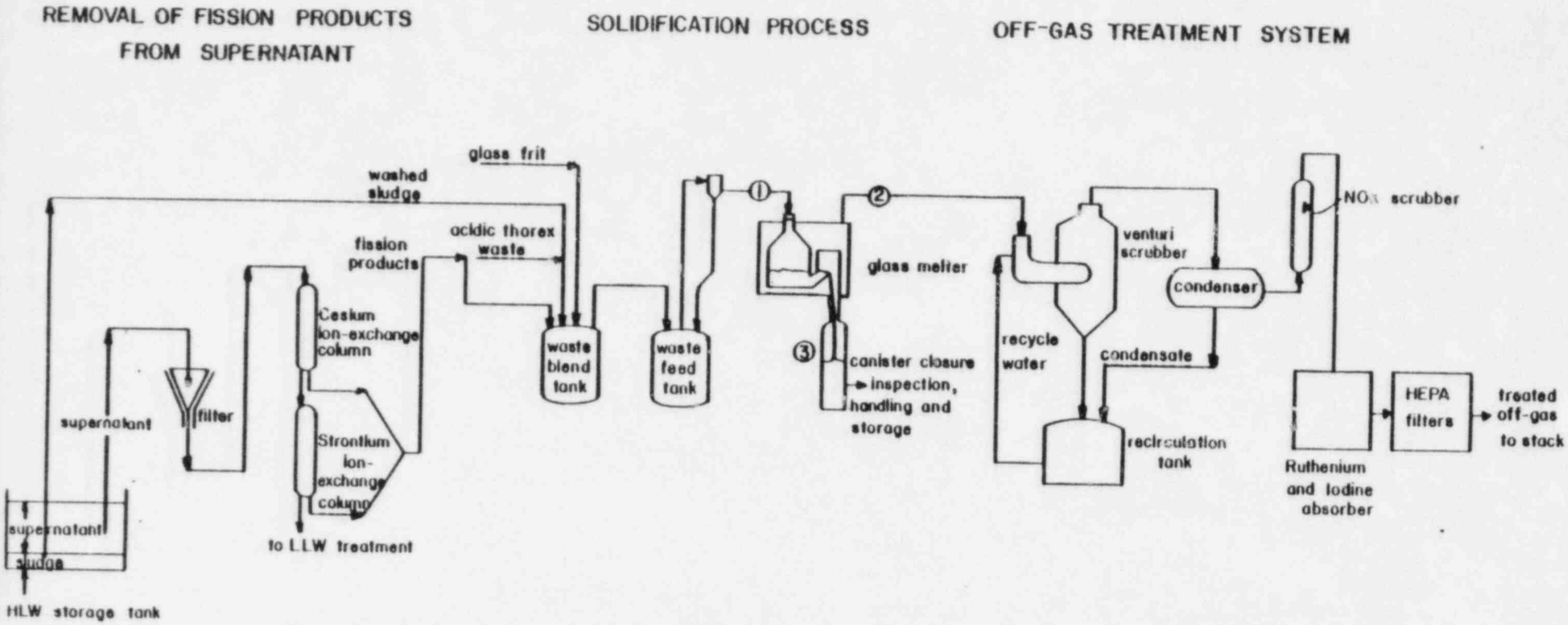
18. U.S. Environmental Protection Agency, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste," Federal Register, Vol. 47, No. 250, pp. 58196-58206, Washington, D.C., December 29, 1982.

19. U.S. Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Wastes in Geologic Repositories: Technical Criteria," Federal Register, Vol. 46, No. 130 pp. 35280-35296, Washington, D.C., July 8, 1981.

20. Interim Performance Specifications and Data Requirements for Waste Forms for Geologic Isolation, Draft Report NWTS-19, Office of Nuclear Waste Isolation, U.S. Department of Energy, October 1981.

TABLE 1. CANDIDATE WASTE FORMS CONSIDERED FOR GEOLOGIC DISPOSAL OF HIGH-LEVEL WASTE

Waste Form	Developer/Contractor
Borosilicate Glass	Pacific Northwest Laboratory Savannah River Laboratory
Synroc	Lawrence Livermore National Laboratory Argonne National Laboratory North Carolina State University
High-Silica Glass (Porous Glass Matrix)	Catholic University of America NPD Nuclear Systems, Inc.
Tailored Ceramic	Rockwell International Pennsylvania State University
Coated Sol-Gel Spheres	Oak Ridge National Laboratory
FUETAP Concrete	Oak Ridge National Laboratory
Matrix Forms	Pacific Northwest Laboratory Brookhaven National Laboratory
Phosphate Glass	Pacific Northwest Laboratory Brookhaven National Laboratory
Clay Ceramic	Rockwell Hanford Laboratory Pacific Northwest Laboratory
Glass Ceramic	Idaho Chemical Processing Plant
Titanate Ion Exchanger	Sandia National Laboratory
Stabilized Calcine	Idaho Chemical Processing Plant
Pelletized Calcine	Idaho Chemical Processing Plant
Normal Concrete	Pennsylvania State University Savannah River Laboratory
Hot-Pressed Concrete	Pennsylvania State University
Cement	Oak Ridge National Laboratory
Disc-Pelletized Coated Particles	Pacific Northwest Laboratory Battelle Columbus Laboratory



1. BLENDED HLW FEED TO MELTER
2. OFF-GAS FROM CERAMIC MELTER
3. POURING OF BOROSILICATE GLASS LOG

FIGURE 1. WVDP Borosilicate Glass Reference Process Flowsheet

TABLE 2. FEATURES OF WEST VALLEY DEMONSTRATION PROJECT WASTE FORM AND CANISTER

Feature	West Valley Reference
Waste Loading, wt. percent	28
Borosilicate Glass Density, g/cm^3	2.75
Borosilicate Glass Weight, kg	1480
Canister Material	304 l Stainless Steel
Canister Dimensions	0.61 m diameter 3.0 m length 0.95 cm wall
Total Canisters Weight (with borosilicate glass), kg.	1930
Heat Generation, watts	365
Heat Generation, after 1,000 years	<1
Radionuclide Content, curies	130,000
Radionuclide Content, after 1,000 years, curies	500
Number of Canisters	300

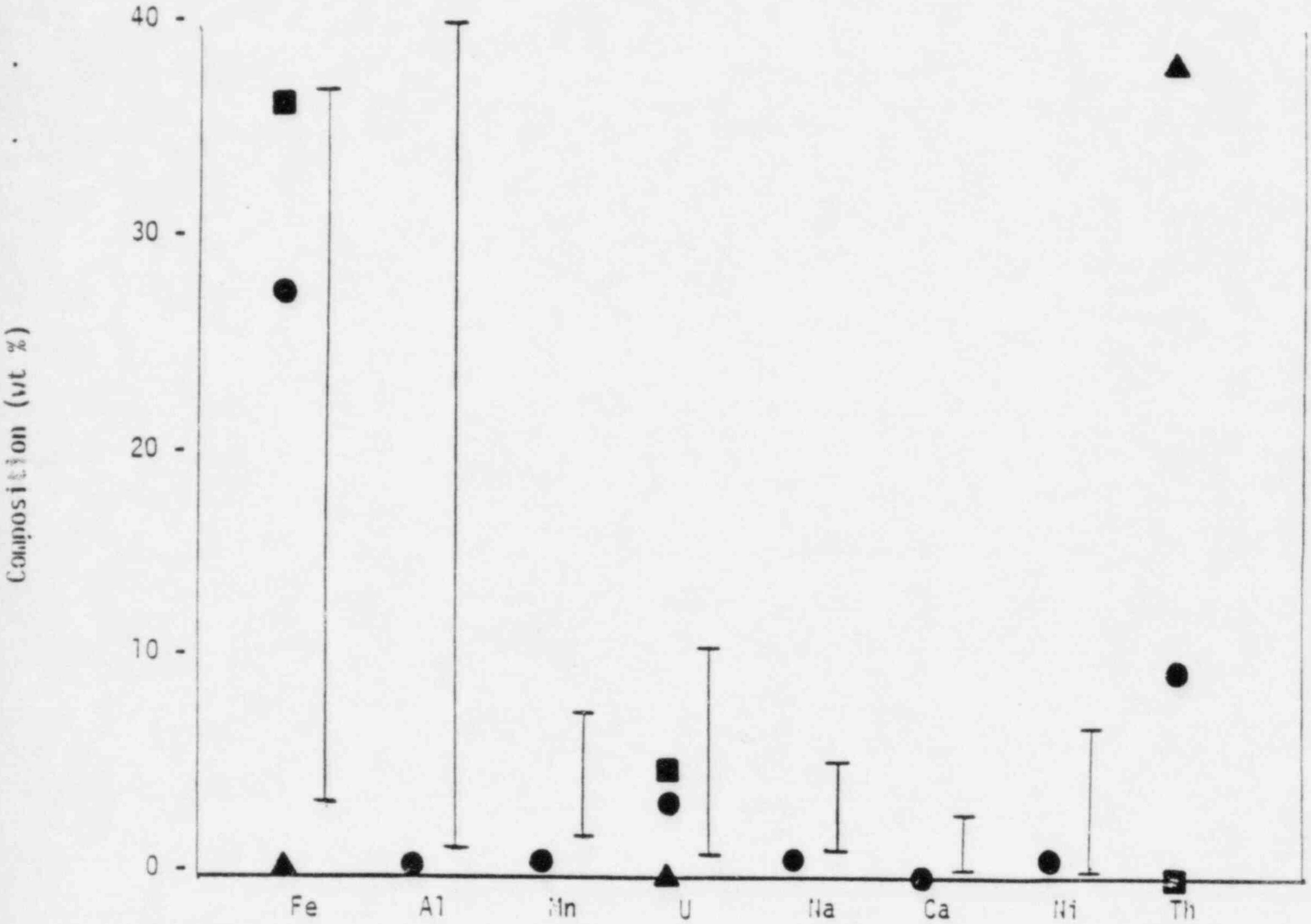


Figure 2. Comparison of WVDP and SRP Wastes. (■ WVDP alkaline, ▲ WVDP acidic, ● WVDP 75% alkaline 25% acidic Blend, ⊢⊣ SRP range. For clarity, when WVDP symbols overlap, only the blend, ●, is shown.)

Fe - Iron
Al - Aluminum
Mn - Manganese
U - Uranium
Na - Sodium
Ca - Calcium
Ni - Nickel
Th - Thorium

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DESCRIPTION:

enclosed for your information is a copy of a report discussing the basis for selection of borosilicate glass

07/11/83 INITIAL CCe