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DISPOSAL OF SOLID WASTE FROM THE REPROCESSING OF NUCLEAR FUELS BY THE FLUIDIZED-BED FLUORIDE-VOLATILITY PROCESS: EVALUATION OF THE CANNING OF WASTE POWDERS

C. L. Fitzgerald
W. E. Shockley
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CHEMICAL TECHNOLOGY DIVISION

Chemical Development Section B

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DECEMBER 1969

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ABSTRACT

The development of methods for disposing of solid wastes that would be generated by the fluidized-bed volatility processing of power reactor fuels was directed, primarily, toward evaluating the problems associated with simply canning (i.e. sealing in a stainless steel pot) the untreated powders. Based on the results of the studies described in this report, canning appears to be a suitable method for disposing of these wastes. Much of this information will have application in the disposal of waste solids from the Burn-Leach method for reprocessing graphite-base fuels from high-temperature gas-cooled reactors (HTGR).

Simulated waste powders, like the waste powders that would be generated by the HF-O_2, HCl, and interhalogen variations in the fluoride-volatility process, were studied by means of gross weight loss and thermal gravimetric techniques. These studies indicated that storage problems could arise at temperatures above 500°C due to the presence of moisture and volatile fluoride compounds. However, it was found that the addition of alkaline earth oxides, such as CaO, could be used to stabilize the powders prior to disposal. Leaching of the powders containing ^{137}Cs tracer resulted in the removal of 80 to 90% of the cesium within one week. In tests with simulated waste powders sealed in nickel and stainless steel containers at 250, 550, and 850°C, the pressure in each container gradually decreased with time. A more pronounced decrease in pressure was observed in a similar test at 850°C in a ^{60}Co irradiation facility. The measured thermal conductivity of an Alcoa T-61 alumina powder was found to be essentially the same as that of a simulated waste powder. Both of these conductivities should be adequate for most proposed waste management systems. Packing characteristics, which have a major effect on thermal conductivity, were determined for each of the waste powders by means of particle-size measurements.

1. INTRODUCTION

The purpose of our laboratory studies concerning the disposal of solid waste that would be generated by the fluidized-bed volatility processing[1] of power reactor fuels was to obtain information that would serve as a basis for choosing the maximum acceptable centerline temperature in the storage pot, for selecting a material of construction for the pot, and for evaluating the relative safety of various waste disposal programs. Emphasis was centered on the problems that were associated with simply canning the untreated powders. Much of this information will have application in the disposal of waste solids from the Burn-Leach method[2,3] for reprocessing graphite-base fuels from high-temperature gas-cooled reactors (HTGR).

The maximum allowable centerline temperature in the storage pot would be determined by the stability of the fluorides of aluminum, stainless steel, and fission products, which were expected to be present in fluoride-volatility waste powders in appreciable quantities. Unfortunately only a small amount of detailed information is available on the stability of these fluorides at elevated temperatures or in a radiation field. Initial laboratory experiments with pure fluorides and simulated waste powders showed that the volatility of fluorides would become a problem at 500°C (i.e. approximately the temperature of the bed in the reactor) and higher. Thermochemical calculations indicated that the addition of alkaline earth oxides to the waste powders should convert these volatile fluorides to stable oxides plus the more stable alkaline earth fluorides. Results of laboratory experiments confirmed that the addition of CaO reduces the volatility of fluorides substantially. Stability as a function of temperature and time in a radiation field (^{60}Co source) was also studied.

For a given maximum centerline temperature, the size of a waste storage vessel is fixed, primarily, by the thermal conductivity of the material that is added to the vessel. Other material properties influencing the temperature rise in the vessel include density, heat capacity, and heat generation rate. The conductivities of

fluidized-bed powders, as determined by measurements, fall in a range that would be suitable for most proposed waste management programs.[4] However, higher conductivities would allow the use of a larger, more-economical vessel or would allow wastes with higher heat generation rates to be put into a particular vessel.

The waste powders could be incorporated in glass to ensure safety, with regard to leaching, during shipping and storage. Also, higher thermal conductivities, which would allow larger, more-economical pots to be used, could be attained by incorporating the powders in glass.[5,6]

2. CHEMICAL CHARACTERISTICS OF THE WASTE POWDERS

Waste powders from the fluoride-volatility process would consist, primarily, of aluminum oxide, aluminum fluoride, the fluorides of stainless steel or Zircaloy, and the fission-product fluorides which do not volatilize from the reactor during processing. Exposure of the powders to the atmosphere would result in absorption of moisture, the amount depending on factors such as the relative humidity of the atmosphere, the surface area of the powder, and the period of exposure.

The stability of the powders at elevated temperatures would be of primary concern if simple canning of the powders were used as a disposal method. Table 1 lists values for some thermal properties of several of the waste components; this information indicates that the vapor pressures of AlF_3, RbF, ZrF_4, and CsF could become troublesome at temperatures above 500°C. The presence of moisture would cause difficulties at even lower temperatures since it promotes the formation of various hydrates that can decompose at temperatures as low as 120°C. Thermochemical calculations indicate that the hydrolysis of some fluorides is possible at temperatures of about 250°C.

2.1 Weight Loss Studies

Studies of the weight losses of simulated waste powders (see Table 2 for composition) as a function of temperature and time were made in order to establish

Table 1. Thermal Properties of Selected Fluorides[a]

Fluoride	Melting Temp. (°C)	Boiling Temp. (°C)	Vapor Pressure (mm Hg) 0.0001	0.001	0.01	0.1	1	10	100
					Temperature, °C				
AlF	(827)[b]	(1402)[b]							
AlF_3	1291 Subl. 760						965	1051	1149
BaF_2	1280	2137	971	1068	1181				
CaF_2	1360	ca. 2500	1123	1223	1338				
CeF_3	1324	(2300)[b]		1076	1175	1289			
CeF_4	1460	Decomp. 1700							
CrF_2	1100	>1300	902	980	1069				
CrF_3	>1000	Subl. 1000							
CrF_4	277	297							
CrF_5	102	117							
CsF	684	1251					712	844	1025
FeF_2	1102	(1800)[b]			833	916			
FeF_3	(1000)[b]	(1100)[b]					988	1113	1265
LaF_3	(1400)[b]	(2300)[b]	1066	1161	1271				
MgF_2	1266	2239	979	1066	1166				
MoF_6	17	25					-65.5	-40.8	-22.1
NdF_3	1410	2300		1074	1178	1300			
NiF_2	(1000)[b]	(1600)[b]		780	850				
PrF_3	1370								
RbF	775	1410					921	1016	1168
RuF_5	101	250					110	145	221
SnF_2	>600	>1200					452	555	690
SnF_4		Subl. 704							
SrF_2	1450+	2489	1118	1214	1322				
ZrF_4	918	Subl. 903					637	716	810

[a]Thermal properties from listed references:

A. Glasser, Thermochemical Properties of Oxides, Fluorides, and Chlorides to 2500°K, ANL-5750 (1957).

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S. M. Stroller and R. B. Richards, Reactor Handbook, Vol. II, Interscience Publishers, N. Y., 1961.

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Mahn Jick Lim, Vapor Pressure and Heat of Sublimation of Cerium(III) Fluoride (Thesis), UCRL-16150 (May 20, 1965).

[b]Parentheses indicate estimated values.

Table 2. Composition of Simulated Waste Powders Selected for Study

Powder[a]	Al (%)	F (%)	Sn (%)	U (%)	Zr (%)	Fe (%)	Cr (%)	Ni (%)
ANL-7	53	0.72	<0.01	0.022	0.051	b	b	b
ANL-13	52.8	2.23	0.02	0.015	0.12	b	b	b
FBVE-11	49	7.48	b	0.22	b	1.96	0.30	0.29
BRF5-5[c]	41.7	17.8	0.04	0.20	0.30	0.20	b	0.40
BRF5-8[c]	48.1	9.33	0.02	0.133	0.2	b	b	b

[a]Alcoa T-61 was used as the bed material for ANL-7, ANL-13, BRF5-5, and BRF5-8; Norton RR was used for FBVE-11. ANL-7 and ANL-13 were made at Argonne National Laboratory in pilot plant-scale equipment. BRF5-5 and BRF5-8 were made at Argonne National Laboratory and Oak Ridge Gaseous Diffusion Plant in pilot plant-scale equipment. FBVE-11 was made at Oak Ridge National Laboratory in engineering-scale equipment.

[b]Not determined.

[c]Contains fission products (stable isotopes) that would be expected to be present in a bed which is used to process five batches of fuel irradiated to a burnup of to 21,000 Mwd/metric ton.

a basis for predicting the behavior of fluoride-volatility waste powders under storage conditions. The waste powders selected for study represent the HCl (ANL-7 and -13), the HF-O_2 (FBVE-11), and the interhalogen (BRF5-5 and -8) flowsheets.[1] These different processing alternatives will not be described here, and are mentioned only to point out reasons for variations that are encountered in waste powders. All the powders were prepared under actual operating conditions in engineering- and pilot plant-scale equipment. The batches of waste powder ranged from 2 kg in engineering-scale equipment to 40 kg in pilot plant-scale equipment. The difference between the BRF5-5 and the BRF5-8 powders probably was, in large measure, a result of the difference in the particle size of the alumina that was added to the fluidized-bed reactor during processing. These two powders (i.e., BRF5-5 and -8) contained fission products (stable isotopes) which would be expected to be present in a bed used for processing five batches of fuel that had been irradiated to a burnup of 21,000 Mwd/metric ton. The stable isotopes were added to the alumina powder at the beginning of the process; i.e., they were carried through the oxidation and fluorination steps.

Two techniques were used in the weight loss studies: (1) gross weight loss, as determined by weighing a sample of the material before and after it was held at temperature for a given period of time, and (2) thermal gravimetric analysis (TGA), which provides a continuous record of weight loss as a function of time and temperature. The latter method can be used to identify the volatile species by differentiating the weight loss with respect to time, and plotting the results as a function of temperature. A series of peaks is obtained at the temperatures at which the various components are volatilized. These peaks are then compared with those of known compounds. The two techniques and the results obtained are discussed in more detail below.

2.1.1 Gross Weight Loss Measurements

The experimental arrangement used in these studies is shown in Fig. 1. The system consists of a 1-in.-diam x 2-ft-long alumina tube, a tube furnace, a

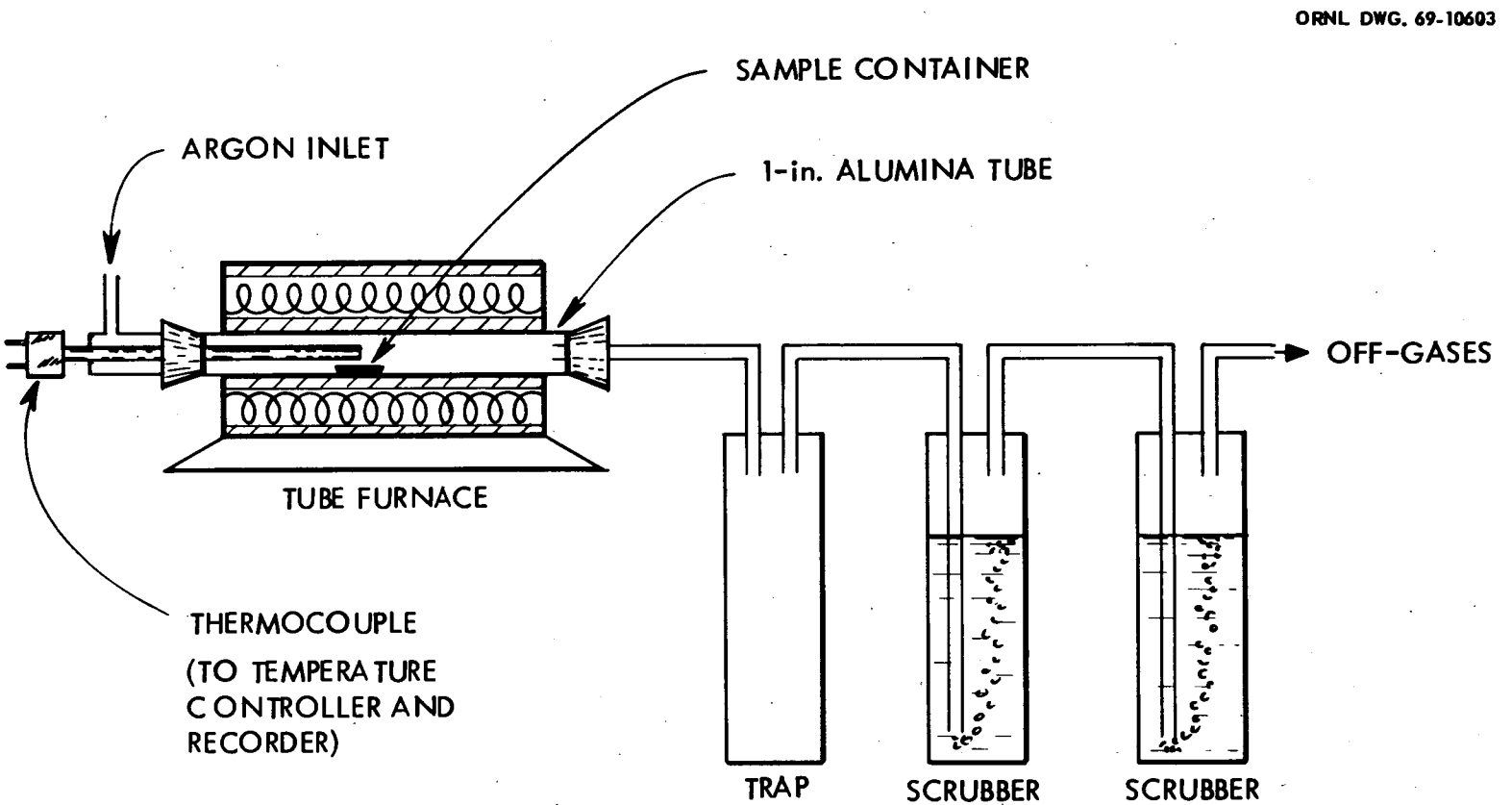

Fig. 1. Experimental Arrangement for Gross Weight Loss Studies of Waste Powders from Fluidized-Bed Processing.

temperature controller and recorder, a gas purge system, and a liquid off-gas scrubber system. Approximately 2 g of waste powder was weighed and placed in a platinum boat, which was, in turn, inserted in the alumina tube. An inert atmosphere was maintained by using dry argon, flowing at the rate of about 140 ml/min, under ambient conditions. The temperature of the furnace was increased to the desired level and held for the length of the test period. After being heated for the prescribed time and then cooled, the sample was reweighed to determine the loss in weight. The off-gas scrubber solutions were analyzed to determine which compounds had been volatilized.

Waste powder representing the HCl flowsheet (ANL-7) was tested for fluoride volatility by heating at 850°C for 18.5 hr. The weight loss of the untreated powder was 0.91%. The weight loss of the waste powder representing the HF-O_2 flowsheet (FBVE-11) under the same conditions was 5.78%; after 74 hr at 850°C, it was 5.99%. An untreated waste powder (BRF5-5) was tested for stability at 250, 550, and 850°C for 18.5 hr. The weight losses were 0.43, 2.14, and 7.35% respectively. The wide variation in the weight losses of these powders under the same conditions is explained partly by the chemical compositions of the powders. Those with higher fluoride contents (fluoride contents are in the order: BRF5-5 > FBVE-11 > ANL-7) should contain more volatile fluoride compounds; in addition, most of these fluorides, on exposure to moisture, should form stable hydrates that decompose at elevated temperatures.

2.1.2 Thermal Gravimetric Analysis (TGA) Measurements

To determine the stability of volatile waste fluorides, the weight losses of the simulated waste powders and of powders of the pure components comprising the waste were measured as a function of time and temperature. The TGA apparatus used for these experiments is shown in Fig. 2.

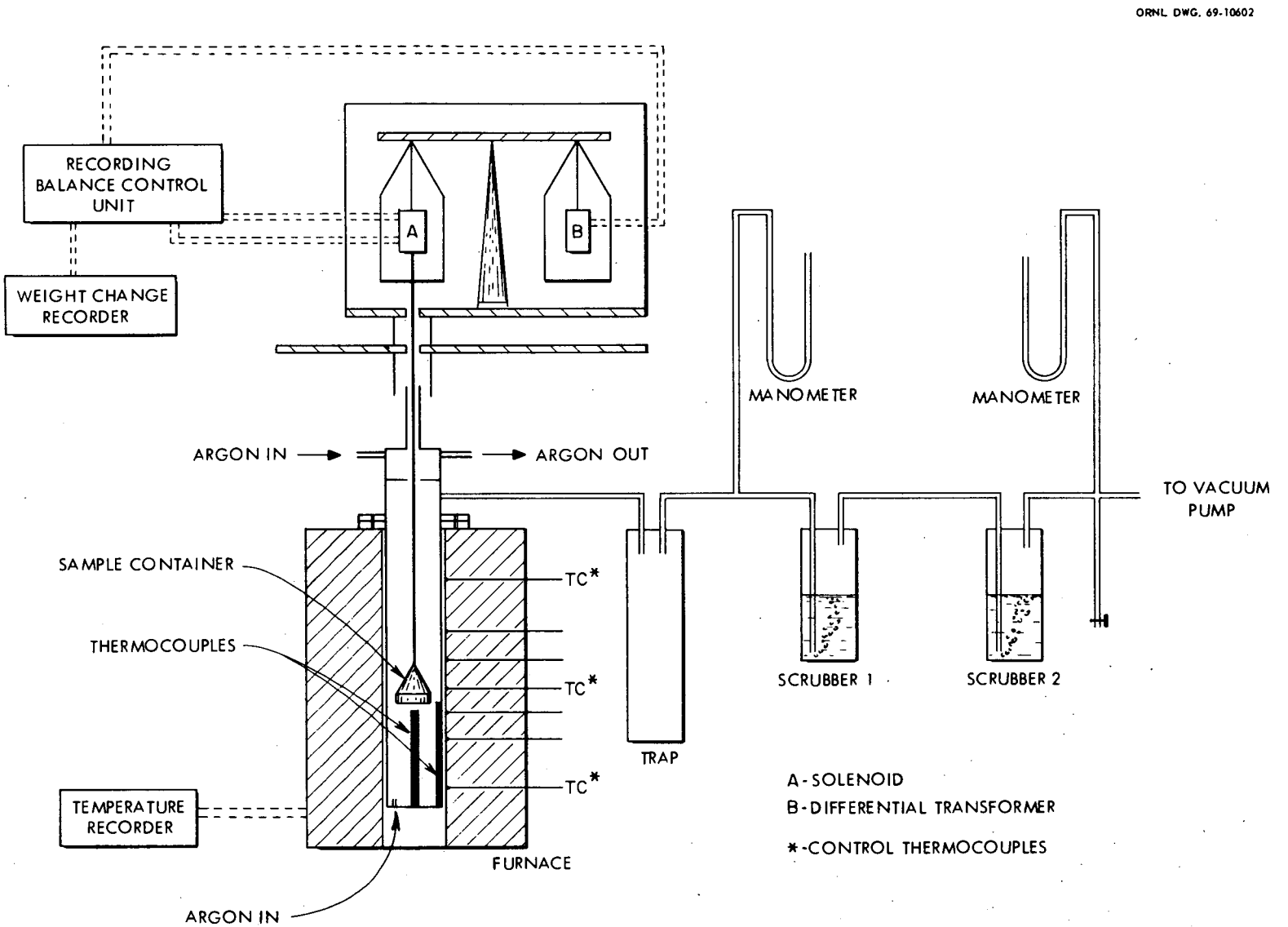

Fig. 2. Thermal Gravimetric Apparatus.

Weight losses obtained for the waste powder representing the HF-O_2 flowsheet (FBVE-11) were 2.99% and 3.20% (Fig. 3). Data obtained in the two experiments with the waste powder representing the HCl flowsheet (ANL-13) showed a weight loss averaging 0.99% (Fig. 3). In these experiments, each of the samples was heated at the rate of 4.7°C/min to 850°C and then held at this temperature until constant weight was attained. The inert-atmosphere gas, argon, was discharged through caustic scrubbers, the contents of which were subsequently analyzed. Results of analyses of the scrubber solutions from the ANL-13 experiment indicated that HF was the primary off-gas. Analyses of the scrubber solutions from the FBVE-11 experiments also indicated that hydrolysis of the fluorides occurred at the elevated temperatures, giving HF as the primary off-gas component. Plots of differential weight losses with time (Δ weight/Δ time) vs temperature for the experiments (Fig. 4) gave peaks at 125 and 650°C for ANL-13 and at 130, 470, and 660°C for FBVE-11. The peaks at 125-130°C correspond to the dehydration of $Al_2F_6 \cdot 7H_2O$. The difference in weight loss, 0.21%, between the two samples (i.e. ANL-13 and FBVE-11) can be explained by the difference in amount of the Al_2F_6 that is hydrated. The peak at 470°C corresponds to the dehydration of $Al_2O_3 \cdot H_2O$. The peaks at 650 and 660°C have not yet been identified. These results suggest that corrosion by HF and H_2O, which are evolved during storage, could be a problem. In addition, they corroborate and help to explain the gross weight loss values.

2.2 Addition of Alkaline Earth Oxides

Since the stability of the waste powders would be questionable at temperatures above 500°C, the addition of stabilizing compounds was considered. Alkaline earth oxides were the logical choice since the corresponding fluorides are quite stable at the storage temperatures under consideration, and since thermochemical calculations show that the conversion of the metal fluorides to the stable oxides by CaO, MgO, or BaO is possible. The results of studies that were made to determine the effects of adding CaO and MgO to the simulated waste powders are summarized in Table 3. They show that, although wide variations occurred, the addition of the oxides reduced

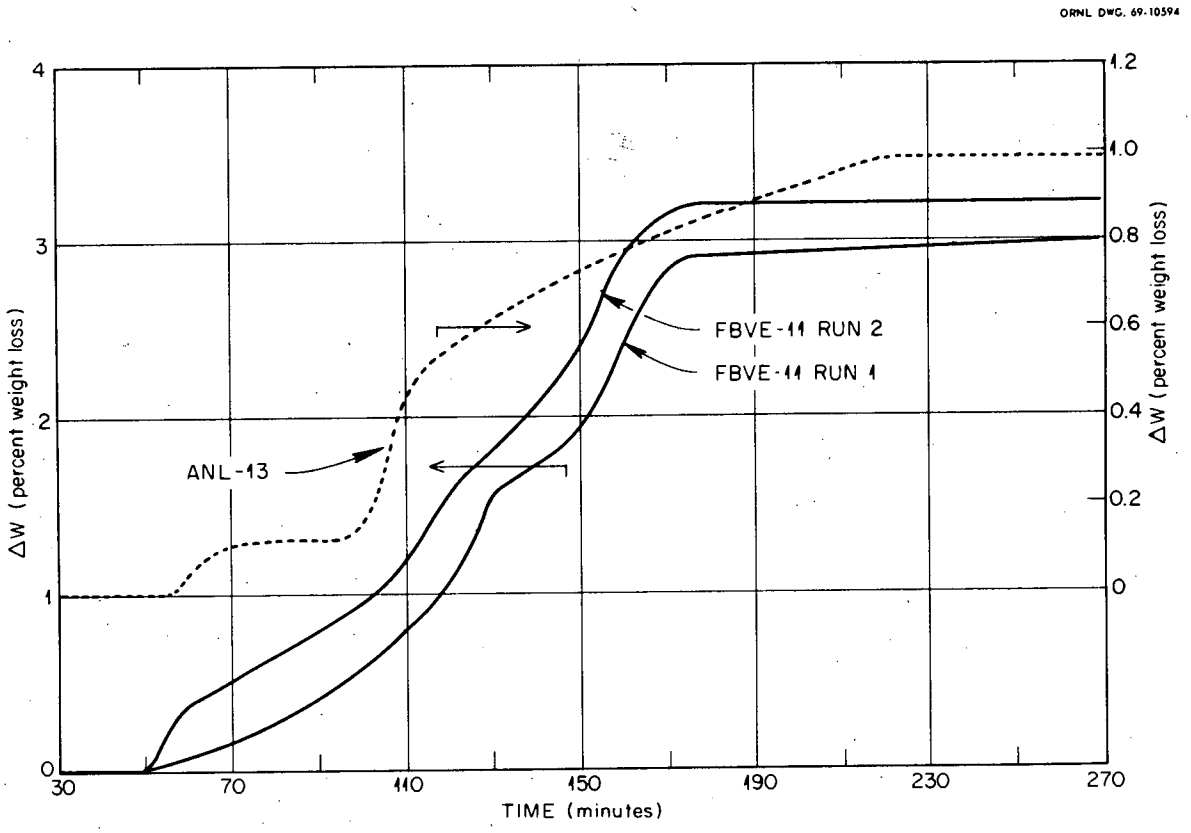

Fig. 3. Integral Weight Loss Curves for ANL-13 and FBVE-11 Waste Powders.

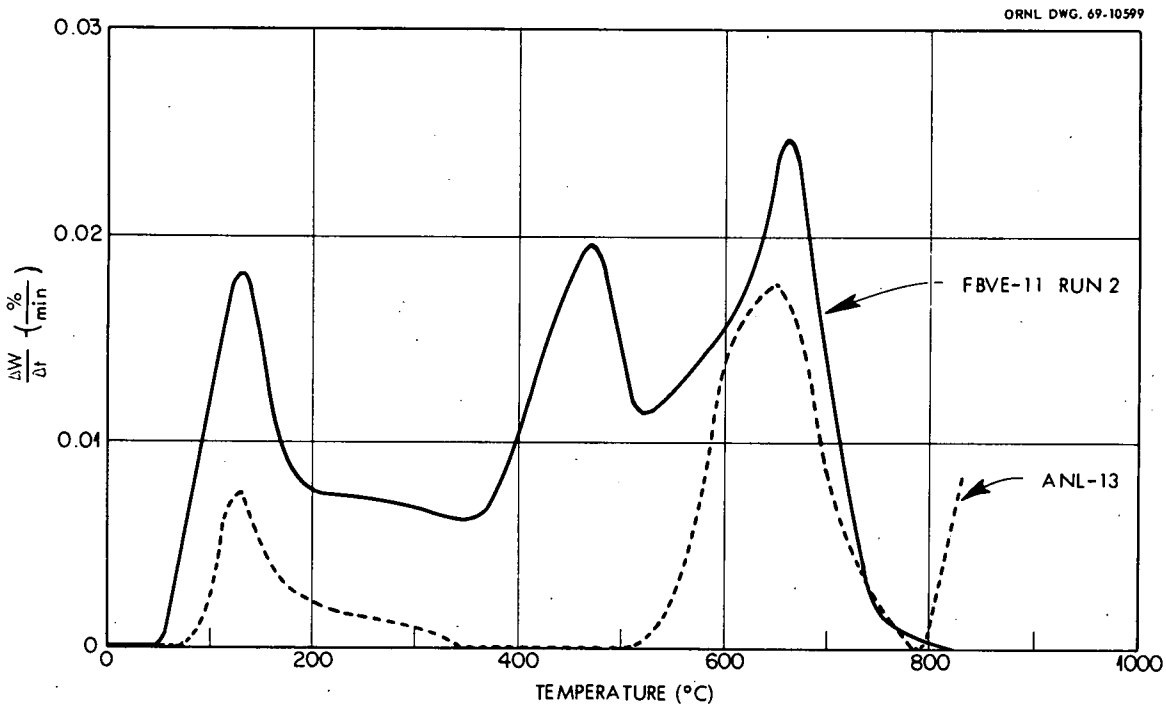

Fig. 4. Differential Weight Loss Curves for ANL-13 and FBVE-11 Waste Powders.

Table 3. Effects of the Addition of CaO and MgO on Weight Losses for Simulated Waste Powders

Experiment No.	Temperature (°C)	Time at Temp. (hr)	Additive	Powder:Additive Weight Ratio	% Weight Loss
		A. Powder ANL-7[a]			
1	850	18.5	None	-	0.91
2	850	18.5	CaO	49:1	0.34
3	850	18.5	MgO	49:1	0.53
4	850	74	MgO	49:1	0.69
5	850	18.5	MgO	19:1	0.65
6	850	74	MgO	19:1	0.66
7	850	18.5	MgO	9:1	0.65
		B. Powder FBVE-11[a]			
8	850	18.5	None	-	5.78
9	850	74	None	-	5.99
10	850	18.5	CaO	19:1	2.25
11	850	74	CaO	19:1	2.71
12	850	18.5	CaO	9:1	1.27
13	850	74	CaO	9:1	1.42
		C. Powder BRF5-5[a]			
14	250	18.5	None	-	0.43
15	250	18.5	CaO	4:1	0.69
16	550	18.5	None	-	2.14
17	550	18.5	CaO	4:1	2.23
18	850	18.5	None	-	7.35
19	850	18.5	CaO	4:1	5.22

[a]Composition given in Table 2.

the weight losses to approximately those represented by moisture; CaO was found to be more efficient than MgO.

2.3 Leaching Studies

Tests were also made in which the ANL-13, FBVE-11, BRF5-5, and BRF5-8 powders were leached with water. Soluble cesium was added to the powders by simply wetting them with a dilute solution of cesium-137 chloride and then air drying them. The purpose of this addition was to allow a direct comparison of the leaching, by water, of soluble isotopes from the untreated powder and from the powder dispersed in a glass, as discussed in ref. 5. About 2 μc/g of cesium-137 was added to these powders, and then about 50 g of each powder was transferred to a 1-liter polyethylene bottle. A 500-ml volume of distilled water was added to each bottle, and the bottles were connected to a shaking table so that the water was gently agitated. The water was renewed every day, and, on completion of a test, the entire leachate was submitted for analysis. All of the leachates were analyzed for ^{137}Cs; in addition, the ANL-13 leachate was analyzed for aluminum, fluoride, and zirconium, and the FBVE-11 leachate was analyzed for aluminum and fluoride (Figs. 5 and 6). After a 24-hr period, 72, 51, 91, and greater than 99% of the original cesium had been leached from the ANL-13, FBVE-11, BRF5-5, and BRF5-8 powders respectively. Eighty to ninety percent of the cesium had been leached from the powders at the end of one week. As might be expected, aluminum was leached slowly. Fluoride was leached much more rapidly from FBVE-11 than from ANL-13, thus indicating that the FBVE-11 has a much higher concentration of soluble fluorides. These results suggest that any soluble radioactive isotopes would be rapidly leached from the powders if the latter should come into contact with water. In fact, these leach rates for ^{137}Cs are about 10^5 times greater than those obtained when the powder is dispersed in a glass, as demonstrated previously.[5]

2.4 Radiation and Thermal Stability Studies

Experiments were made to study the stability of the ANL-13 and BRF5-5 waste powders as a function of temperature and of radiation dose received from a ^{60}Co

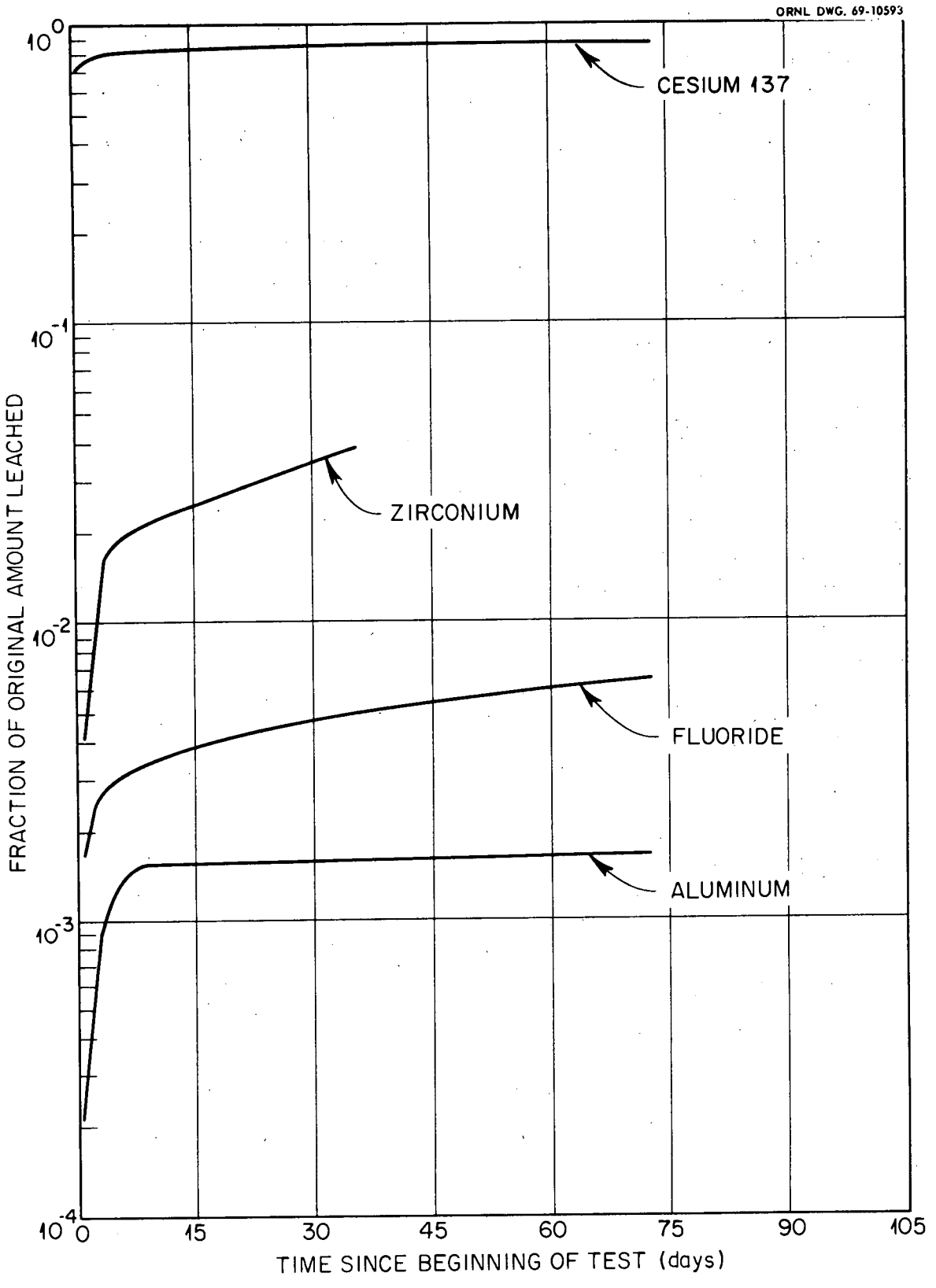

Fig. 5. Leach Test Results for ANL-13 Waste Powder.

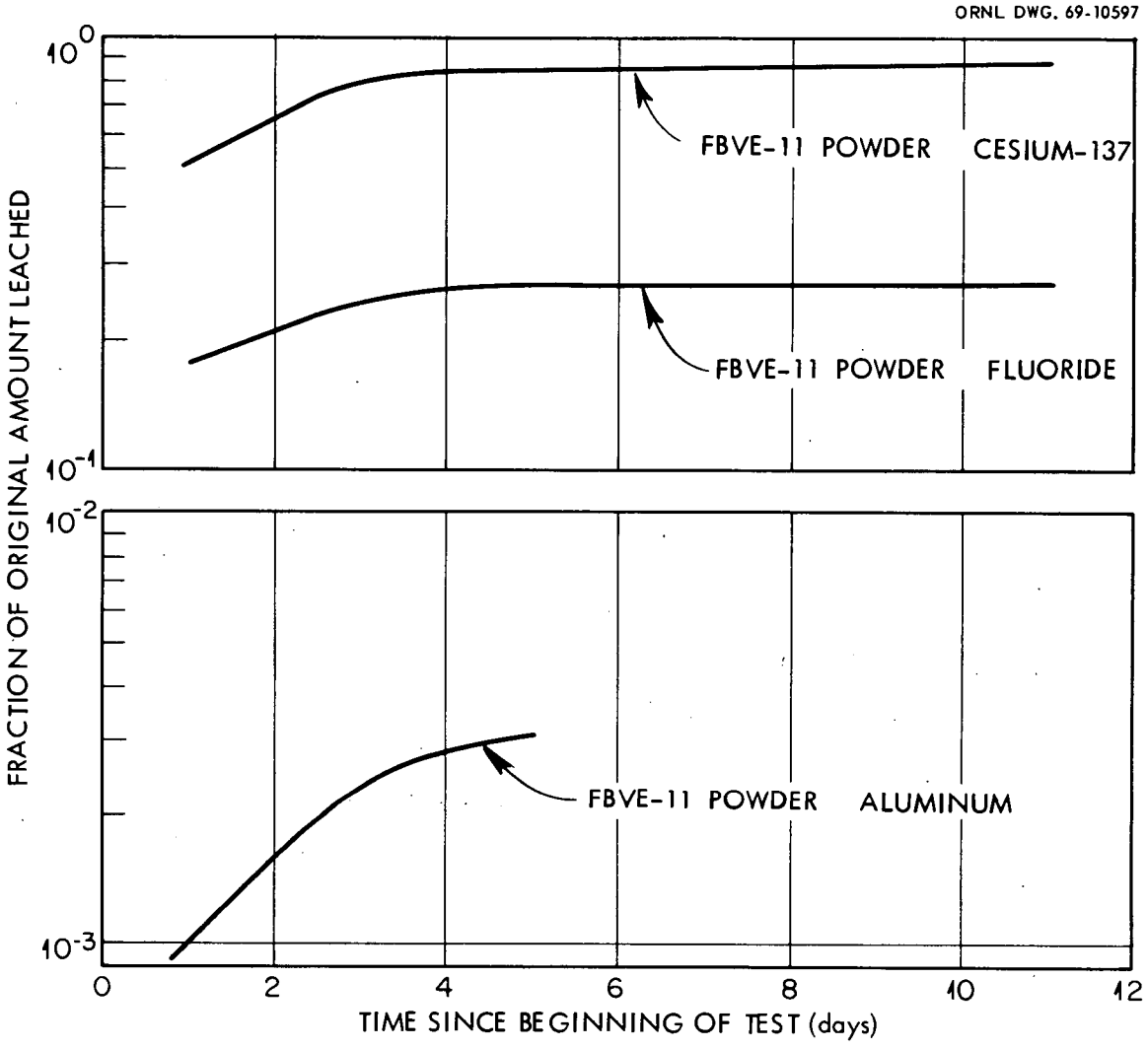

Fig. 6. Leach Test Results for FBVE-11 Waste Powder.

source. Samples of the powders in 3/8-in.-ID, 4-in.-long stainless steel or nickel containers (Fig. 7) were heated, while vented to an off-gas scrubber system, to 250, 550, and 850°C, and then sealed. The pressure in each container was continuously recorded. In all cases the pressure decreased from the original 745 ± 5 mm Hg to values ranging from 720 mm Hg, in the case of ANL-13 at 250°C in nickel (Fig. 8), to 23 mm Hg in the case of BRF5-5 at 850°C in stainless steel (Fig. 9). The magnitude of these pressure decreases was surprising. One explanation is that gas (oxygen and water vapor from the air, as well as hydrogen fluoride and steam from the powder) present in the interstices of the powder at the time of sealing reacts with the metal of the container to give a decrease in gas volume. Any hydrogen that is formed in the reactions with HF and H_2O would probably diffuse out of the system. At the end of the experiment, the containers were cut lengthwise into halves. Visible corrosion was negligible in the containers that had been heated at 250°C or 550°C, and was minimal in the containers that had been heated at 850°C. The experiment with ANL-13 powder at 850°C was repeated in a ^{60}Co irradiation facility. A photograph of the setup taken through the hot-cell window is presented in Fig. 10. Figure 11 shows a plot of the pressure in the sample container as a function of time and absorbed dose. It is obvious that the pressure of the ANL-13 powder at 850°C decreased more rapidly after being irradiated by a ^{60}Co source (see Fig. 8 for comparison). To determine how much of this decrease was caused by the radiation and how much was caused by nonuniformity of samples and nonreproducibility of the experimental conditions would require more data.

3. PHYSICAL CHARACTERISTICS OF THE WASTE POWDER-GAS SYSTEM

The physical properties of a waste powder-gas system (e.g., thermal conductivity, heat capacity, and bulk density) will depend on the properties of the solid, the properties of the gas, and the manner in which the solid and the gas are combined. The properties of each phase can easily be determined, but difficulty arises when the whole system is considered because of the complex additive

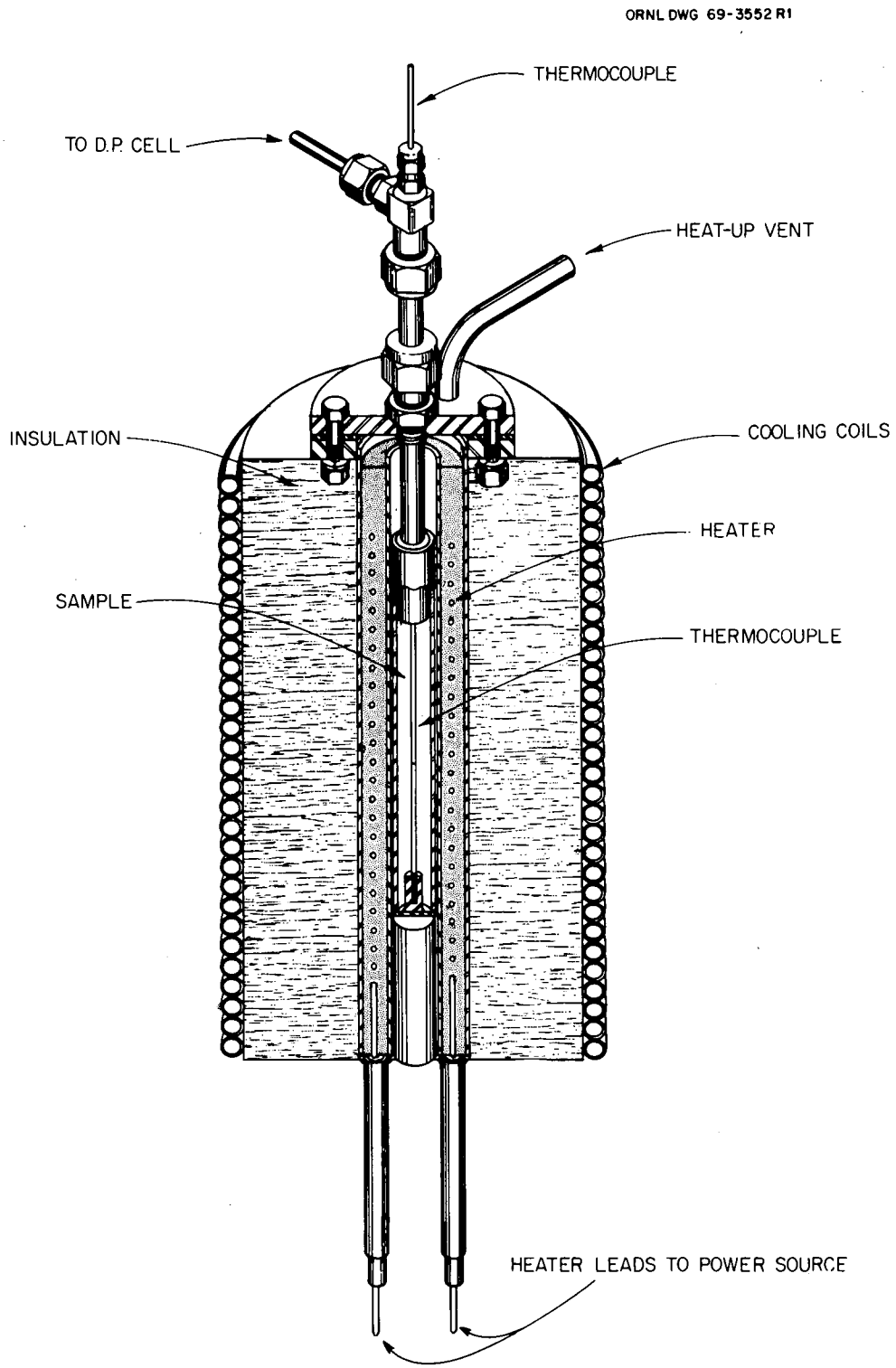

Fig. 7. Container Used for Radiation and Thermal Stability Experiments.

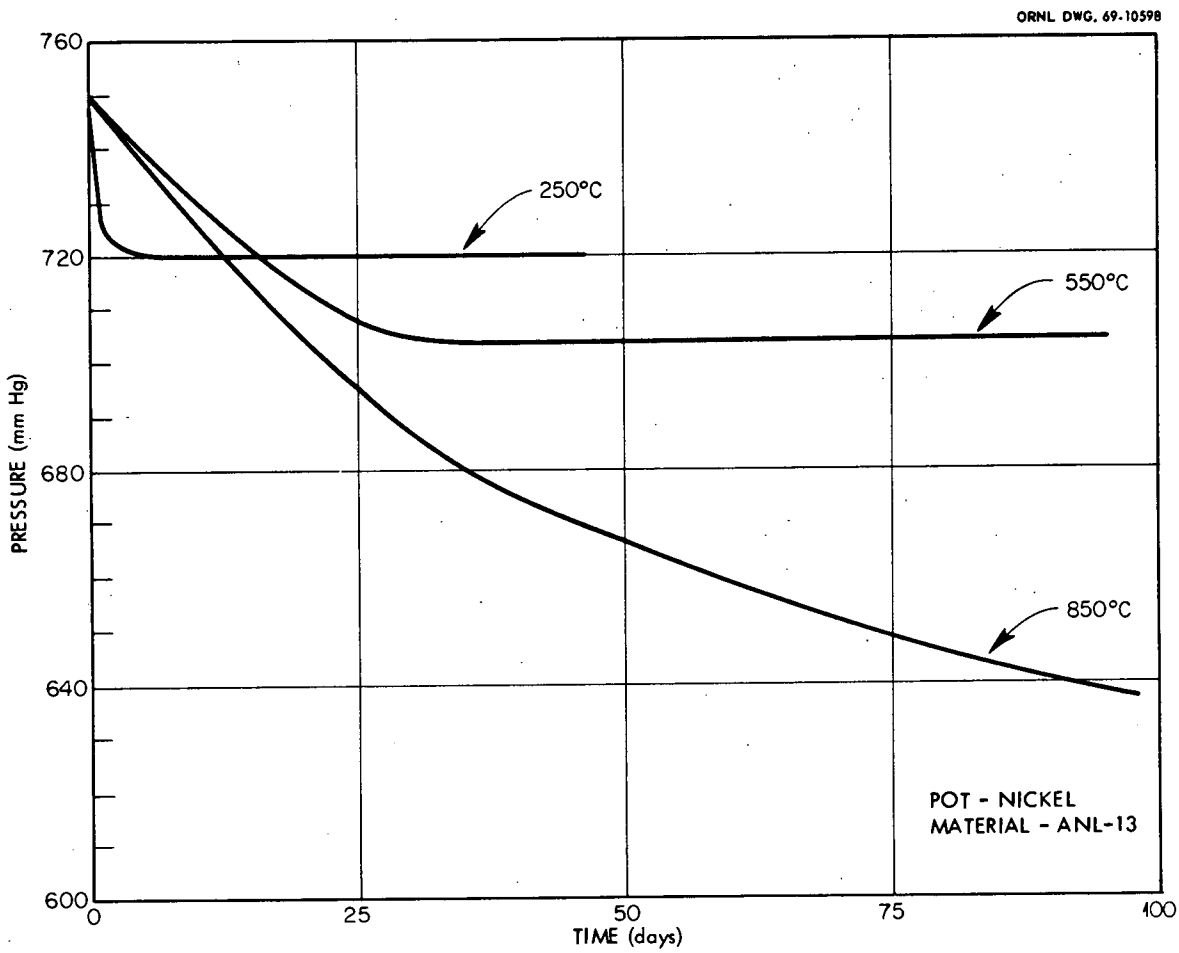

Fig. 8. Results of Thermal Stability Tests with ANL-13 Waste Powder.

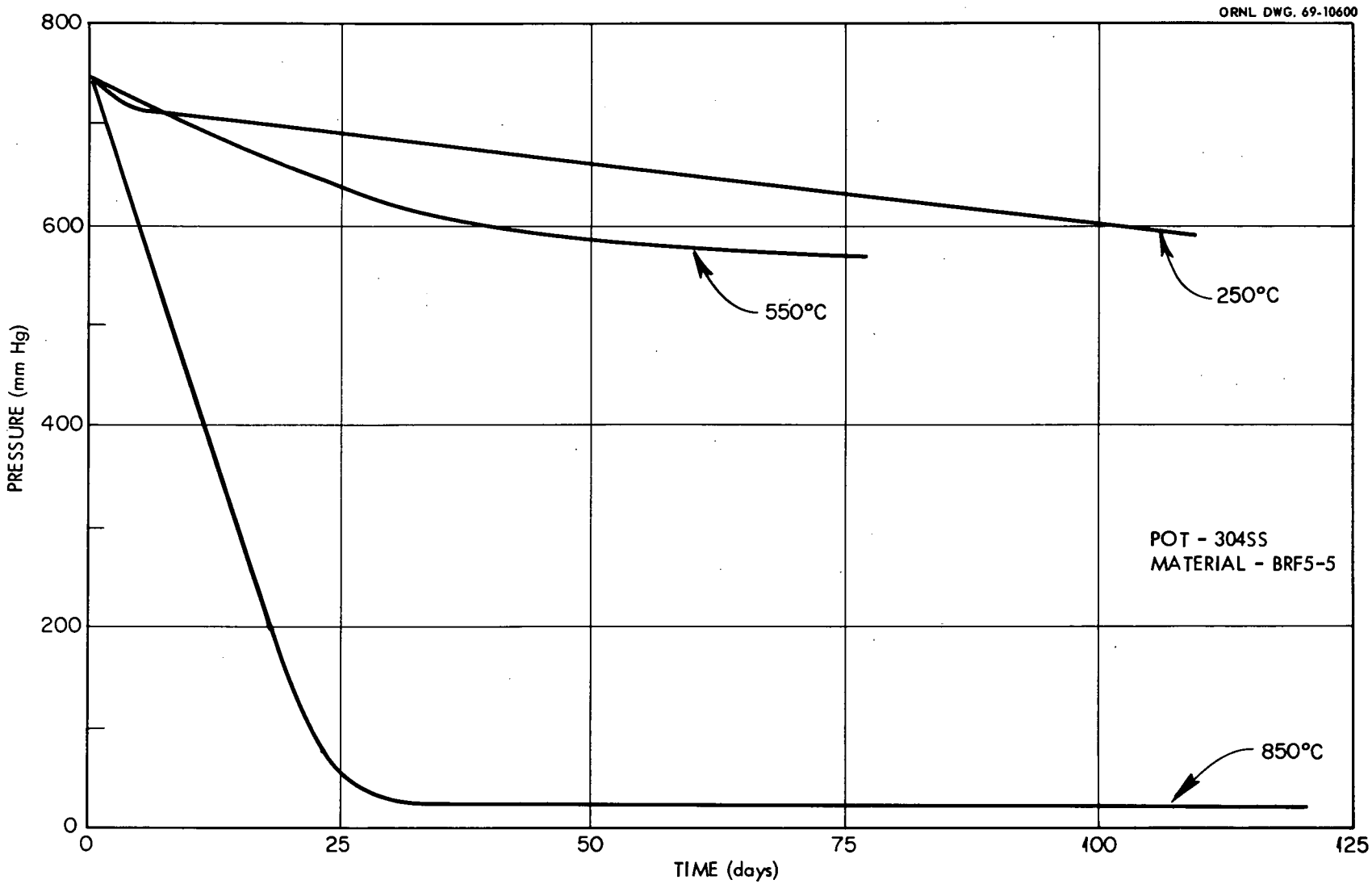

Fig. 9. Results of Thermal Stability Test with BRF5-5 Waste Powder.

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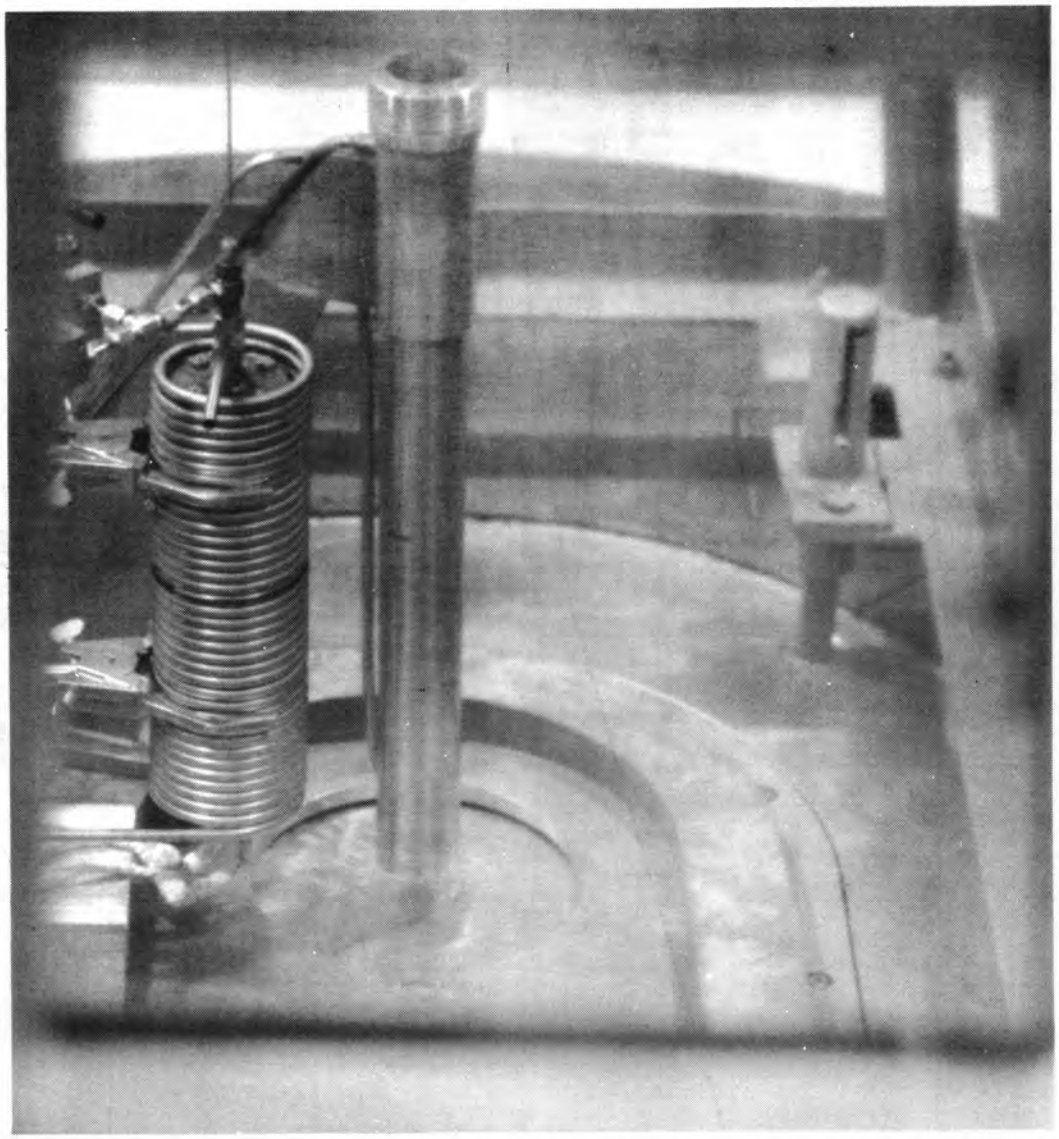

Fig. 10. View Through Hot-Cell Window, Showing Setup for Irradiating Waste Powder ANL-13 with a ^{60}Co Source.

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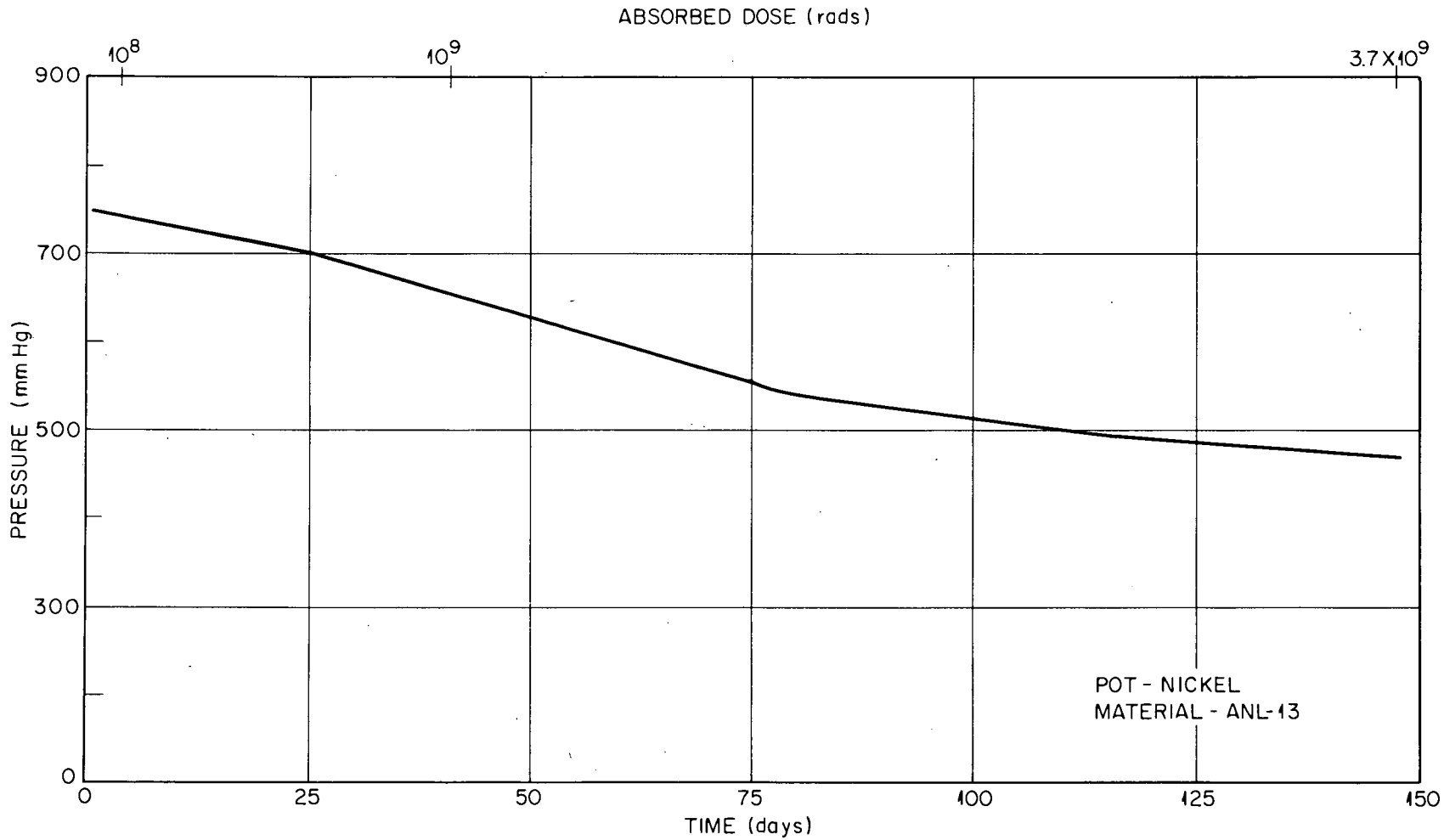

Fig. 11. Results of Radiation and Thermal Stability Test with ANL-13 at 850°C.

nature of the properties of the individual phases. The gross properties of powders are determined by three major subclasses of properties. The first includes the properties of the pure bulk components, the second consists of properties that are created by subdividing the solid, and the third is comprised of properties of the solid-gas system. In the measurement of properties falling in the second and third classes, it is assumed that the amount of sample initially taken is sufficiently large that additional sampling will not give rise to any significant differences.

3.1 Particle Parameters

The particle size of each powder, as determined by sieving, is assumed to be the arithmetic average of the opening in the screen that passes it and that which retains it. The screen analyses of all the simulated waste powders except BRF5-5 are given in the Appendix (Table A-1). Since BRF5-5 powder could not be screened, a particle count was made (see Fig. 13 in the Appendix). The mass mean particle sizes (and standard deviation) of the powders, as determined from these particle-size determinations, are listed in Table 4. The bulk (or "as-poured") and the pore-free densities and the surface areas of the powders are also given in Table 4. These properties are needed for considerations of heat and mass transfer through the powder.

3.2 Thermal Conductivity

Facilities for storing wastes that are generated by the processing of nuclear fuels must contain provisions for dissipating the heat that is produced by the radioactive decay of unstable nuclides. Conditions must preclude the attainment of a temperature that will be detrimental to the waste, its container, or the surrounding medium. One of the most important properties affecting the temperature rise in stored solid wastes is the effective thermal conductivity of the system.

The steady-state radial-heat-flow experimental arrangement that is used to make thermal conductivity measurements is described in detail in ref. 7. The container used in measuring the conductivity of an Alcoa T-61 alumina (see Table 4) was 4 in.

Table 4. Physical Properties of Waste Powders Selected for Study

Material	Mass Mean Particle Size (μ)	Standard Deviation (μ)	Bulk Density (g/cc)	Pore-Free Density (g/cc)	Surface Area (m^2/g)
ANL-7	282	114	a	a	a
ANL-13	275	125	1.72	a	0.245
FBVE-11	108	23	1.65	3.84	2.05
BRF5-5	a	a	1.94	3.81	0.801
BRF5-8	187	48	a	3.63	0.280
Alcoa T-61[b]	419	156	1.56	3.72	a
Norton-RR[c]	97	27	1.67	3.95	0.040

[a]Not determined.

[b]Used as reactor bed material for ANL-7, ANL-13, BRF5-5, and BRF5-8.

[c]Used as reactor bed material for FBVE-11.

ID and 24 in. long with a 1-in.-OD central heater. Because of the limited quantity of BRF5-5 powder, a smaller container, 2-1/2 in. ID x 12 in. long with a 3/8-in.-OD central heater, was fabricated for it. Except for the containers, the same equipment was used for the two powders. To prevent moisture pickup, a dry air purge, 30 to 40 ml/min, was maintained during the measurements. As packed, the Alcoa T-61 and the BRF5-5 materials contained 52% and 43% voids respectively. The conductivity of the Alcoa T-61 varied from 0.323 Btu hr^{-1} ft^{-1} $°F^{-1}$ at 250°F to 0.430 Btu hr^{-1} ft^{-1} $°F^{-1}$ at 1736°F (Fig. 12). The conductivity of the BRF5-5 varied from 0.222 Btu hr^{-1} ft^{-1} $°F^{-1}$ at 104°F to 0.238 Btu hr^{-1} ft^{-1} $°F^{-1}$ at 227°F (Table 5). The BRF5-5 was not heated to higher temperatures since, as evidenced by odors from the container, fluorides were already being evolved. These thermal conductivities should be adequate for most proposed waste management methods.[4]

Table 5. Thermal Conductivity of BRF5-5 Powder[a]

Temperature (°F)	Thermal Conductivity (Btu hr^{-1} ft^{-1} $°F^{-1}$)
104	0.222
110	0.217
117	0.229
189	0.234
192	0.232
227	0.238

[a]Chemical and physical characteristics are given in Tables 2 and 4.

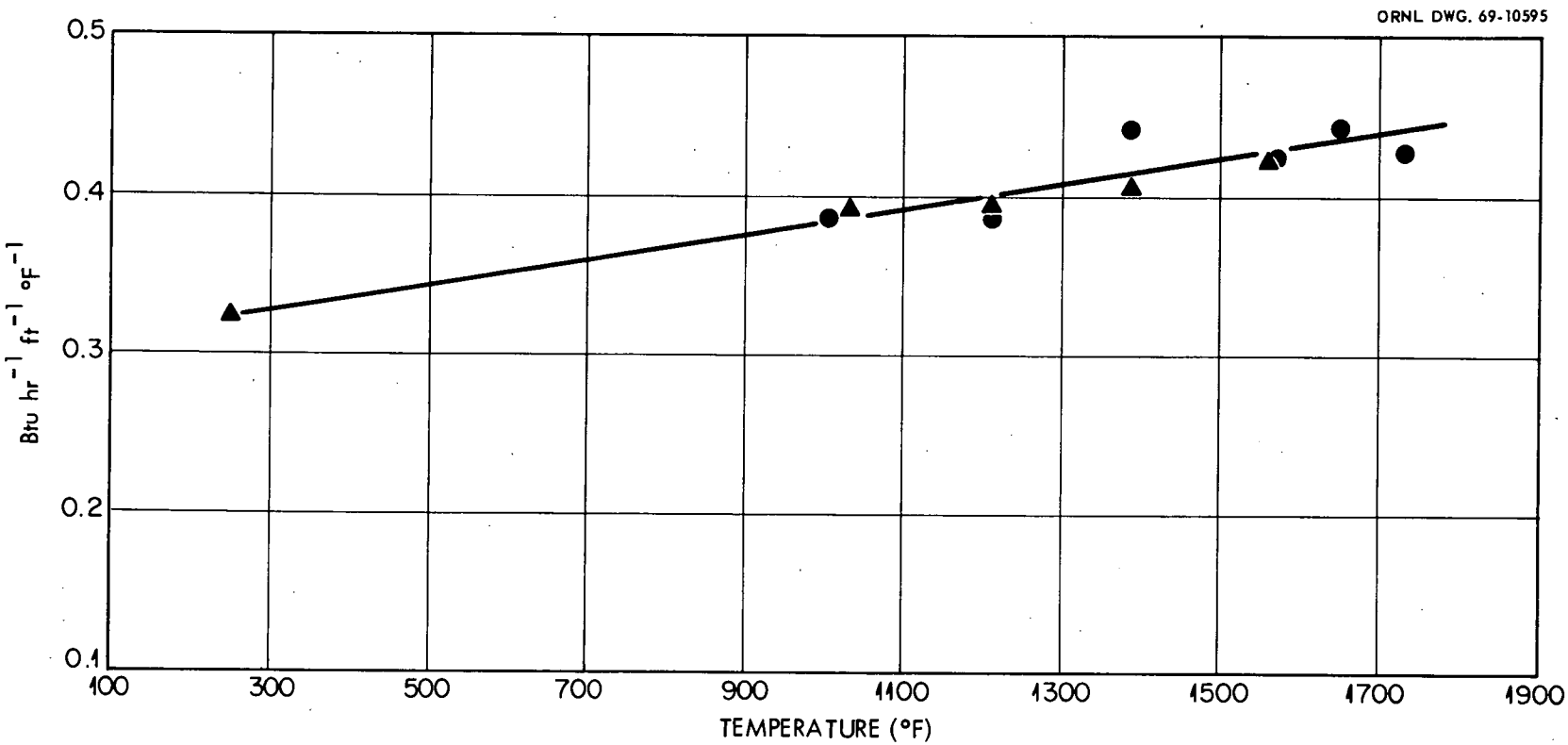

Fig. 12. Thermal Conductivity of Alcoa T-61 Alumina Containing 52% Voids.

4. CONCLUSIONS AND RECOMMENDATIONS

It was concluded that canning (i.e. sealing in a stainless steel pot) appears to be a suitable method for disposing of the solid wastes that would be generated by the fluidized-bed volatility processing of power reactor fuels. Gross weight loss studies using two alkaline earth oxides, CaO and MgO, as "fluoride getters" showed that, with either of these additives present, the weight losses of the simulated waste powders on heating to 850°C could be reduced to essentially the amount attributable to water; CaO was found to be superior to MgO in this application. Analysis of TGA data confirmed the presence of $Al_2F_6 \cdot H_2O$ and $Al_2O_3 \cdot H_2O$ in all the waste powders studied. When samples of the waste powders were leached with water, 80 to 90% of the ^{137}Cs (which was added as a tracer) was removed in about one week, thus indicating that the readily soluble elements in these powders are about 10^5 times more leachable than they would be if the powders were incorporated in a glass. Results of tests in which samples of the powders, sealed in stainless steel and nickel containers, were heated to 250, 550, and 850°C (with and without ^{60}Co irradiation) showed that pressures in the containers gradually decreased with time; the amount of decrease, from 95% to 3%, of the original (1 atm) pressure depended upon the temperature, the material of construction of the container, and the fluoride and water contents of the powder. Thermal conductivity measurements of a pure alumina (Alcoa T-61) powder, used as fluidized-bed material, and of a simulated waste powder gave results that would be satisfactory for proposed waste management programs.

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6. APPENDIX

Supplemental information is presented in Table A-1, which lists the results of screen analyses of alumina (fluidized-bed material) and of waste powders. Figure 13 shows the particle size distribution for BRF5-5 waste powder.

Table A-1. Screen Analyses of Alumina and Simulated Waste Powders[a]

Mesh Size	Cumulative Weight % Passing Through Screen					
	ANL-7	ANL-13	FBVE-11	BRF5-8	Alcoa T-61[b]	Norton RR[c]
16	100.00	100.00	-	-	-	-
18	99.90	99.00	-	-	100.00	-
20	99.80	99.60	-	-	99.69	-
25	99.70	99.40	-	-	97.59	-
30	99.60	99.10	-	-	93.27	-
35	99.50	98.90	-	-	86.94	-
40	98.80	98.31	-	-	79.62	-
45	91.74	91.94	-	-	65.36	-
50	72.04	75.02	-	100.00	37.35	-
60	56.91	60.99	-	99.80	15.46	-
70	45.77	50.05	-	92.30	6.12	-
80	34.33	38.50	-	68.20	2.91	-
100	17.31	21.99	100.00	44.10	1.41	100.00
120	7.86	9.55	99.59	15.46	0.60	96.80
140	-	4.67	81.28	8.78	0.40	88.10
170	3.88	2.48	36.44	4.84	-	63.80
200	1.29	1.29	12.41	2.89	-	38.48
230	0.60	0.70	7.11	2.39	-	16.35
270	0.30	0.50	4.30	1.89	-	12.36
325	0.20	0.30	3.40	1.49	-	6.28
400	0.10	0.20	1.80	1.19	-	2.19
Pan	-	0.10	1.30	1.00	0.20	0.70

[a]Except waste powder BRF5-5.

[b]Bed material for ANL-7, ANL-13, BRF5-5, and BRF5-8.

[c]Bed material for FBVE-11.

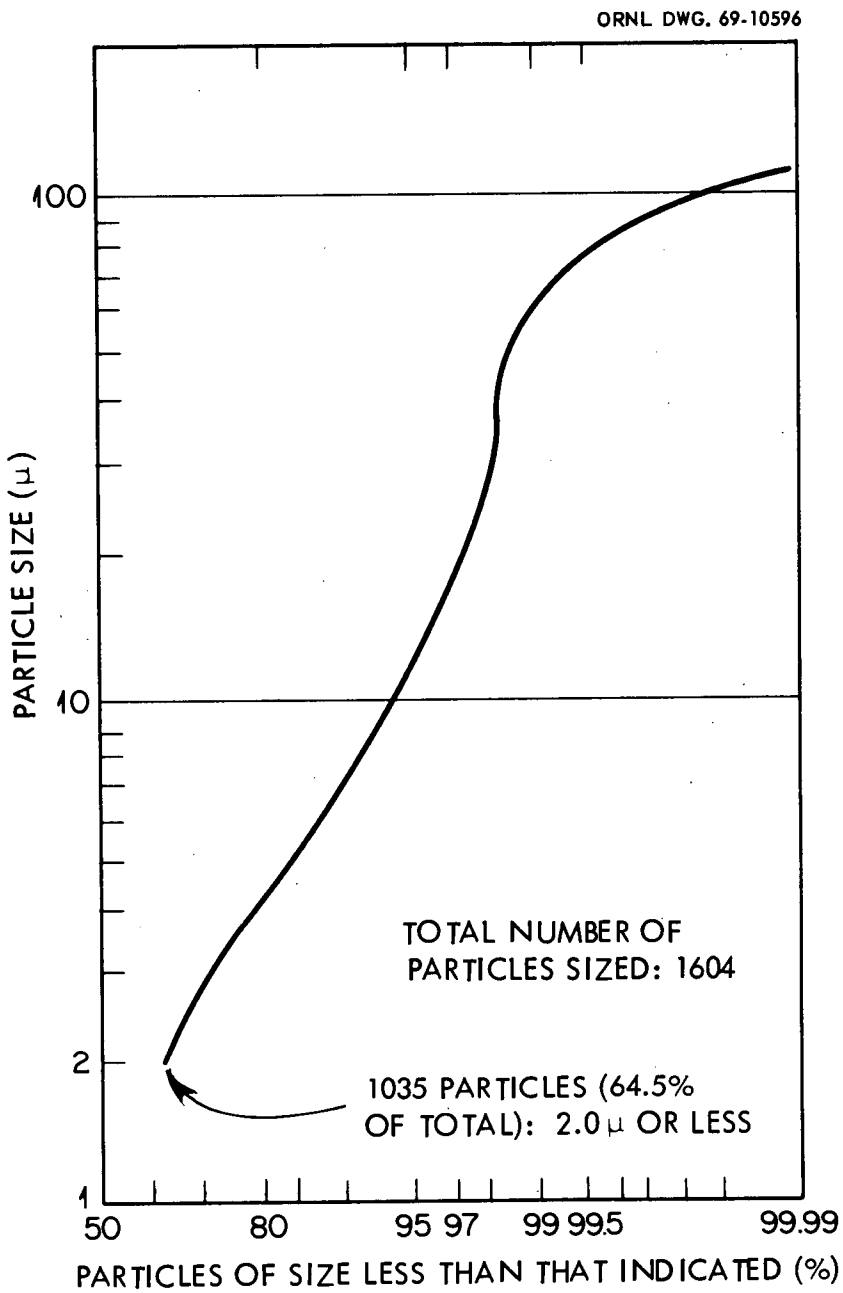

Fig. 13. Results of Particle Count of BRF5-5 Waste Powder.

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