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DESCRIPTION OF DWPF REFERENCE WASTE FORM AND CANISTER

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Long-Term Design Liaison:
Waste Management Programs

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ABSTRACT

This document describes the reference waste form and canister for the Defense Waste Processing Facility (DWPF). The facility is planned for location at the Savannah River Plant in Aiken, SC, and is scheduled for construction authorization during FY-1983.

The reference canister is fabricated of 24 in.-OD 304L stainless steel pipe with a dished bottom, domed head, and lifting and welding flanges on the head neck. The overall canister length is 9 ft 10 in., with a wall thickness of 3/8-in. (schedule 20 pipe). The canister length was selected to reduce equipment cell height in the DWPF to a practical size. The canister diameter was selected to ensure that a filled canister with its shipping cask could be accommodated on a legal-weight truck. The overall dimensions and weight appear to be generally compatible with preliminary assessments of repository requirements.

The reference waste form is borosilicate glass containing approximately 28 wt % sludge oxides with the balance glass frit. Borosilicate glass was chosen because of its high resistance to leaching by water, its relatively high solubility for nuclides found in the sludge, and its reasonably low melting temperature. The glass frit contains approximately 58% SiO_2 and 15% B_2O_3. This composition results in a low average leachability in the waste form of approximately 5×10^{-9} g/cm^2-day based on ^{137}Cs over 365 days in 25°C water. The canister is filled with 3,260 lb of glass which occupies about 85% of the free canister volume. The filled canister will generate approximately 425 watts when filled with oxides from 5-year-old sludge and 15-year-old supernate from the Stage 1 and Stage 2 processes. The radionuclide content of the canister is about 150,000 curies, with a radiation level of 2×10^4 rem/hour at 1 cm.

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DESCRIPTION OF DWPF REFERENCE WASTE FORM AND CANISTER

INTRODUCTION

This document describes the reference glass waste form and the canister planned for the Defense Waste Processing Facility (DWPF). The borosilicate glass waste form and steel canister are the basis for the design and March 1981 budget quality cost estimate for the facility. Waste forms other than borosilicate glass are being studied at SRL and at other sites, however, the glass and canister described in this report is the reference form until a final waste form decision is made by October 1983. At that time, borosilicate glass will be compared to the other alternatives and a selection will be made of the form to be produced in the DWPF. In the meantime, the information outlined in this report is suitable for transportation and repository design purposes.

HLW FORM CHARACTERISTICS

The reference waste form for the DWPF is a borosilicate glass containing approximately 28 wt % sludge with the balance being glass frit. Borosilicate glass was chosen as a waste form because of its resistance to leaching by water, its relatively high solubility for nuclides found in the sludge, its relatively low melting temperature, and because the process is based upon well-developed technology.

Description of the waste glass characteristics is divided into three sections: composition, mechanical properties, and leachability. Glass composition is further divided by Stage 1 and Stage 2. Stage 1 is based upon processing just the 5-year-old or older waste sludge. Stage 2 is based upon processing the 5-year-old or older sludge plus a 15-year-old or older supernate fraction containing virtually all of the Cs-137 fraction. Mechanical properties of the waste glass are based upon the current frit candidate, designated as Frit 131.

Data on leachability are based upon an earlier frit composition designated as Frit 21. Current leachability tests in progress are based upon Frit 131 but incorporate testing procedures recommended by the Materials Characterization Committee. These testing procedures supersede those performed with Frit 21. Final results of the tests will be issued as they become available, but results to date indicate that properties of frit 21 and frit 131 glasses are comparable.

COMPOSITION OF DWPF WASTE GLASS

Feed to the DWPF is divided into two stages. Settled, washed sludge is the Stage 1 feed for the DWPF. The feed for Stage 1 is comprised only of waste tank sludges containing nearly all of the stable and radioactive fission products, actinide elements, and elements added in the separations processes (primarily Fe, Mn, Al, and Hg). The sludge is treated with sodium hydroxide to dissolve hydrated aluminum oxides, washed with water to remove soluble salts to 2 wt % on a dry basis, and then allowed to settle.

In Stage 2, the supernate is processed. The supernate contains the soluble salts, including the Cs-137 fraction. The salt fraction and concentrated supernate are the basis for the Stage 2 feed.

Stage 1

A description of the chemical composition of Stage 1 feed is in Table 1, and the isotopic content is shown in Table 2. The soluble solids are principally NaOH (32%), $NaNO_3$ (29%), $NaAlO_2$ (16%), and $NaNO_2$ (12%) which constitute about 88 wt % of the solids in this fraction. Of the insolubles, $Fe(OH)_3$ (38%), $Al(OH)_3$ (16%), and MnO_2 (6%) constitute approximately 60 wt % of the solids in this fraction. Activity of the Stage 1 feed is 187 Ci/gal with a decay heat of 0.58 watt/gal for 5-year aged waste. Of this activity, 76% is due to Sr-90, Y-90, and Pm-147.

Chemical composition of the current reference frit, designated as Frit 131, is shown in Table 3. The frit is approximately 58% SiO_2, 18% Na_2O, and 15% B_2O_3. The frit was developed after an extensive series of tests designed to produce a waste glass product with good leach resistance, high solubility for waste oxides, and a practical melting temperature.

Chemical composition of the Stage 1 glass waste form is described in Table 4, and the isotopic content is shown in Table 5. The total activity is 41 Ci/lb, with a decay heat of 0.127 watt/lb for 5-year old waste. Thus, the 3,260-lb canister with Stage 1 waste glass contains about 134,000 Ci with a decay heat of 416 watts. The isotopes of Sr-90, Y-90, and Pm-147 contribute about 76% to the waste-form activity.

Stage 2

A description of the chemical composition of Stage 2 feed is in Table 6, and the isotopic content is shown in Table 7. The soluble solids are principally $NaNO_3$ (45%), $NaNO_2$ (17%), and $NaAlO_2$ (10%) which constitute about 73 wt % of the solids in this fraction. Of the insolubles, $Al(OH)_3$ (33%) and $Fe(OH)_3$ (30%) represent approximately 63 wt % of the solids in this fraction. Activity of the Stage 2 feed is 4.4 Ci/gal with a decay heat of 0.01 watt/gal for 15-year-old supernate. Of this activity, 99% is due to Cs-137 and its beta decay daughter, Ba-137m.

The chemical composition of combined Stage 1 sludge and Stage 2 supernate waste glass is shown in Table 8, and the isotopic content is shown in Table 9. Total activity is 46 Ci/lb with a decay heat of 0.130 watt/lb for 5-year-old sludge and 15-year-old supernate. Thus, the 3,260-lb canister with both stages contains about 150,000 Ci with a decay heat of 423 watts. The isotopes of Y-90, Sr-90, Cs-137, Ba-137m, and Pm-147 contribute about 84% of the activity.

PHYSICAL PROPERTIES OF DWPF WASTE GLASS

Physical properties of DWPF waste glass have been measured and also estimated by calculation. Most of the properties determined by experiment are based upon Frit 21 rather than the current reference frit, Frit 131, but no significant differences are expected. The principal differences between the two is that Frit 131 is higher in wt % of SiO_2 and B_2O_3, but lower in TiO_2 than Frit 21. In addition, La_2O_3, MgO, and ZrO_2 were incorporated into Frit 131 to improve glass durability. A detailed comparison with several of the frits evaluated can be made from data in Table 10.

Physical properties of glass waste forms are listed in Table 11. Of these values, the fractional thermal expansion, the density at 100°C, and the softening point were experimentally determined for Frit 131 glasses. Other values are based on Frit 21 or other typical glass compositions.

Several physical properties of SRP waste glasses have not been determined experimentally, but can be estimated by calculation. Heat capacity, thermal conductivity, density, and refractive index for three types of DWPF waste glass (composite, high iron, and high aluminum) have been calculated on the basis of glass containing 25.4% sludge oxides and the balance glass Frit 131. Typical compositions for these three types of glass are shown in Table 12.

Heat Capacity

Heat capacities for DWPF waste glass are listed in Table 13. Cpm is the mean heat capacity referenced to 0°C; Cpt is the true heat capacity at the indicated temperature.

Densities

Densities for DWPF waste glass are listed in Table 14. The transition temperature, Tr ≅ 450°C, is approximate and differs somewhat for each type of glass.

Thermal Expansion

Waste glass thermal expansion as a function of temperature is shown in Figure 1 for composite glass, in Figure 2 for high-Fe glass, and in Figure 3 for high-Al glass.

Index of Refraction

Refractive indices for three types of waste glass are listed in Table 15. The data presented are for a wavelength of 4860 Å and at room temperature. Changes due to temperature are only about 1% over a range of 1000°C.

Thermal Conductivity

Thermal conductivity of a substance is a measure of the heat transferred through a substance by conduction. The effective thermal conductivity is described in Table 16. The change in values around 700°C is due to the increasing effect of radiant conductivity.

Electrical Resistivity

Electrical resistivity of the glass melt as a function of temperature is shown in Figure 4. At the operating melt temperature of 1150°C, the resistivity is approximately 2.5 ohm-cm.

LEACHABILITY STUDIES ON DWPF WASTE GLASS

Studies on glass leachability have been in progress at the Savannah River Laboratory for the past seven years as part of a program investigating the properties of glasses containing radioactive waste. The borosilicate glass formulations used contain approximately 28% sludge oxides and are melted with frit compositions of 52 to 58% SiO_2 and 10 to 15% B_2O_3. These glasses have an initial leach rate of 1×10^{-5} g/cm^2/d, which drops to about 5×10^{-8} g/cm^2/d after 100 days, then to 5×10^{-9} g/cm^2/d after 400 days. These nominal values are for temperatures of 25°C and 90°C in both distilled water and brine and are based upon Cs-137 leachability. See Figure 5 which summarizes the band of data for published leach rates of glasses studied at SRL.

Figure 6 describes leach rate data for high-iron, composite, and high-aluminum simulated waste using Frit 21 in brine at 25°C. The cumulative amount leached is based on Cs-137 and is expressed in g/cm^2. For the 67-day test period, the cumulative and average leachabilities are:

	Cumulative Amount, g/cm^2	Average Rate, g/cm^2/d
High Fe	10×10^{-6}	2×10^{-7}
Composite	6.5×10^{-6}	1×10^{-7}
High Al	5×10^{-6}	0.7×10^{-7}

Glass leach rates in 90°C brine decreased with time as did rates in 25°C brine; however, the leachability at 90°C was approximately five times higher than at 25°C.

Figures 7 and 8 describe leach rate data for actual sludges obtained from waste Tanks 13H and 16H, using Frit 21 glass and solutions at 25°C buffered to pH of 4, 7, and 9. The cumulative amount leached is based upon Sr-90. For the 200-day test period, the cumulative leachabilities based upon Tank 16H are:

Leachant	Cumulative Amount, g/cm^2	Average Rate, g/cm^2/d
Water	2×10^{-5}	1×10^{-7}
pH 4 Buffer	2×10^{-3}	1×10^{-5}
pH 7 Buffer	6×10^{-5}	3×10^{-7}
pH 9 Buffer	8×10^{-5}	4×10^{-7}

A listing of the principal metal ions found in Tanks 13 and 16 is shown in Table 17.

Leachability of SRP waste glasses has been studied using three types of tests. Most of the earlier work was done either with Soxhlet tests or those recommended by the International Standards Organization and the International Atomic Energy Agency. Recent work is based upon standardized leaching procedures developed by the Materials Characterization Center.

Glass Cracking

Since the total amount of material leached is dependent upon the surface area, glass fracture during cooling has been investigated at Battelle-Pacific Northwest Laboratories (PNL) and at SRL. Tests have shown that cracking can be reduced by the use of canister materials that match the glass coefficient of thermal expansion, by the use of canister liners, by slow cooling through the annealing range, and by annealing the solidified form. Based upon data from tests at PNL, the surface area increases by about a factor of 10 when comparing cooling rates of 1°C/hr by annealing with rates of 500°C/hr. Thus, if the total glass surface area of the DWPF waste form of 5 m^2 is increased by a factor of 10 due to convection cooling, and is combined with an initial leach rate of 5×10^{-6} g/cm^2/day, then initially about 2 g of glass would be leached per day. After a year, however, the leach rate drops by a factor of 1000, to only 0.002 g of glass per day.

Repository Temperature

The most radioactive waste planned for processing in the DWPF is aged 5 years, out of reactor. For Stage 1 plus Stage 2 processing, the heat generated per canister is 423 watts, or 0.677 watt/L of glass. Repository studies indicate that with this low power density the cavity temperatures will be below 100°C for a canister spacing of approximately 5 feet. Consequently, glass structural changes due to temperature changes are negligible, and the high temperature (300°C) hydrothermal reactions will not take place.

Radiation Stability

During long-term storage, the glass waste form will be continuously irradiated by beta-gamma emissions from fission products and by alpha emissions from transuranic nuclides. The estimated dose during the storage period of 1×10^6 years is calculated to be 14×10^{10} rads. Results of radiolysis studies indicate that this dose rate has an insignificant effect on the leachability and stored energy of the glass. Larger alpha particle doses increase waste glass leachability by less than a factor of two. SRL tests on waste glasses doped with ^{244}Cm and ^{238}Pu, to simulate an alpha dose in excess of one million years storage (4×10^{17} α/g), indicated only a doubling in leach rate. Similar results were obtained by PNL for dose rates of 10^{20} α/g.

After 2×10^{5} years of storage, approximately 56 L (STP) of helium will have been produced by radionuclide decay in 625 L of waste glass. Assuming helium diffuses through the glass into the 103-L freeboard above the surface, the gas pressure will increase by about 8 psi.

Measurements of thermal expansion indicate a growth of less than 1% due to alpha irradiation over a similar time period.

Groundwater pH

The effect of leachant pH on the rate of borosilicate glass dissolution was measured at SRL at room temperature and 90°C. The studies indicate an optimum pH of 6 to 8.5. Above pH 9 and below pH 5, glass corrosion increases. Most groundwaters from the proposed repositories of brine, basalt, tuff, shale, and granite fall between a pH of 5 to 9.

DWPF CANISTER

Lifting Fixture Dimensions

The lifting fixture is specific for the DWPF canister and is described in the attached drawing W712900, Revision 0, "2 Jaw Grappler Assembly." The fixture operates by using an air motor to drive two opposed jaws which fit under the lower of the two canister neck flanges. In the event of air motor failure, a mechanical connector driven by a crane impact wrench is provided as a backup. The upper canister flange is used to provide an electrical grounding surface for the upset resistance weld process. In the future, the neck design may be simplified by combining the lifting and grounding flanges, thereby shortening the neck.

Canister Dimensions

Canister dimensions and weight are shown on the attached drawing D179292, Revision 16, "Canister."

Principal dimensions and tolerances are:

Overall Length	9 ft 10.0 in. ±0.25 in.
Outside Diameter	24.00 in. $^{+0.35}_{-0.10}$ in.
Wall Thickness	0.375 in. nominal pipe tolerance
Bow	1/4 in. max.
Surface Finish	125 rms
Inside Volume	25.7 ft^3 nominal
Weight, empty	1000 lb ±5%
Weight, full	4260 lb ±5%
Material	304L stainless steel

Material of Construction

Type 304L stainless steel was chosen as the canister material for vitrified waste using the continuous melter process. This recommendation is based on long-term heating tests for up to 20,000 hours (2.3 yr) at temperatures that bracket those expected during interim storage. In these tests, the lifetime of canisters containing vitrified waste glass stored in air was predicted. The thickness of reaction layer observed between the canister alloy and the canister alloy-environment, similar to that expected during interim storage, was extrapolated to estimate the time required for penetration of the 3/8-in.-thick canister.

Data from tests up to 20,000 hours indicate that a 3/8-in.-thick canister of Type 304L stainless steel would not be penetrated for more than 8000 years in a surface facility. By contrast, a 3/8-in.-thick low carbon steel canister would be penetrated by oxidation in about 200 years of storage in a surface facility, and its strength would be reduced in a much shorter period.

Differences in canister lifetime, predicted from the data from these tests, are attributable to the differences in corrosion resistance of the candidate alloys. Both Type 304L stainless steel and low carbon steel react similarly with vitrified waste, but Type 304L stainless steel is much more resistant to atmospheric corrosion in a radiation field than is low carbon steel. The lifetime of canisters constructed from other compositions of austenitic stainless steels would be expected to be similar to Type 304L.

Stainless steel has the additional advantage of a relatively low spallation rate when used in the backup in-can melting process. Tests made at PNL indicate that an inert gas blanket would have to be used with a carbon steel canister to reduce the oxide scale formation to less than 22 lb per canister. Furthermore, the stainless steel surface is easier to decontaminate by blasting with a frit-water slurry than is carbon steel.

The 0.375-in. nominal wall thickness of a schedule 20, 24-in. stainless steel pipe is adequate for DWPF processing. A theoretical stress analysis was made on the reference canister just after filling with glass at the instantaneous pour rate of 3.8 lb/min. A maximum wall temperature of 427°C and a maximum bottom head temperature of 649°C was assumed. The calculations show that the wall thickness is sufficient to pick up the canister immediately after filling, despite the residual shell hoop stress of 32,500 psi caused by the lower coefficient thermal expansion of glass compared to stainless steel. Similarly, the thermal axial stresses were calculated to be 18,900 psi, and the simple static stresses due to weight were 477 psi shear and 177 psi axial. None of these stress levels indicates the need for a wall thickness greater than 3/8 in.

The canister should not be less than 24-in. diam, but could be larger. Cost analyses on the DWPF of various canister geometries are being developed to update an earlier study which indicated that a penalty of $225 million (expressed in 1984 dollars) would be incurred over the campaign life for processing SR waste, if the canister diameter were reduced from 24 to 18 in. The study included the cost impact on canisters, processing building, interim storage building, shipping facilities, and shipping casks. The updated studies of the effect of canister diameter on the DWPF facility are expected to be completed by June 1981, and the transportation section by July 1981. The companion studies for repository costs are being done by the Office of Waste Isolation and are scheduled for completion by December 1981.

Canister Weight

The canister is filled with approximately 165 gal of glass (22.1 ft^3) to a fill height of 7 ft 7 in. This volume corresponds to a weight of 3260 lb for the current frit and waste loading, and is about 86% of the available canister volume. The fill volume was chosen based upon operating experience at PNL where about a 15% void is made available in the event of: low density foam partially filling the canister; "roping" of the glass stream, causing voids in the frozen melt; and the possibility of spilling glass on the process room floor due to malfunction of load cells, failure of pouring equipment, operator error, etc. After DWPF operating experience is gained, it may be possible to fill the canister to a higher level. Maximum weight of the glass form when the canister is filled to 100% capacity is 3800 lb; estimated weight of the empty stainless steel canister shell is approximately 1000 lb.

Internal Pressurization Potential

Internal pressure within the canister is due to accumulation of helium from alpha emissions of transuranic nuclides. A DWPF canister filled with waste glass produces about 0.32 cm^3 of helium per year at 40°C. The helium produced is assumed to diffuse through the glass into the void space above the solid glass surface. At the end of 1000 years, the 3.64 ft^3 void space pressure has increased by only 0.05 psi. This negligible pressure buildup is of no concern in waste package design.

Seal Weld

The reference process for sealing the canister is to upset resistance weld a 5-in.-dia, 1/2-in.-thick, 304L stainless steel plug into the canister neck. A force of 75,000 lb, a current of 230,000 amps, and a voltage of approximately 11 volts is used to make the 2-sec weld. The technique was chosen after consideration of seven alternative processes including gas tungsten arc, gas metal arc, plasma arc, Thermit, electron beam, laser beam, and friction welding. Weld tensile strength measurements were made on the upset resistance weld under varying conditions of oxidation to determine the need for machining the throat surface after filling the canister with glass. An upset resistance weld with a 5-in.-dia plug and a machined canister neck was leak-tight to approximately 10^{-8} atm-cm^3/sec for a hydrostatic test pressure of 5,000 psig. If the canister neck is heated to 600°C, but not machined prior to welding, then the weld strength as measured by tensile and hydrostatic tests was reduced by about 20%. However, temperature measurements made on the canister neck during glass filling indicate that the maximum neck temperature does not exceed 300°C, so the canister seal weld is capable of withstanding at least 4,000 psi internal pressure while still maintaining a leak specification of 1×10^{-8} atm-cm^3/sec. Leak testing of the plug weld may be required before the canister is placed into a repository. To accomplish this, the plug would have a helium-filled capsule attached to the bottom face of the plug, projecting into the canister void space. The capsule will have a low melting alloy disc which when heated will release helium gas within the canister. The weld can then be checked with a standard helium leak detector.

In the event the canister is used in a repository with a flexible overpack and an open-ended sleeve, the canister could be subjected to relatively high lithostatic or hydrostatic pressures. Burial in a salt repository at 600 m is equivalent to a hydrostatic pressure of 850 psi, which would buckle the 3/8-in. canister dome above the glass melt surface. To prevent buckling, the dome head could have supporting ribs welded to the head interior. Modification to the canister head, if required, will be accomplished when repository criteria are determined.

Fissionable Material and Heat Flux

The radionuclide content and decay heat generation for glasses containing sludge and supernate are listed below. The ages were chosen to illustrate decay heat variation with waste age.

Stage	Waste Content	Watts per Canister	Curies
1	5-yr Sludge	416	1.34×10^5
2	5-yr Sludge Plus 15-yr Supernate	423	1.50×10^5
1	15-yr Sludge	224	$\sim 0.7 \times 10^5$
2	15-yr Sludge Plus 15-yr Supernate	256	$\sim 0.8 \times 10^5$

Radioactive decay heat as a function of waste age is shown in Table 18 for Stage 1 and Stage 1 plus 2 waste glass. In 50 years, the canister power has dropped to approximately 110 watts; by 1000 years, the power is only approximately 0.7 watt.

Surface temperatures of a bare glass form containing 5-yr-old waste with DWPF dimensions of 23-1/4 in. dia, 91 in. height, and power levels of 500 and 1000 watts are shown in Table 19. A typical temperature distribution for a 1000-watt canister and overpack, is shown in Figure 11.

Surface Radiation Dose and Gamma Spectrum

Surface radiation dose as a function of distance for a reference canister is shown in Table 20. The calculations are based upon the photon energy distribution for 5-year-old waste shown in Table 21. The radiation dose 1 cm from the surface is calculated to be 2.5×10^4 rems/hr.

Canister Surface Contamination

The criteria selected for canister surface contamination levels are identical to those specified for Department of Transportation shipping limits and are useful guides for canister decontamination by the frit-water slurry blasting technique. Canisters decontaminated to these levels are not expected to significantly contribute to air contamination within the Interim Storage Building. The canister surface contamination limits selected are:

Alpha	220 dis/min/100 cm^2
Beta-Gamma	2200 dis/min/100 cm^2

Labeling

Each canister will have a number stamped on the horizontal and vertical faces of the upper flange. The numbers will be approximately 1-in. high and will be visible by television viewing. Each number will identify the canister fabrication and processing history.

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TABLES

TABLE 1

Stage 1 Feed Composition*

Soluble Solids		Insoluble Solids			
Species	Wt %	Species	Wt %	Species	Wt %
$NaNO_3$	2.892E+1	$Fe(OH)_3$	3.797E+1	$PbSO_4$	1.760E-1
$NaNO_2$	1.171E+1	$Al(OH)_3$	1.571E+1	$Cr(OH)_3$	4.778E-1
$NaAlO_2$	1.608E+1	MnO_2	6.414	AgOH	2.515E-2
NaOH	3.159E+1	$UO_2(OH)_2$	4.237	$Cu(OH)_2$	1.383E-1
Na_2CO_3	4.885	$Ni(OH)_2$	2.427	$Co(OH)_3$	7.546E-2
Na_2SO_4	6.550	$CaCO_3$	4.992	$Zn(OH)_2$	3.646E-1
NaCl	1.980E-1	Zeolite	4.602	$Mg(OH)_2$	6.288E-1
NaF	1.284E-2	SiO_2	7.332	C	1.257E-1
Na[HgO(OH)]	3.967E-2	NaOH	4.086		
		$NaNO_3$	3.521	Group A**	3.416E-1
Group A**	8.259E-4	HgO	1.987	Group B†	1.123
Group B†	2.368E-4	$CaSO_4$	5.911E-1	PuO_2	4.557E-2
$Na_2PuO_2(OH)_4$	1.607E-6	CaC_2O_4	5.030E-1	$SrCO_3$	1.308E-1
$UO_2(OH)_2$	6.793E-6	$Ca_3(PO_4)_2$	4.652E-1	$Y_2(CO_3)_3$	8.626E-2
Na_2RuO_4	3.234E-3	CaF_2	1.257E-1	RuO_2	8.248E-2
Na_2RhO_4	3.314E-4	NaCl	1.257E-1	RhO_2	1.748E-2
$CsNO_3$	6.176E-3	NaI	1.257E-2	$CsNO_3$	1.316E-2
$BaNO_3$	4.941E-3	ThO_2	7.168E-1	$Ba(NO_3)_2$	5.532E-3
$Sr(NO_3)_2$	9.284E-6	$BaSO_4$	3.143E-1		
$Y(NO_3)_3$	6.588E-6				
NaI	1.864E-5				

* Dry Basis.
** Tc, Se, Te, Rb, Mo.
† Ag, Cd, Cr, Pd, Th, La, Ce, Pr, Pm, Nd, Sm, Tb, Sn, Sb, Co, Zr, Nb, Eu, Np, Am, Cm.

TABLE 2

Isotopic Content of Stage 1 Feed - Ci/gal (FS-1-1)

ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION
H 3	6.35077E-05	SN126	2.52141E-05	PR144	1.64622E+01	U235	8.82582E-08
CR 51	1.48331E-1[illegible]	SB124	1.19509E-10	PR144M	1.97543E-01	U236	1.91428E-06
CO 60	2.86177E-01	SB125	1.41250E+00	ND144	8.02685E-13	U238	4.86155E-07
SE 79	2.27291E-04	SB126	3.52997E-06	ND147	2.11823E-47	NP236	2.89601E-11
RB 87	1.50827E-03	SB126M	2.52141E-05	PM147	4.03393E+01	NP237	1.47265E-05
SR 89	8.48843E-03	TE125M	3.31008E-01	PM148	1.16056E-13	PU236	1.04512E-04
SR 90	5.08585E+01	TE127	1.44495E-04	PM148M	1.68276E-12	PU237	7.62708E-15
Y 90	5.08717E+01	TE127M	1.47519E-04	SM147	3.18789E-09	PU238	1.25546E+00
Y 91	1.56656E-06	TE129	3.65090E-15	SM148	9.38640E-15	PU239	1.18165E-02
ZR 93	3.03477E-03	TE129M	5.75014E-15	SM149	2.90951E-15	PU240	7.46734E-03
ZR 95	1.65653E-05	I129	1.33014E-05	SM151	3.93519E-01	PU241	1.40415E+00
NB 95	3.57166E-05	CS134	3.20104E-03	EU152	6.34768E-03	PU242	9.94960E-06
NB 95M	2.10378E-07	CS135	5.52726E-08	EU154	1.04271E+00	AM241	1.80717E-02
TC 99	4.11355E-03	CS136	9.44448E-45	EU155	8.25415E-01	AM242	2.38510E-05
RU103	1.90482E-11	CS137	2.95309E-02	EU156	8.80026E-35	AM242M	2.39706E-05
RU106	2.48778E+00	BA136M	3.02223E-45	TB160	1.86795E-09	AM243	9.63290E-06
RH103M	1.90669E-11	BA137M	2.79362E-02	TL206	7.58394E-21	CM242	5.85452E-05
RH106	2.48779E+00	BA140	3.50468E-43	TL207	1.12570E-10	CM243	9.27861E-06
PD107	1.52708E-05	LA140	7.22159E-40	TL208	1.75650E-06	CM244	2.72091E-04
AG110	2.11596E-02	CE141	5.99319E-14	TL209	7.15550E-15	CM245	1.11008E-08
CD115M	1.53228E-12	CE142	1.59243E-08	U232	8.55505E-06	CM246	8.86082E-10
SN121M	5.46784E-05	CE144	1.64616E+01	U233	1.01380E-09	CM247	1.08927E-15
SN123	4.43787E-04	PR143	1.99844E-37	U234	2.67192E-05	CM248	1.13750E-15

TOTAL ACTIVITY 1.87E+02 Ci/gal

DECAY HEAT

TOTAL PRIMARY 5.54E-01 watt/gal

TOTAL GAMMA 2.50E-02 watt/gal

TABLE 3

Chemical Composition of Glass Frit 131

Oxide	Wt %
SiO_2	57.9
Na_2O	17.7
B_2O_3	14.7
Li_2O	5.7
MgO	2.0
TiO_2	1.0
ZrO_2	0.5
La_2O_3	0.5

TABLE 4

Chemical Composition of Stage 1 Glass Waste Form

Compound	Wt %
SiO_2	45.5
Na_2O	15.0
B_2O_3	10.9
Fe_2O_3	6.57
Li_2O	4.23
Al_2O_3	3.62
Fe_3O_4	3.13
MnO	1.81
MgO	1.64
Zeolite	1.59
UO_2	1.30
CaO	1.16
TiO_2	0.743
NiO	0.677
B*	0.389
La_2O_3	0.371
ZrO_2	0.371
ThO_2	0.248
$Ca_3(PO_4)_2$	0.161
Cr_2O_3	0.122
A**	0.112
ZnO	0.103
BaO	.0696
PbO	.0448
Cu_2O	0.0351
SrO	.0318
RuO_2	.0257
Y_2O_3	0.0188
CoO	0.0178
PuO_2	0.0158
RhO_2	0.00544
Cs_2O	0.00316
Total	100.00

* B = Ag, Cd, Cr, Pd, Tl, La, Ce, Pr, Pm, Nd, Sm, Tb, Sn, Sb, Co, Zr, Nb, Eu, Np, Am, Cm.

** A = Tc, Se, Te, Rb, Mo.

TABLE 5

Isotopic Content of Stage 1 Glass Waste Form - Ci/lb (FS-2-1)

ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION
CR 51	3.25418E-20	SB124	2.62187E-11	ND144	1.76099E-13	U236	4.19969E-07
CO 60	6.27837E-02	SB125	3.09884E-01	ND147	4.64714E-48	U238	1.06656E-07
SE 79	4.73715E-05	SB126	7.74431E-07	PM147	8.84994E+00	NP236	6.35349E-12
RB 87	3.14351E-09	SB126M	5.53166E-06	PM148	2.54612E-14	NP237	3.23081E-06
SR 89	1.86225E-08	TE125M	6.89880E-02	PM148M	3.69177E-13	PU236	2.29285E-05
SR 90	1.11577E+01	TE127	3.01153E-05	SM147	6.99383E-10	PU237	1.67329E-15
Y 90	1.11606E+01	TE127M	3.07456E-05	SM148	2.05926E-15	PU238	2.75432E-01
Y 91	3.43683E-07	TE129	7.60915E-16	SM149	6.38310E-16	PU239	2.59239E-03
ZR 93	6.65792E-04	TE129M	1.19843E-15	SM151	8.63330E-02	PU240	1.63824E-03
ZR 95	3.63421E-06	CS134	7.01898E-04	EU152	1.39260E-03	PU241	3.08053E-01
NB 95	7.83578E-06	CS135	1.21197E-08	EU154	2.28757E-01	PU242	2.18282E-06
NB 95M	4.61544E-08	CS136	2.07091E-45	EU155	1.81086E-01	AM241	3.96470E-03
TC 99	8.57338E-04	CS137	6.47529E-03	EU156	1.93067E-35	AM242	5.23261E-06
RU103	4.17475E-12	BA136M	6.62690E-46	TB160	4.09806E-10	AM242M	5.25885E-06
RU106	5.45243E-01	BA137M	6.12562E-03	TL206	1.66382E-21	AM243	2.11334E-06
RH103M	4.17886E-12	BA140	7.68479E-44	TL207	2.46964E-11	CM242	1.28441E-05
RH106	5.45243E-01	LA140	1.58433E-40	TL208	3.85353E-07	CM243	2.03561E-06
PD107	3.35023E-06	CE141	1.31483E-14	TL209	1.56983E-15	CM244	5.96933E-05
AG110	4.64215E-03	CE142	3.49359E-09	U232	1.87687E-06	CM245	2.43538E-09
CD115M	3.36163E-13	CE144	3.61146E+00	U233	2.22416E-10	CM246	1.94395E-10
SN121M	1.19958E-05	PR143	4.38433E-38	U234	5.86186E-06	CM247	2.38971E-16
SN123	9.73614E-05	PR144	3.61159E+00	U235	1.93628E-08	CM248	2.49552E-16
SN126	5.53165E-06	PR144M	4.33383E-02				

TOTAL ACTIVITY	4.11E+01 Ci/lb
DECAY HEAT	
TOTAL PRIMARY	1.22E-01 watt/lb
TOTAL GAMMA	5.49E-03 watt/lb

TABLE 6

Chemical Composition of Stage 2 DWPF Feed

	lb/gal
Soluble Solids	- 3.11
Insoluble Solids	- 9.75E-5
Water	- 7.26

Soluble Solids, wt %		Insoluble Solids, wt %	
$NaNO_3$	44.89	$Al(OH)_3$	32.96
$NaNO_2$	17.29	$Fe(OH)_3$	30.20
$NaAlO_2$	10.33	SiO_2	5.83
NaOH	9.71	MnO_2	5.10
Na_2SO_4	9.70	$CaCO_3$	3.97
Na_2CO_3	7.24	Zeolite	3.66
NaCl	0.293	$UO_2(OH)_2$	3.37
NaF	0.0191	NaOH	3.25
Na(HgO(OH))	0.0584	$NaNO_3$	2.80*
$Na_2C_2O_4$	0.473	$Ni(OH)_2$	1.93
		HgO	1.58
		$CaSO_4$	0.47
		CaC_2O_4	0.40
		$Ca_3(PO_4)_2$	0.37
		$BaSO_4$	0.25
		$PbSO_4$	0.14
		CaF_2	0.10
		NaCl	0.10*
		C	0.10
		NaI	0.01
		Others	3.41

* Insoluble fraction of normally soluble salt.

TABLE 7

Isotopic Content of Stage 2 Feed - Ci/gal (FS-4-1)

ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION
H 3	3.33631E-04	SN123	8.33427E-16	ND144	5.06482E-16	U238	6.90427E-11
CO 60	1.08714E-05	SN126	1.57895E-08	PM147	1.79805E-03	NP236	4.11260E-15
SE 79	6.56641E-07	SB124	4.07284E-32	PM148	1.73319E-43	NP237	2.10099E-09
RB 87	2.94737E-12	SB125	6.98298E-05	PM148M	2.51306E-42	PU236	1.30500E-09
SR 89	1.18931E-32	SB126	2.21053E-09	SM147	2.57189E-12	PU237	8.67873E-43
SR 90	7.76508E-03	SB126M	1.57895E-08	SM148	5.87796E-18	PU238	1.64756E-04
Y 90	7.76710E-03	TE125M	7.55018E-05	SM149	1.82200E-18	PU239	1.67767E-06
Y 91	5.28285E-29	TE127	3.41502E-17	SM151	2.28719E-04	PU240	1.05937E-06
ZR 93	4.30989E-07	TE127M	3.48648E-17	EU152	5.28736E-07	PU241	1.24443E-04
ZR 95	3.84696E-26	TE129	1.26969E-50	EU154	6.61044E-05	PU242	1.41300E-09
NB 95	8.29446E-26	TE129M	1.99975E-50	EU155	2.76330E-05	AM241	5.05427E-06
NB 95M	4.88561E-28	I129	3.84318E-08	TB160	7.25143E-28	AM242	3.23628E-09
TC 99	2.19128E-04	CS134	1.06496E-02	TL206	7.32144E-22	AM242M	3.25249E-09
RU103	1.74148E-40	CS135	5.31933E-06	TL207	8.94281E-13	AM243	1.36676E-09
RU106	1.38868E-04	CS137	2.25744E+00	TL208	1.08530E-08	CM242	2.68427E-09
RH103M	1.74320E-40	BA137M	2.13553E+00	TL209	9.41467E-17	CM243	1.03323E-09
RH106	1.38868E-04	CE141	5.94908E-51	U232	1.60696E-09	CM244	2.63530E-08
PD107	4.41219E-08	CE142	9.97212E-12	U233	2.35222E-13	CM245	1.57522E-12
AG110	2.64971E-09	CE144	1.40323E-06	U234	8.65191E-09	CM246	1.25655E-13
CD115M	9.84371E-40	PR144	1.40329E-06	U235	1.25342E-11	CM247	1.54695E-19
SN121M	2.98055E-08	PR144M	1.68391E-08	U236	2.72175E-10	CM248	1.61544E-19

Total Activity	4.42E+00 Ci/gal
Decay Heat	
Total Primary	2.40E-03 watt/gal
Total Gammas	7.64E-03 watt/gal

TABLE 8

Chemical Composition of Stage 1/Stage 2 Glass Waste Form

Compound	Wt %	Compound	Wt %
SiO_2	46.3	Group B	.349
Na_2O	16.3	ThO_2	.223
B_2O_3	10.9	$Ca_3(PO_4)_2$	.144
Fe_2O_3	5.90	Cr_2O_3	.109
Li_2O	4.25	Group A	.102
Al_2O_3	3.25	ZnO	.0927
Fe_3O_4	2.81	Cs_2O	.0639
MgO	1.63	PbO	.0402
MnO	1.62	BaO	.0625
Zeolite	1.43	Cu_2O	.0315
UO_2	1.17	SrO	.0285
CaO	1.04	RuO_2	.0231
TiO_2	.746	Y_2O_3	.0169
NiO	.607	CoO	.0160
ZrO_2	.373	PuO_2	.0141
La_2O_3	.373	RhO_2	.00489

Group A: Tc, Se, Te, Rb, Mo

Group B: Ag, Cd, Cr, Pd, Tl, La, Ce, Pr, Pm, Nd, Sm, Tb, Sn, Sb, Co, Zr, Nb, Eu, Np, Am, Cm

TABLE 9

Isotopic Content of Stage 1/Stage 2 Glass Waste Form - Ci/lb (FS-2-1)

ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION	ISOTOPE	CONCENTRATION
CR 51	2.44035E-20	SB124	1.96618E-11	ND144	1.32303E-13	U236	3.15518E-07
CO 60	4.71054E-02	SB125	2.32420E-01	ND147	3.48495E-48	U238	8.01297E-08
SE 79	3.74627E-05	SB126	5.81820E-07	PM147	6.63756E+00	NP236	4.77329E-12
RB 87	2.48597E-09	SB126M	4.15587E-06	PM148	1.90937E-14	NP237	2.42729E-06
SR 89	1.39653E-08	TE125M	5.44657E-02	PM148M	2.76851E-13	PU236	1.71989E-05
SR 90	8.39393E+00	TE127	2.37724E-05	SM147	5.25715E-10	PU237	1.25482E-15
Y 90	8.39611E+00	TE127M	2.42699E-05	SM148	1.54710E-15	PU238	2.07114E-01
Y 91	2.57732E-07	TE129	6.00651E-16	SM149	4.79554E-16	PU239	1.94981E-03
ZR 93	5.00201E-04	TE129M	9.46020E-16	SM151	6.48524E-02	PU240	1.23217E-03
ZR 95	2.72535E-06	CS134	3.70538E-02	EU152	1.04545E-03	PU241	2.31439E-01
NB 95	5.87616E-06	CS135	1.82563E-05	EU154	1.71688E-01	PU242	1.64176E-06
NB 95M	3.46119E-08	CS136	1.55385E-45	EU155	1.35857E-01	AM241	2.98392E-03
TC 99	6.77970E-04	CS137	7.74874E+00	EU156	1.44783E-35	AM242	3.93088E-06
RU103	3.13374E-12	BA136M	4.97230E-46	TB160	3.07319E-10	AM242M	3.95059E-06
RU106	4.09283E-01	BA137M	7.33030E+00	TL206	1.32408E-21	AM243	1.58772E-06
RH103M	3.13683E-12	BA140	5.76606E-44	TL207	1.86134E-11	CM242	9.63765E-06
RH106	4.09283E-01	LA140	1.18811E-40	TL208	2.90113E-07	CM243	1.52872E-06
PD107	2.51698E-06	CE141	9.86009E-15	TL209	1.18706E-15	CM244	4.48207E-05
AG110	3.48121E-03	CE142	2.62469E-09	U232	1.41090E-06	CM245	1.82967E-09
CD115M	2.52093E-13	CE144	2.70829E+00	U233	1.67292E-10	CM246	1.46046E-10
SN121M	9.01014E-06	PR143	3.28787E-38	U234	4.41426E-06	CM247	1.79536E-16
SN123	7.30127E-05	PR144	2.70839E+00	U235	1.45470E-08	CM248	1.87485E-16
SN126	4.15586E-06	PR144M	3.25000E-02				

Total Activity	4.60E+01 Ci/lb
Decay Heat	
Total Primary	9.94E-02 watt/lb
Total Gamma	3.03E-02 watt/lb

TABLE 10

Chemical Compositions of Glass Frits*

Oxide	Frit Number				
	21**	22	211	411	131†
SiO_2	52.5	52.5	58.3	58.3	57.9
Na_2O	18.5	15.2	20.6	12.5	17.7
TiO_2	10.0	10.0	-	-	1.0
B_2O_3	10.0	10.0	11.1	11.1	14.7
Li_2O	4.0	7.3	4.4	12.5	5.7
MgO	-	-	-	-	2.0
ZrO_2	-	-	-	-	0.5
La_2O_3	-	-	-	-	0.5
CaO	5.0	5.0	5.6	5.6	-

* Percent composition by weight.

** Frit used in leachability tests for Figures 5 to 8.

† Current reference frit is Frit 131.

TABLE 11

Physical Properties of Glass Waste Forms

Property	Value
Thermal Conductivity at 100°C	0.55 Btu/(hr)(ft)(°F)
Heat Capacity at 100°C	0.22 cal/(g)(°C)
Fractional Thermal Expansion*	1.22×10^{-5}/°C
Young's Modulus**	9×10^{6} psi
Tensile Strength	9×10^{3} psi
Compressive Strength	1×10^{5} psi
Poisson's Ratio†	0.2
Density at 100°C*	2.75 g/cc
Softening Point*	502°C

* Experimentally determined for Frit 131 glasses.

** Young's modulus, or the modulus of elasticity, measures the stiffness of the material.

† Poisson's ratio is equivalent to the ratio of equatorial to axial strain under an applied axial stress.

TABLE 12

Composition of SRP Simulated Waste Glasses*

Component	Stage 1 Composite, TDS-3A		High-Fe		High-Al	
	Wt. Frac.	Mole Frac.	Wt. Frac.	Mole Frac.	Wt. Frac.	Mole Frac.
SiO_2	0.422	0.4670	0.418	0.466	0.423	0.4596
B_2O_3	0.104	0.0990	0.104	0.1001	0.104	0.0975
Na_2O	0.134	0.1440	0.143	0.1546	0.140	0.1474
Li_2O	0.040	0.0890	0.040	0.0897	0.040	0.0874
CaO	0.011	0.0130	0.012	0.0143	0.003	0.0035
MgO	0.014	0.023	0.014	0.0230	0.014	0.0227
TiO_2	0.007	0.0058	0.007	0.0059	0.007	0.0057
La_2O_3	0.004	0.0008	0.004	0.0008	0.004	0.0008
ZrO_2	0.004	0.0022	0.004	0.0022	0.004	0.0021
Fe_2O_3	0.142	0.0592	0.177	0.0743	0.041	0.0168
MnO_2	0.041	0.0314	0.012	0.0093	0.034	0.0255
Zeolite	0.031	0.0299	0.029	0.0290	0.031	0.0302
Al_2O_3	0.029	0.0192	0.004	0.0026	0.148	0.0948
NiO	0.017	0.0151	0.030	0.0269	0.006	0.0052
Na_2SO_4	0.002	0.00937	0.002	0.0009	0.002	0.0009

* Stage 1 Composite TDS-3A: Composition shown is the basis used for the calculation of physical properties. The composition is similar to the reference composition shown in Table 4, "Chemical Composition of Stage 1 Glass Waste Form."

High-Fe: Similar to Stage 1 Composite TDS-3A, except Fe_2O_3 is 17.7 wt % instead of 14.2 wt %.

High-Al: Similar to Stage 1 Composite TDS-3A, except Al_2O_3 is 14.8 wt % instead of 2.9 wt %.

TABLE 13

Heat Capacities for SRP Simulated Waste Glasses

	Stage 1 Composite, TDS-3A, Cal/(g)(°C)		High-Fe Cal/(g)(°C)		High-Al Cal/(g)(°C)	
Temp, °C	C_{pm}	C_{pt}	C_{pm}	C_{pt}	C_{pm}	C_{pt}
0	0.186	0.186	0.168	0.168	0.173	0.173
100	0.213	0.237	0.198	0.224	0.201	0.225
200	0.234	0.271	0.221	0.262	0.223	0.261
300	0.251	0.296	0.239	0.289	0.240	0.286
400	0.264	0.314	0.254	0.309	0.254	0.305
500	0.276	0.328	0.267	0.324	0.266	0.319
600	0.285	0.338	0.277	0.335	0.275	0.330
700	0.293	0.346	0.286	0.345	0.284	0.339
800	0.300	0.353	0.294	0.348	0.291	0.346
900	0.307	0.359	0.301	0.358	0.298	0.352
950	0.309	0.361	0.304	0.361	0.300	0.354
1000	0.312	0.363	0.307	0.363	0.303	0.356
1025	0.313	0.364	0.308	0.364	0.304	0.357
1050	0.315	0.365	0.309	0.365	0.306	0.358
1075	0.316	0.366	0.311	0.366	0.307	0.359
1100	0.317	0.367	0.312	0.367	0.308	0.360
1125	0.318	0.368	0.313	0.368	0.309	0.361
1150	0.319	0.369	0.314	0.369	0.310	0.362
1175	0.320	0.369	0.316	0.370	0.312	0.363
1200	0.321	0.370	0.317	0.371	0.313	0.364
1250	0.323	0.372	0.319	0.373	0.315	0.365
1300	0.325	0.373	0.321	0.374	0.317	0.366

Cpm: Mean heat capacity referenced to 0°C

Cpt: True heat capacity at the indicated temperature

TABLE 14

Densities of SRP Simulated Waste Glasses

Temp., °C	Stage 1 Composite TDS-3A, g/cm^3	High-Fe, g/cm^3	High-Al, g/cm^3
20	2.750	2.820	2.60
100	2.743	2.813	2.593
200	2.735	2.804	2.585
300	2.726	2.795	2.577
400	2.718	2.786	2.569
450, ≈ T_r*	2.713	2.781	2.565
500	2.672	2.721	2.520
600	2.575	2.607	2.432
700	2.481	2.499	2.348
800	2.391	2.396	2.266
900	2.305	2.298	2.188
1000	2.223	2.204	2.113
1025	2.202	2.181	2.094
1050	2.183	2.159	2.076
1075	2.163	2.137	2.058
1100	2.143	2.115	2.040
1125	2.124	2.093	2.023
1150	2.105	2.072	2.006
1175	2.086	2.051	1.988
1200	2.068	2.031	1.971

* The transition temperature, T_r, is different for each type of glass.

TABLE 15

Index of Refraction for SRP Simulated Waste Glasses*

Type of Waste	Index of Refraction at λ = 4860 Å
Stage 1 Composite TDS-3A	1.662
High-Fe	1.6971
High-Al	1.577

* At room temperature.

TABLE 16

Thermal Conductivity of SRP Simulated Waste Glasses*

Temp., °C	K_{eff} Stage 1 Composite Waste	High-Fe Waste	High-Al Waste
0	0.4893	0.4670	0.5389
100	0.5616	0.5479	0.5655
200	0.6339	0.6288	0.5921
300	0.7062	0.7097	0.6187
400	0.7785	0.7906	0.6453
500	0.8508	0.8715	0.6719
600	0.9231	0.9524	0.6985
670	0.9737	1.009	0.7171
685	1.0105	1.026	0.7211
700	1.044	1.060	0.7251
800	1.313	1.317	1.054
900	1.660	1.646	1.525
1000	2.085	2.045	2.12
1025	2.200	2.156	2.29
1050	2.33	2.270	2.47
1075	2.45	2.39	2.65
1100	2.58	2.51	2.84
1125	2.71	2.64	3.03
1150	2.85	2.77	3.22
1175	2.99	2.90	3.43
1200	3.14	3.03	3.64

* Btu/(hr)(ft)(°F)

TABLE 17

Principal Metal Ions in Washed, Dried Sludges from SRP Tanks 13H and 16H*

Ions	Wt %	
	Tank 13H	Tank 16H
Fe	25.57	13.91
Al	8.70	16.61
Mn	7.85	2.59
U	4.18	4.49
Na	2.58	2.19
Sr	3.50**	Not determined
Ca	1.76	2.87
Hg	2.32	2.80
Ni	0.45	0.30

* From J. A. Stone, see reference section.

** $Sr_3(PO_4)_2$ carrier added.

TABLE 18

DWPF Reference Canister Heat Generation

Years	Watts	
	Stage 1	Stage 1/Stage 2
5	416	423
10	257	292
15	224	256
20	199	228
25	177	203
30	159	181
35	142	162
40	128	145
50	103	117
75	62	69
100	39	42
200	10	8.7
300	4.5	3.5
400	2.6	2.0
500	1.8	1.3
750	0.99	0.75
1000	0.76	0.57

TABLE 19

Reference Glass Waste Form Surface Temperature*

Watts	°C
500	48
1000	57

* Reference DWPF waste form, 2 ft x 7 ft x 7 in., 165 gallons of waste glass containing 28% sludge oxides, and ambient air convection cooling.

TABLE 20

Radiation from Reference Canister of Stage 1/Stage 2 Glass*

Distance from Surface, cm	Rem/hr
1	2.48 E 04
10	1.82 E 04
30	1.06 E 04
90	3.31 E 03
180	1.18 E 03
200	9.98 E 02
210	9.07 E 02
500	1.85 E 02
1000	4.81 E 01
5000	1.97 E 00

* 5-yr-old sludge plus 15-yr-old supernate.

TABLE 21

Source Terms for Stage 1/Stage 2 Glass

Energy, keV	Phot./Sec/Canister*
70-100	5.158 E 12
100-150	3.604 E 13
150-300	2.163 E 12
300-450	9.149 E 12
450-700	8.344 E 14
700-1000	4.535 E 12
1000-1500	1.365 E 13
1500-2000	1.258 E 11
2000-2500	2.463 E 12
2500-3000	4.889 E 9

* Based upon a glass volume of 165 gallons.

FIGURES

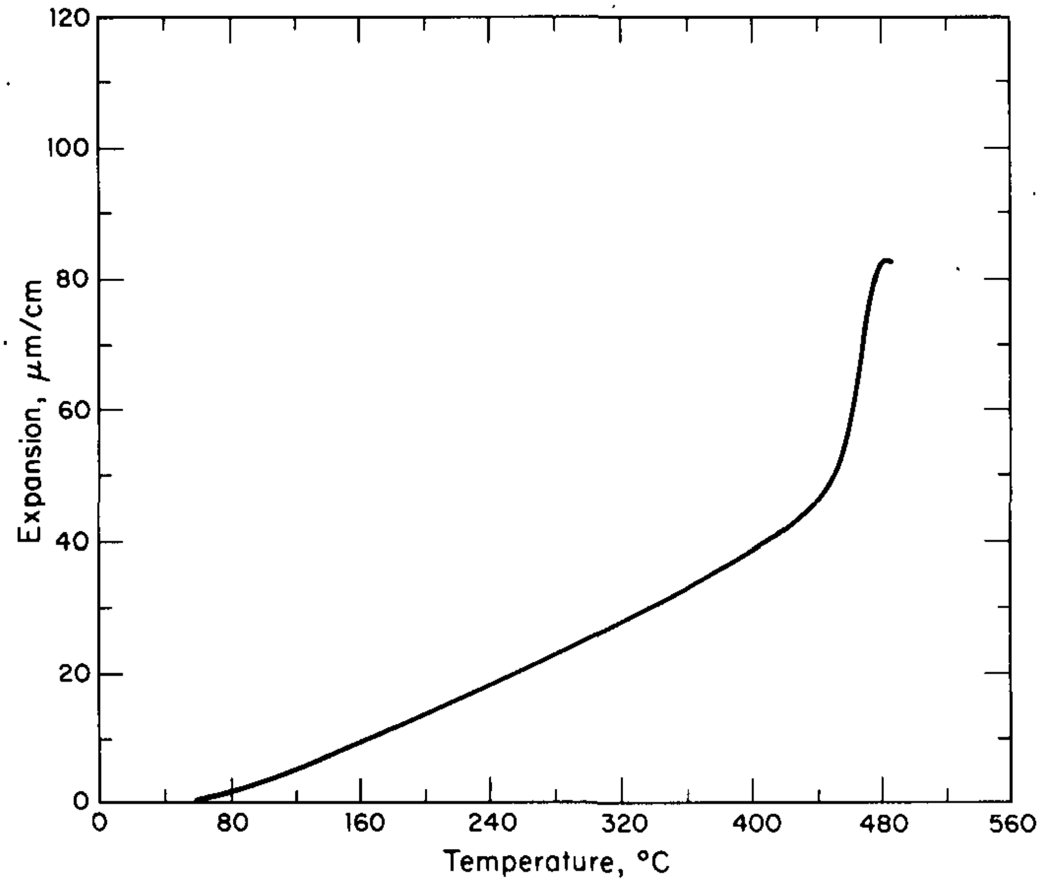


FIGURE 1. Thermal Expansion Data for 28 Percent Composite Sludge Plus Frit 131

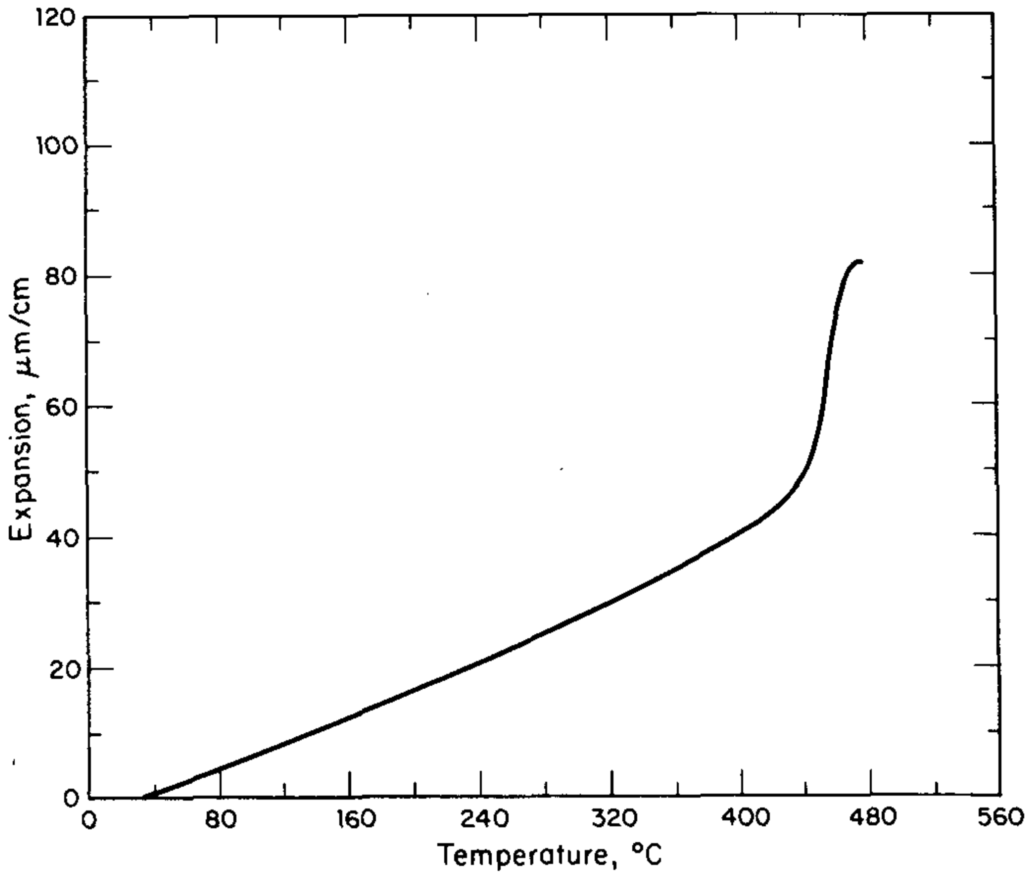


FIGURE 2. Thermal Expansion Data for 20 Percent High-Iron

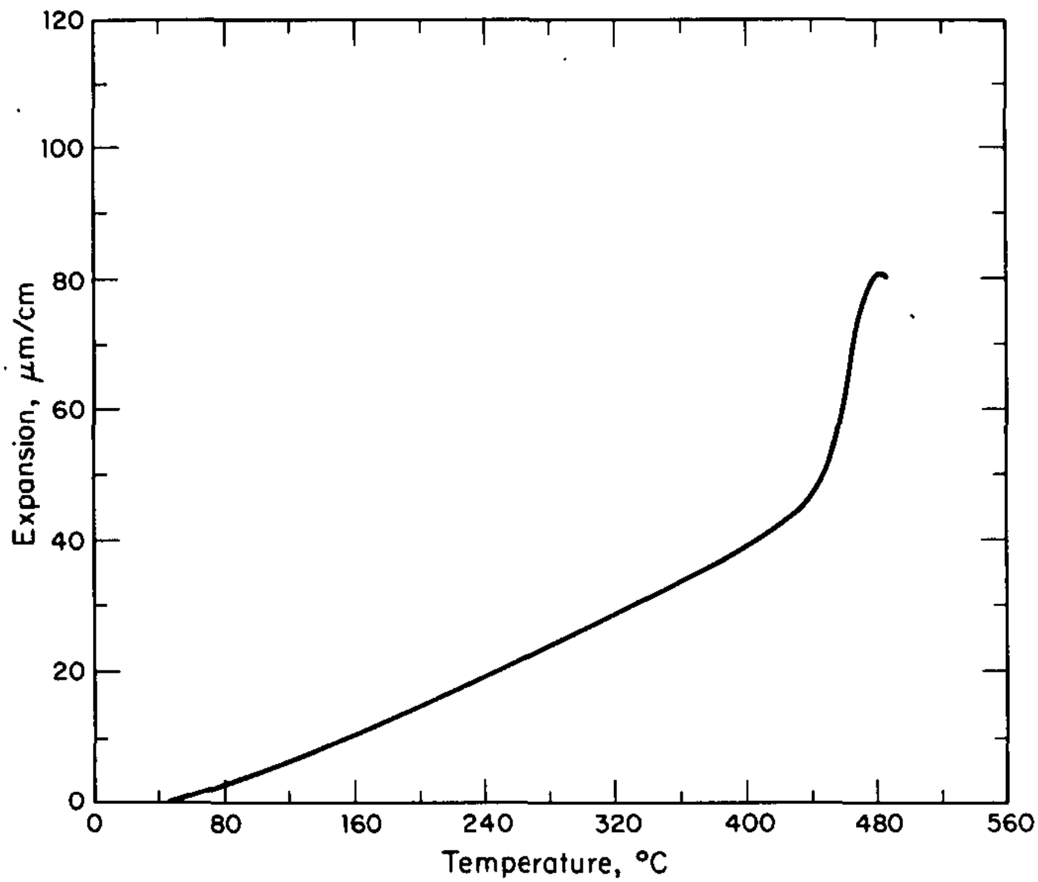


FIGURE 3. Thermal Expansion Data for 20 Percent High-Aluminum

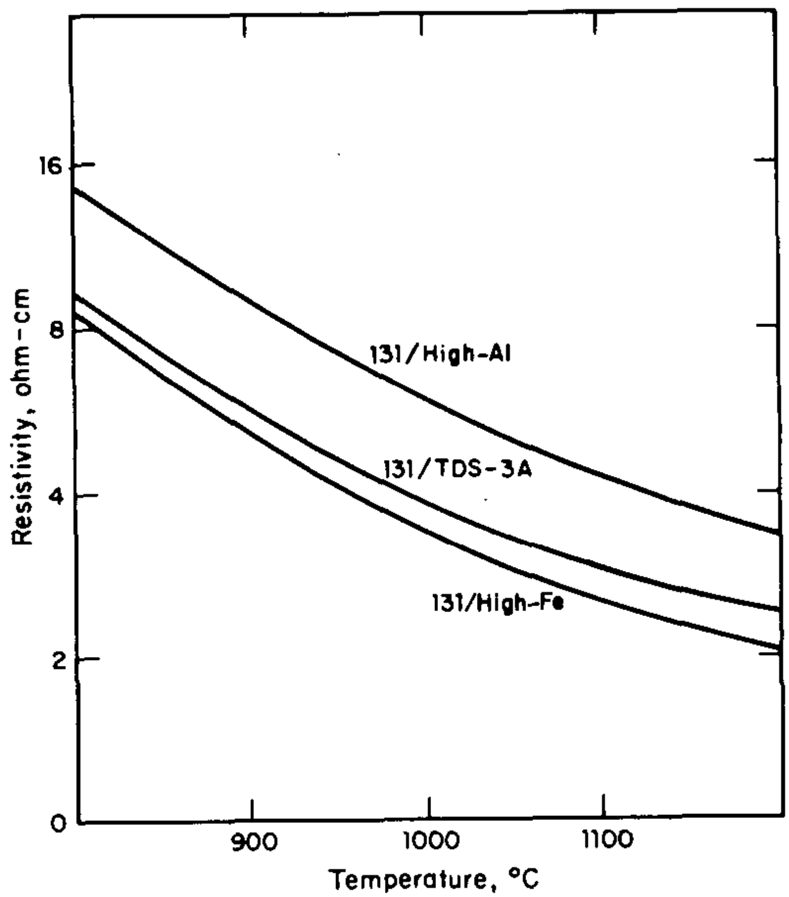


FIGURE 4. Resistivity of Frit 131/Waste Glasses

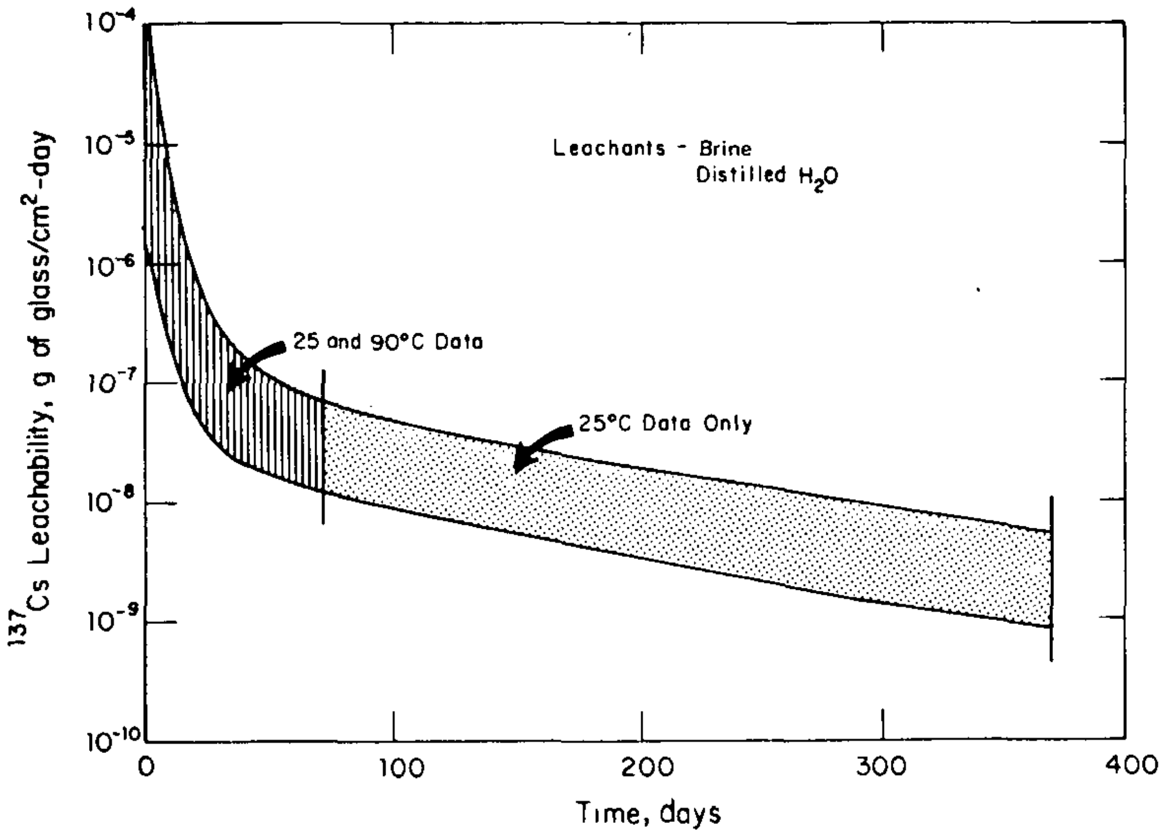


FIGURE 5. Published Leach Rates of SRP Glasses

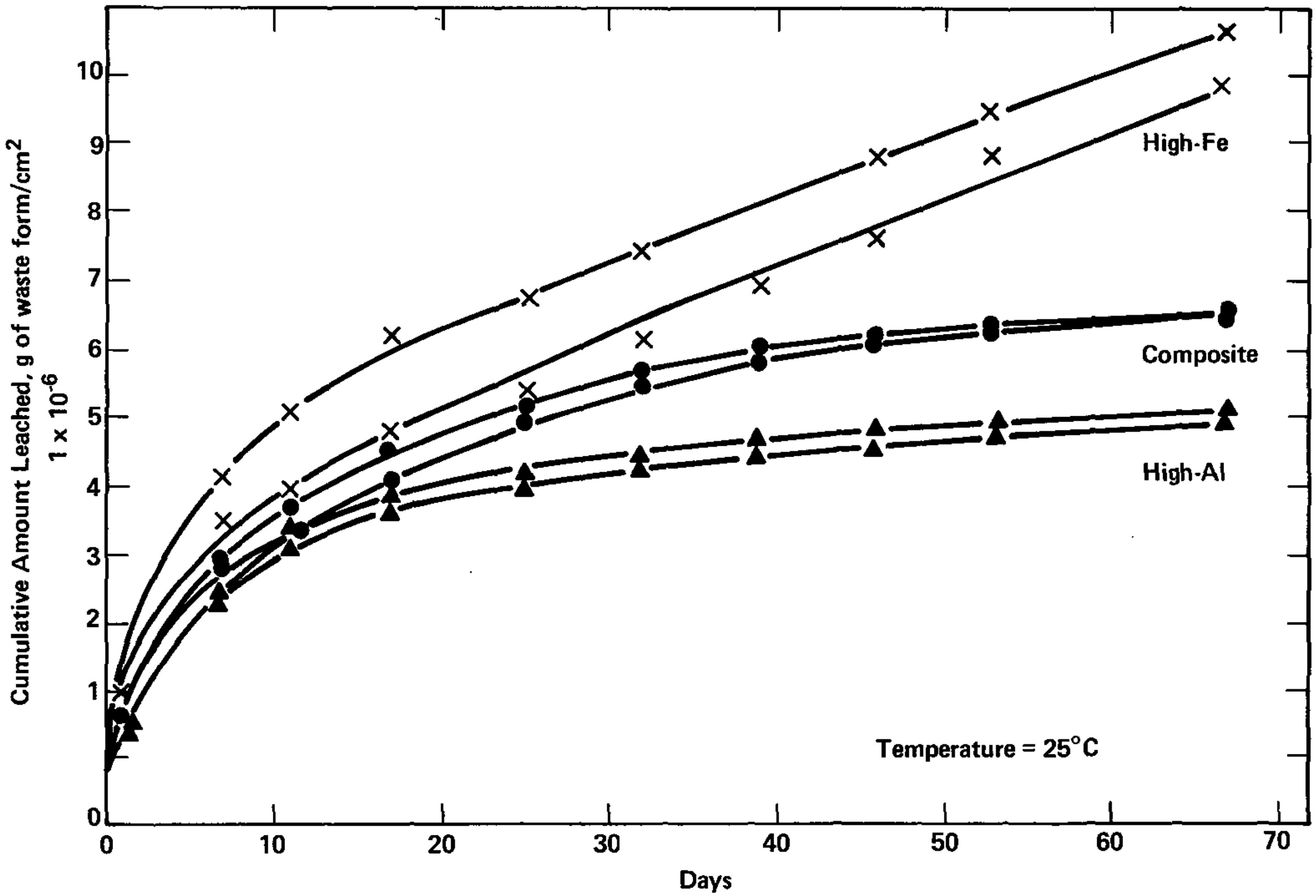


FIGURE 6. Cumulative Leaching of Frit 21-Simulated SRP Sludge Glass in Brine Based on ^{137}Cs

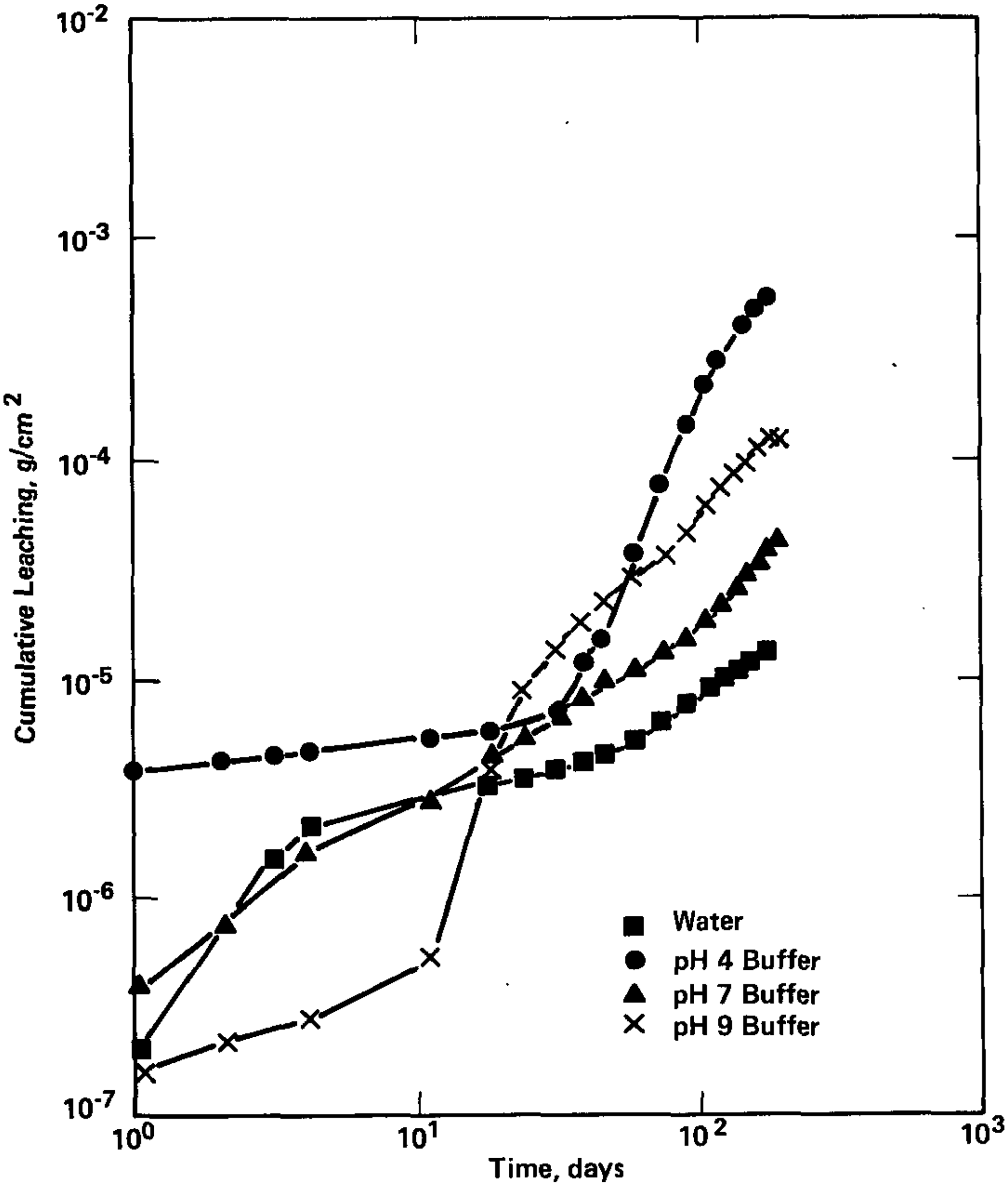


FIGURE 7. Cumulative Leaching of Frit 21-SRP Waste Tank No. 13 Glass Based on ^{90}Sr

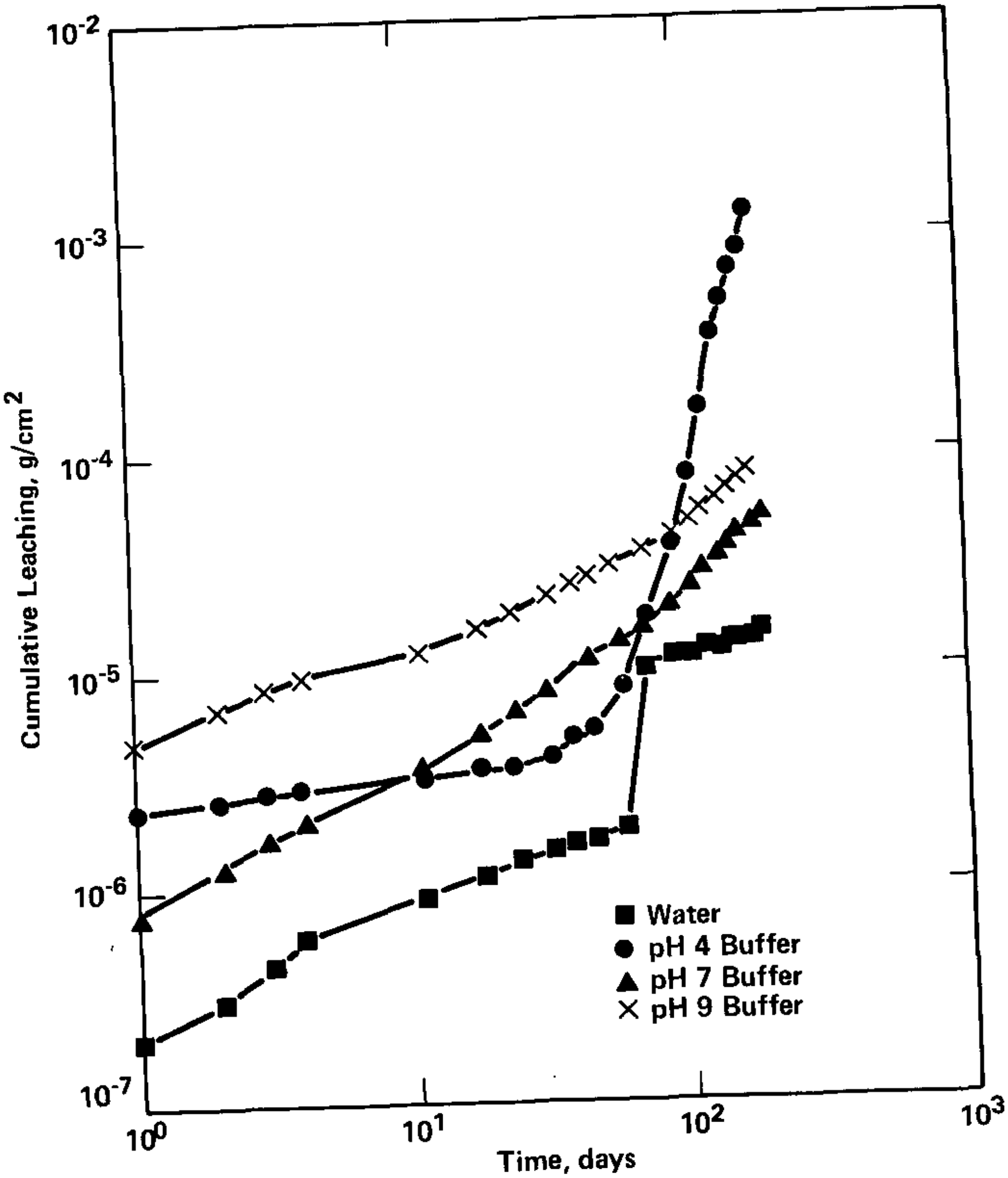


FIGURE 8. Cumulative Leaching of Frit 21-SRP Waste Tank No. 16 Glass Based on ^{90}Sr

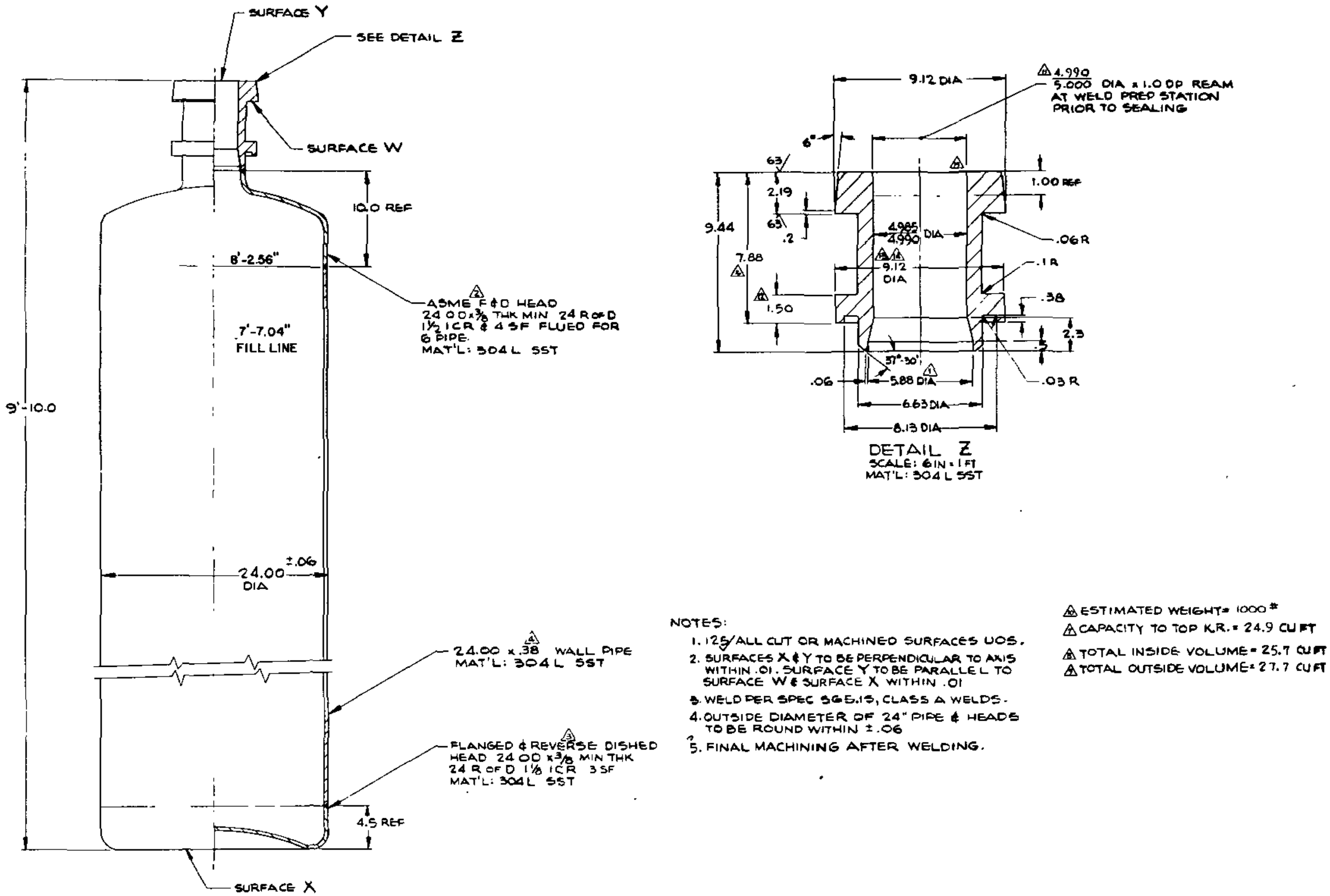


FIGURE 9. Canister Drawing

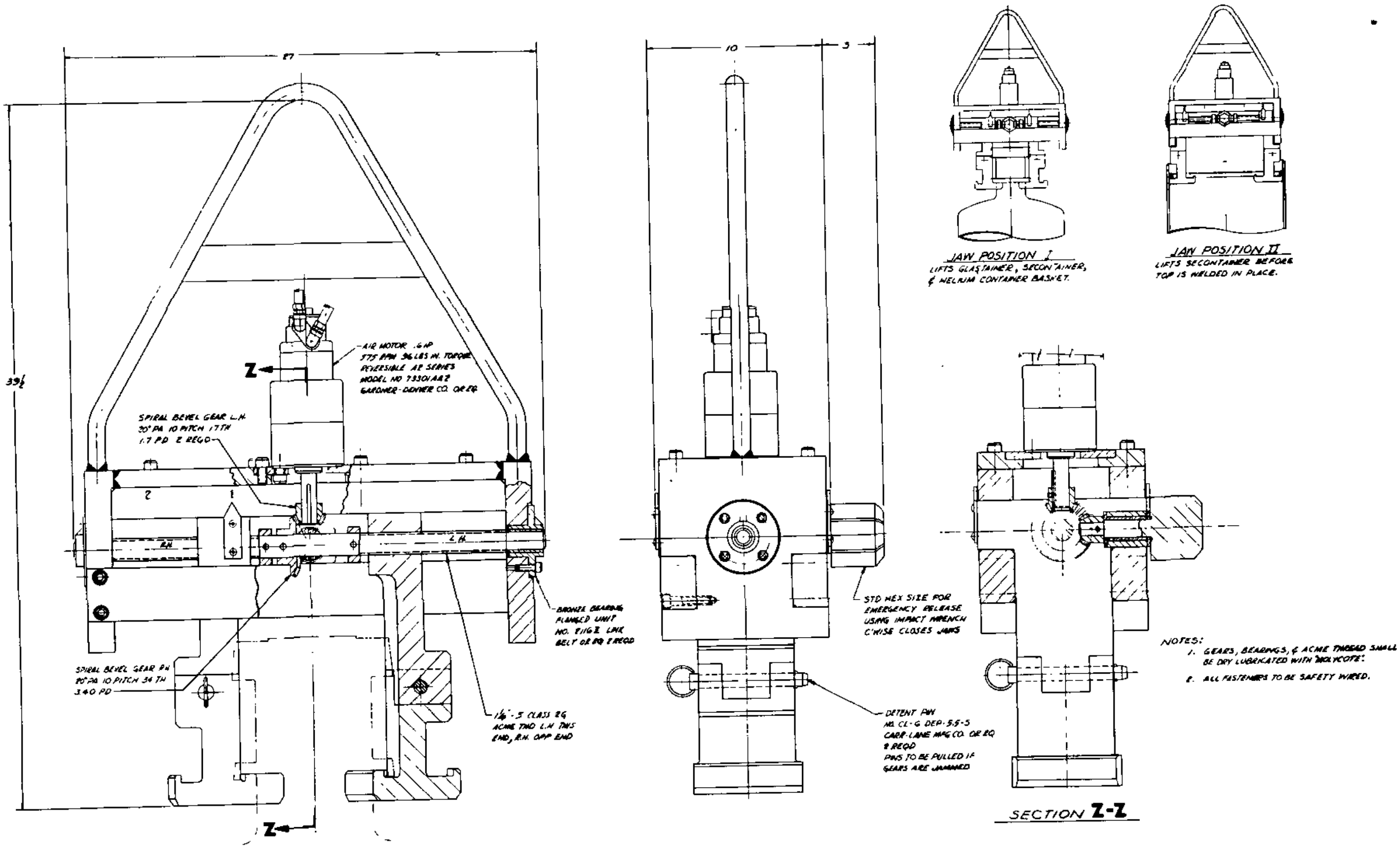
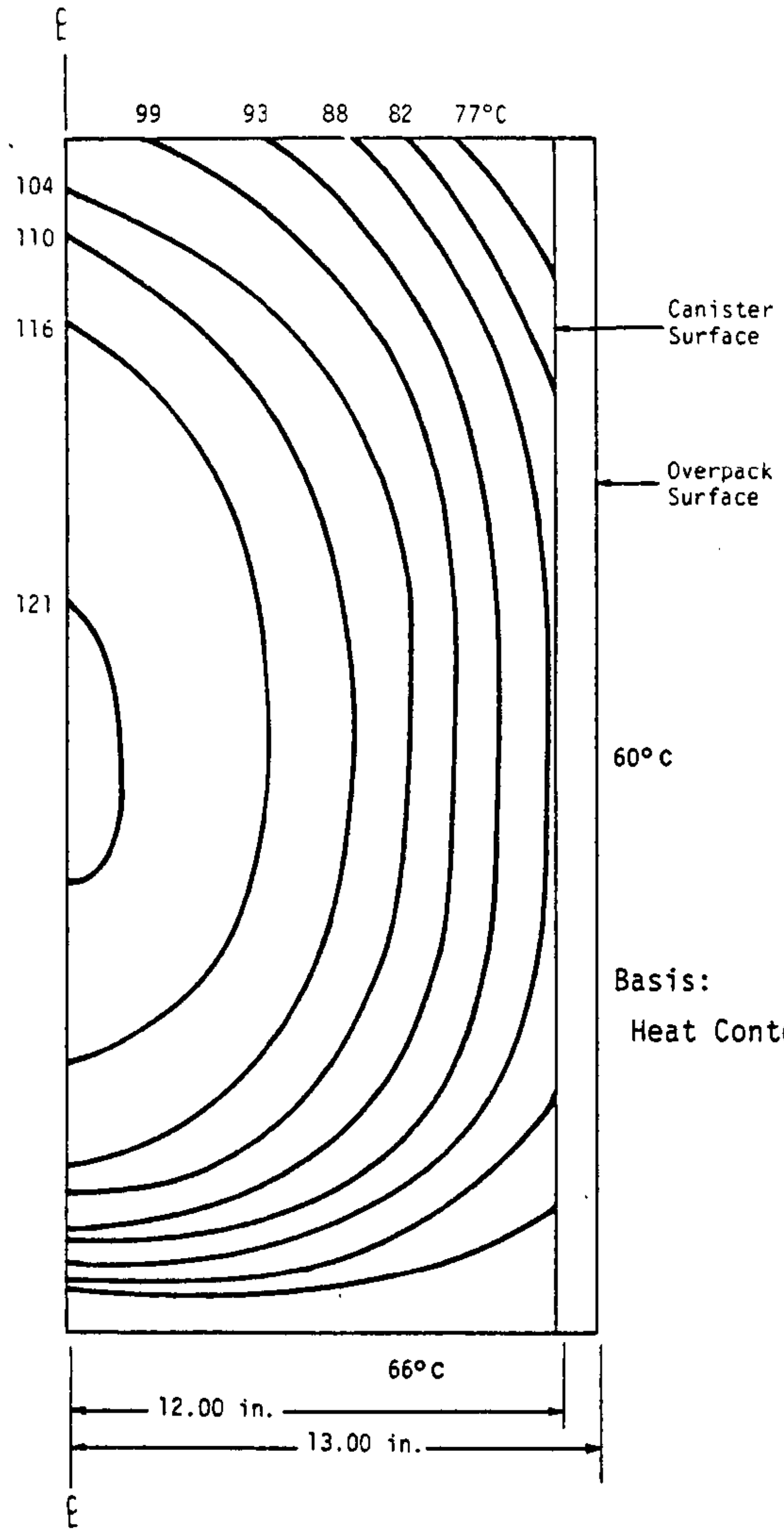


FIGURE 10. Two Jaw Grappler Assembly



Basis:
Heat Content - 1000 watts

FIGURE 11. Canister Isotherms at Steady State