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**QUARTERLY PROGRESS REPORT
RESEARCH AND DEVELOPMENT ACTIVITIES
FIXATION OF RADIOACTIVE RESIDUES
JULY - SEPTEMBER, 1965**

A. M. PLATT

OCTOBER, 1965

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RESEARCH AND DEVELOPMENT ACTIVITIES
FIXATION OF RADIOACTIVE RESIDUES
JULY-SEPTEMBER, 1965

By

Members of the Staff
Chemistry Department

Edited by

A. M. Platt
Chemical Development

October, 1965

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First		HW-60584	59-1
Second		HW-61635	59-2
Third		HW-63048	59-3
Fourth		HW-63949	59-4
	<u>1960</u>		
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	<u>1963</u>		
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	<u>1965</u>		
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* Reference notation used in this report.

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QUARTERLY PROGRESS REPORT
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INTRODUCTION

This progress report is the twenty-seventh in a series presenting research and development activities in the field of radioactive wastes.

Experimental work charged to programs other than those of the Division of Reactor Development and Technology is included for general interest and completeness; such work is identified in the headings.

SUMMARY

The calcined-waste containers produced during the Hot Cell Pilot Plant experiments in 1962 and 1963 have generated a maximum pressure of 3 psig.

Design verification tests with the prototype spray calciner have shown satisfactory performance when producing high melting point powders. Later tests on other feeds showed poor atomization and cake buildup in the calciner.

Design of the prototype equipment is complete. Procurement and fabrication of prototype equipment is done except for a few cleanup items and final field-fitting of jumpers.

Design verification tests on the pot storage station indicated satisfactory calorimeter performance.

A GE-412 computer has been successfully used in design verification tests for data collection, calculation, and correlations.

Studies are continuing on fixation of sulfates from acid condensates generated in a glass-making process.

Lead sulfate-borax melts produced by a continuous feed melter at 900 °C appear to be quite fluid, but exhibited a high (22%) evolution of sulfate. Studies were initiated on incorporation of the neutralized condensate into asphalt.

Release rates of up to 2%/hr for Cs¹³⁷ from a simulated phosphate ceramic waste material were observed from exposures to temperatures up to 1200 °C. Release rates of other isotopes which appear to be a thousand-fold lower than for cesium established volatilization as the predominate mode of cesium release. A technique for varying the phosphate content of the simulated ceramic wastes has been developed.

CALCINATION AND SOLIDIFICATION STUDIES

(R. E. Burns, C. R. Cooley, and R. L. Moore)

HOT CELL EXPERIMENTS

Pressure in Calcined Waste Pots - R. T. Allemann

A few calcined waste containers were stored after the completion of the Hot Cell Pilot Plant studies of spray and pot calcination.⁽¹⁾ Because the storage space is now needed, the containers are to be sent to burial. A final check of the storage pressures has shown the following:

<u>Pot</u>	<u>Type of Calcined Waste Contained</u>	<u>Date Sealed</u>	<u>Pressure on Sept. 15, 1965</u>
8	Spray calcined acidic Purex Waste	10/28/62	Loose-fitting, test N. G.
10	Spray calcined acidic Purex Waste	12/4/62	+ 0.5 psig
12	Spray calcined neutralized Purex Waste + sugar	2/14/63	+ 3 psig
15	Pot calcined acidic Purex Waste	5/28/63	0 pressure

Because these containers were not welded shut or helium leak tested after sealing, it cannot be guaranteed that leakage did not occur. However, the indications from these tests are that little pressure buildup occurs for these calcined wastes over a 2 yr period.

LABORATORY STUDIES

Effect of Varying Composition on Properties - G. B. Barton

The measurements on the 10% Fission Product (weight percent of oxides before phosphate addition) sulfate free phosphate system were completed with measurements on the 1000 °C melted and cast materials. The major significant difference is the decreased drip temperature when sulfate

(1) R. T. Allemann, F. P. Roberts, and U. L. Upson. Solidification of High-Level Radioactive Fuel Reprocessing Waste by Spray and Pot Calcination, Hot Cell Pilot Plant Studies, HW-83896. General Electric Company, Richland, Washington. September 19, 1964.

is absent and the phosphate addition is low (M/P 3.5 to 3.1)*. The solubility in this phosphate range is also reduced by absence of sulfate. However, this is not a marked enough effect to be the deciding factor in whether or not an effort should be made to produce sulfate free wastes.

For convenience, all the data on the sulfate bearing versus the sulfate free samples are summarized in Table I. Parts of this have been previously published in the quarterly reports (65-1, 65-2), as well as BNWL-80.⁽¹⁾ It is likely that the fact that sulfate is largely eliminated from these compositions during melting accounts for the similarity in behavior of most of the comparable samples.

Higher Fission Product Levels

The preliminary measurements on drip temperature of a series containing fission product oxides: process oxide in the weight ratio of 75:25 were reported in 65-1. During this quarter the additional equipment needed to make measurements of drip temperatures in excess of 1085 °C was received. The results obtained are given in Table II. The results on these materials are erratic. At least two observed factors contribute to this: (1) the viscosity of the melts is very high and varies with M/P; and (2) the temperature gradient in the small platinum wound furnace was large. As a consequence, small variations in the position of the outlet tube would induce variations in the observed drip temperature.

One would conclude that to process a waste containing this high a fission product level it would be necessary to add phosphate to an M/P ratio of 1.1 or less (assuming the drip temperature represents the minimum temperature at which a container could be filled solidly and that 900 °C is the limiting temperature), or alternatively, one can add diluents to reduce the fission product fraction to somewhat lower levels. It is planned to investigate the type and quantity of diluent that can most satisfactorily accomplish the modification.

* Metal oxide to phosphate ratio

(1) G. B. Barton. Solidification of High-Level Wastes - Part IV: Phosphate Melts for Fixation of Radioactive Residues from Purex-Type Wastes - Three to Fifty Per Cent Fission Product Oxides, BNWL-80. July, 1965.

TABLE I
 PROPERTIES OF SULFATE BEARING VERSUS SULFATE FREE MELTS
 10% Fission Product 90% Process Oxides

M/P	1000 °C Melted and Cast					1200 °C Melted and Cast					
	Drip Temperature, °C		Solubility, %			Drip Temperature, °C			Solubility, %		
			+	-	Recrystal- lized	+	-	Cast	Cast	Recrystal- lized	Recrystal- lized
	+	-									
3.50	918	789	23.70	14.70	22.20	789	773		9.98	28.80	19.50
3.30	887	801	18.20	10.10	13.50	833	800		13.30	24.00	10.40
3.10	878	839	18.70	13.00	13.40	864	802		13.10	11.20	10.60
3.00	824	874	16.00	15.00	11.50	908	817		2.01	18.90	9.24
2.90	839	896	14.60	6.41	13.00	896	846		2.14	17.30	11.90
2.70	827	881	19.70	24.30	25.60	918	856	906	1.18	26.40	20.40
2.50	860	856	8.69	9.40	4.58	947	824	961	0.92	31.40	12.20
2.40	861	817	2.77	5.61	3.17	954	817	958	0.46	5.03	2.50
2.30	871	871	0.93	0.70	1.45	915	832	906	0.33	2.76	1.14
2.20	827	830	11.50	1.00	13.30	873	837	842	0.15	10.60	0.66
2.10	842	806	26.70	3.64	3.35	839	815	839	0.24	21.80	7.18
2.00	856	799	58.50	4.85	6.29	874	785	908	0.26	12.80	24.60
1.90	876	835	40.70	7.70	36.40	881	754	937	0.23	26.90	3.28
1.80	901	863	44.00	31.40	42.30	917	795	977	0.25	44.50	39.70
1.70	903	909	39.00	44.40	42.60	944	813	964	1.25	44.10	39.90
1.60	896	925	40.40	43.90	42.10	977	861	916	0.39	44.10	41.00
1.50	874	947	7.88	44.00	45.10	973	860	966	0.66	45.70	45.40
1.40	888	889	29.50	61.50	50.90	942	779	925	0.48	49.50	46.60
1.30	897	845	2.12	27.60	59.90	892	897	917	0.62	50.80	51.30
1.20	885	833	1.73	5.16	66.30	885	876	898	1.28	56.90	1.52
1.10	879	849	2.97	3.44	2.24	865	875	849	1.73	12.10	0.51
1.00	871	823	2.15	9.02	0.79	864	861	894	1.29	3.79	0.60
0.90	805	809	28.40	19.50	37.40	853	739	884	2.24	58.80	22.50
0.82	871	736	37.50	66.10	65.00	865	754	854	2.34	60.20	59.40
0.75	817	680	45.80	69.40	69.20	901	754	857	0.16	63.30	62.80

* (+) indicates presence of sulfate in starting solutions;
 (-) indicates absence of sulfates

TABLE II
DRIP TEMPERATURE AND SOLUBILITY
OF PHOSPHATES CONTAINING 75% FISSION
PRODUCT OXIDES, 25% PROCESS OXIDES
BEFORE PHOSPHATE ADDITION

	M/P	Drip Temperature, °C	Solubility in Successive 24-hr Periods, %		
M*	3.0	1166	22.60	0.78	0.30
H*	3.0	1075	22.30	1.35	0.38
M	2.4	1084	7.26	7.42	5.37
H	2.4	1174	17.10	7.65	1.88
M	2.3	1132	10.10	16.10	2.41
H	2.3	1186	22.80	4.62	1.04
M	2.2	1179	7.05	9.93	6.38
H	2.2	ND	4.67	9.40	7.92
M	2.1	1092	1.15	0.92	1.48
H	2.1	ND	0.42	0.48	0.50
M	2.0	1174	12.30	4.56	3.04
H	2.0	ND	0.24	0.19	0.39
M	1.9	1203	26.80	4.51	1.66
H	1.9	ND	0.32	0.22	0.35
M	1.8	1170	32.90	2.52	0.90
H	1.8	ND	0.31	0.54	1.50
M	1.2	1108	0.57	0.48	0.67
H	1.2	1077	0.79	0.86	1.45
M	1.1	ND	ND		
H	1.1	873	1.08	1.39	1.87
M	1.0	ND	ND		
H	1.0	817	0.89	1.02	1.31
M	0.9	ND	ND		
H	0.9	846	1.89	0.63	0.96

* M melted at 1000 to 1075 °C, then crucible air-cooled;
H melted at 1200 °C, then crucible air-cooled.

Effect of Changing Fission Product Mixture

This program was designed to test the effects of: (a) omitting the precious metals from the synthetic fission product mixtures, and (b) changing the fission product element ratios to simulate different types of fuels and exposures. The measurements on materials of M/P 2.3 were reported last quarter (65-3) and the measurements on materials of M/P 1.0 are reported herewith in Table III.

The previous conclusion that the precious metals should be included in the compositions tested if the laboratory studies are to reliably simulate expected wastes is sustained. Statistical analysis of the data indicated further that fission product type had a significant effect on drip temperature

TABLE III
RARE METAL EFFECT ON SOLUBILITY AND DRIP TEMPERATURE
OF VARIOUS FISSION PRODUCT MIXTURES IN PUREX PROCESS WASTES
THAT HAVE BEEN SOLIDIFIED THROUGH DIFFERENT THERMAL HISTORIES

M/P 1.0	Concentration, %	Thermal History							
		Melted 1000 °C Slow Cooled				Melted 1200 °C Then Chill Cast			
		Without Precious Metals		With Precious Metals		Without Precious Metals		With Precious Metals	
		Drip Temperature, °C	Solubility, %	Drip Temperature, °C	Solubility, %	Drip Temperature, °C	Solubility, %	Drip Temperature, °C	Solubility, %
Low Exposure	5	809	6.82	790	14.36	829	1.31	824	2.36
	10	854	0.66	817	15.34	854	0.84	834	1.12
	20	814	3.71	795	13.85	854	0.69	877	1.60
Plutonium Recycle	5	783	18.25	790	17.11	827	1.68	834	1.34
	10	802	11.51	829	5.48	824	1.70	855	1.10
	20	813	4.83	829	5.71	849	1.14	863	0.72
High Exposure	5	808	7.66	729	17.29	832	1.67	828	1.77
	10	824	5.73	805	10.60	819	1.63	825	1.87
	20	769	7.49	805	7.54	847	0.93	848	1.27

and the concentration had a significant effect on solubility. All future laboratory work will include the precious metals with the possible exception of comparison experiments to predict what might happen with pilot plant runs. It appears there is economic justification for omitting the precious metals from the synthetic materials used in the pilot plant. Only a single fission product type--representing the Yankee fuel--will be used at present. If the statistically designed program now underway yields coefficients for individual elements this may eliminate many experiments on combinations.

In conjunction with the experiments on precious metal effects, a more extended series of measurements on effect of thermal history was also made. Nine samples of a given composition (50:50 fission product oxides:process oxides, M/P 2.2) were prepared and subjected to thermal histories with two maximum temperatures. The heating schedules approximated the variation in heating that had occurred while preparing earlier samples. The heating cycles were:

Temperature, °C	Time at Temperature, hr		
	Group I	Group II	Group III
200	1	1	1
325	1	1	1
700	1	1	1
800	-	-	1
900	-	1	-
1000	2	1	2

The crucibles were heated in groups of six (duplicates from three batches of powder) in a muffle furnace according to one of the above cycles. Three of the crucibles were withdrawn for heating to 1200 °C and the others were cast on a steel plate except for the one nearest the front of the furnace. This crucible and melt was at a visibly lower temperature than the others and would not pour. The materials heated to 1200 °C bubbled extensively and required frequent stirring to prevent them going over the crucible. They were heated until quiescent--usually about 2 hr.

The solubility and drip temperatures were measured and are summarized in Table IV. It can be seen that there is a wide variation in solubility for the 1000 °C melts. This may be the result of sulfate retention at

TABLE IV
VARIABILITY IN DRIP TEMPERATURE AND SOLUBILITY
AT A GIVEN COMPOSITION
 (50% Fission Product M/P 2.2)

All sample groups listed in order from back
 of furnace to front; i. e., lowest temperature in front.

<u>1000 °C Maximum Temperature</u>				<u>1200 °C Maximum Temperature</u>			
<u>Drip</u> <u>Temperature,</u> <u>°C</u>	<u>Solubility*</u>			<u>Drip</u> <u>Temperature,</u> <u>°C</u>	<u>Solubility</u>		
<u>Group I</u>							
937	4.30	4.18	3.69	901	0.58	0.36	0.34
931	7.57	6.78	6.83	883	0.77	0.47	0.58
967	27.33	3.55	1.85	886	0.68	0.37	0.33
<u>Group II</u>							
941	3.91	17.76	5.59	903	0.46	0.28	0.28
926	1.08	0.75	0.76	891	0.55	0.33	0.35
935	20.99	7.86	2.42	889	0.74	0.51	0.41
<u>Group III</u>							
913	1.10	0.92	0.95	885	0.83	0.42	0.43
913	6.44	5.96	4.93	910	0.47	0.28	0.31
983	25.73	3.65	2.33	916	0.45	0.27	0.25

* Successive 24-hr periods

the lower temperature since it follows the temperature profile of the samples in the furnace or it may be the result of changes in the structure of the solids produced. The decreased solubility and variability of solubility for the 1200 °C samples is in line with previous data.

The drip temperature variation for the 1000 °C melts is larger than expected but that for the 1200 °C melts is not. However, the average temperature for the 1200 °C melts is lower than for the 1000 °C ones in contrast to previous measurements at this M/P.

These results suggested that a further look needed to be taken at the relation of melting temperature and time at temperature. A master batch of powder was prepared from the residues of the above series and used to

obtain the results in Table V. It was surprising to find so little time dependence and the rather marked steepness of the temperature dependence of first 24-hr solubility. The small spread in drip temperature indicates the method is reproducible and suggests the variation in drip temperatures reported in Table I may be partially a measure of composition variation when preparing supposedly duplicate powders. Further work on this is in progress to extend the measurements to 1200 °C. The programmed temperature control equipment is on hand so the effects of heating and particularly cooling rates can be measured.

TABLE V
EFFECT OF TIME AND TEMPERATURE
ON SOLUBILITY AND DRIP TEMPERATURE

Temperature, °C	Time, hr	Drip Temperature, °C	Solubility, %			Sum, %
900	1	1010	29.15	1.92	0.96	32.03
	2	1010	29.18	1.93	0.95	32.06
	4	1012	28.22	1.98	1.99	32.19
950	1	1007	28.63	2.17	0.99	31.79
	2	1018	27.30	2.94	1.56	31.80
	4	1008	27.42	2.97	1.26	31.65
1000	1	994	14.32	8.11	4.50	26.93
	2:12	1006	8.38	9.94	5.27	23.59
	4	1006	10.49	7.51	5.15	23.15

Correlation of Laboratory Measurements with Pilot Plant Data

Efforts were made to correlate drip temperature measurements with slump temperature on several products from the continuous melter. The drip temperature measurements were made in the normal fashion and the settling temperature estimates were from the furnace pyrometer reading. The results are given in Table VI along with solubility measured in the usual manner. These data indicate flow will occur below the drip temperature but give no indication of what temperature difference would be tolerable.

TABLE VI
DRIP TEMPERATURE VERSUS SETTLING TEMPERATURE
ON CONTINUOUS MELTER PRODUCTS
COMPOSITION NFS-FIRST CYCLE
 (High Iron 1.35M)

<u>M/P</u>	<u>Drip Temperature, °C</u>	<u>Furnace Observations</u>		<u>Initial Solubility, %</u>
		<u>°C</u>	<u>Settling</u>	
3.17	1025	950	Very Slight	7.900
2.86	989	950	Complete	1.730
		900	Very Slight	
2.67	1025	990	Barely Melted	0.810
2.43	975	990	Fluid	0.066
2.12	989	990	Viscous	0.380

These melts are of a higher iron composition than has been used so far in the laboratory work so it is interesting to observe that the solubility is lower than for laboratory samples of comparable M/P.

Drip temperatures were measured on some of the materials whose viscosities were reported in BNWL-76 (65-1), p 20. The results were: M/P 2.9, 861°; M/P 2.3, 865°; M/P 1.8, 834°; 30% waste oxides 70% Colemanite, 829. There is no close correlation between drip temperature and viscosity. Extrapolating the viscosity curves back to the drip temperature indicates a maximum viscosity of approximately 150 poises for M/P 1.8.

Thermal Properties of Solidified Wastes - W. V. DeMier

Thermal diffusivity measurements on a high sodium PW2 type melt (from development run SC-133) were completed by Ceramics Research. Diffusivity ranged from 0.007 cm²/sec at 100 °C to 0.004 cm²/sec at 600 °C. An unusually large scatter observed in the experimental data is believed to be caused by inhomogeneity or changes in sample characteristics during the tests. The specific heat capacity was found by

W. J. Van Slyke (Engineering Development) to be 0.25 cal/g C at 30 °C. Density of the Sc^{133} product is 2.75 g/cm³. If heat capacity and density changes are ignored, the above diffusivity numbers are equivalent to thermal conductivities of 0.021 to 0.012 W/(cm²)(°C/cm) [1.21 to 0.69 Btu/(hr-ft² °F/ft)].

Spray Calciner-Melter Flowsheets - J. E. Mendel

Flowsheets by which PW-1 and PW-2 (composition given in "Projected Waste Compositions for WSEP Studies,")(1) can be processed in the spray calciner-melter are being investigated in the laboratory.

PW-1 Flowsheet

The proposed flowsheet for processing PW-1 consists of adding sufficient 85% orthophosphoric acid to the waste to make the M/P ratio about 2.5. The M/P ratio of 2.5 represents a compromise. As the M/P ratio is increased the melting point of the calcine increases.

<u>M/P</u>	<u>"Stickpoint",* °C</u>	<u>Melting Point, °C</u>
2.00	825	975
2.10	875	1025
2.50	900	1075
3.00	850	1125

The lower melting calcine is most desirable from the standpoint of melter operation and filling of storage containers. However, excessive deposits have formed on the off-gas filters during some pilot plant spray calciner-melter runs when the M/P ratio was less than 2.2.

PW-2 Flowsheet

The goal of the laboratories studies is a flowsheet which will process PW-2 in the spray calciner-melter without generating a sulfate side stream. Melts have been prepared with PW-2 from which sulfate is lost

(1) C. R. Cooley. Unpublished Data. Pacific Northwest Laboratory, May 6, 1965. (Personal Communication)

* Temperature at which calcine begins to adhere to a stainless steel wire.

at a sufficiently low rate that a sulfate recycle flowsheet is probably possible, although this has not been demonstrated in a dynamic system. In static tests the loss of sulfate from the melts is found to be proportional to the square root of time until about 50% of the sulfate is evolved. Sulfate loss rate is dependent upon the ratio of surface area to depth of the melt and increases rapidly with temperature. The melts were prepared using formulation, of the type developed at ORNL, in which sodium, lithium, aluminum, and calcium are added in addition to phosphate.

The initial ORNL-type formulations which were prepared yielded calciner with "stickpoints" of about 600 °C. Normally, the spray calciner operates with wall temperatures of 700 °C. Even when using reduced wall temperatures deposits have formed in the spray calciner when using PW-2 plus 2.7M Na, 2.4M Li, 0.75M Al, and 3.6M PO₄. A statistically designed experiment is now underway in an attempt to find a melt with a higher "stickpoint" which will satisfactorily retain sulfate. Three different levels of sodium, lithium, aluminum, calcium, and phosphoric acid additions to PW-2 are being evaluated. The 46 formulations required have been prepared and calcined and data collection has begun.

WASTE SOLIDIFICATION ENGINEERING PROTOTYPES

(C. R. Cooley)

General Description - K J. Schneider and G. Rey

The WSEP is a pilot plant to provide for full radioactivity-level demonstration of practical, technical, economic, and safety aspects of several of the more promising processes for solidification of highly radioactive wastes. The demonstration is a focal point for research and development on this program. The major objective of the program is to provide actual radioactive performance information for process selection, design, fabrication, and operation as a production plant.

Three processes for solidifying radioactive wastes are incorporated into the WSEP program: (1) pot calcination and rising-level glass, developed by ORNL (Oak Ridge National Laboratory); (2) spray solidification,

developed by Hanford Laboratories of General Electric's Hanford Atomic Products Operation (now Pacific Northwest Laboratory); and (3) continuous phosphate glass process, developed by ^{Brookhaven National Laboratory} Pacific Northwest Laboratory.

The principal processing feature of the WSEP can be seen in Figure 1. Maximum design capacity is 10 gal/hr of wastes, which is equivalent to wastes from 1 to 3 tons of reactor fuel per day. The liquid waste is introduced into the plant from a shielded transfer cask, and chemically adjusted in a feed tank. If necessary, thermal digestion is used to accomplish feed preparation or to aid in decomposition of organic residues. The wastes to the plant may also be evaporated to reduce volume and eliminate gross quantities of nitric acid. Wastes are fed from the feed tank or the evaporator directly to one of the three processes--spray solidification, pot calcination, or phosphate glass solidification. The vapors produced are routed through a condenser and collected or recycled to the evaporator. In the evaporator, the condensates are reconcentrated (along with incoming wastes if waste is fed from the evaporator). The vapors from the evaporator are decontaminated further from entrained aerosols by recondensing and feeding to an acid fractionator. The vapors from the fractionator are again condensed and collected for disposal as an innocuous water stream. The remaining gases are passed through "absolute" filtration, scrubbing, and two additional stages of "absolute" filtration before discharge to the atmosphere. The recovered acid is recycled to the production separations plant. The detailed engineering flow diagrams for the WSEP are shown in Figures 2 and 3.

The calcines or "glasses" are collected in containers or "pots" 8 to 12 in. in diam and 8 ft long. Nominal fill level in each container is 6 ft high. Each container is sealed by a screwed lid and stored in B-Cell (in air and/or water as required). Prolonged observations of temperature, pressure, and product characteristics are then made. After this, the pot lids are welded on and are ready for long term storage.

The WSEP equipment is divided into "plug-in" racks on a functional basis as in Table VII. These major equipment racks are arranged in the cell as shown in Figure 4. The service racks are located in the corners of

FIGURE 1
Simplified Flow Diagram

FIGURE 3

WSEP Engineering Flow Diagram

TABLE VII
WSEP EQUIPMENT RACK ASSIGNMENTS

<u>Rack</u>	<u>Rack Function</u>	<u>Major Equipment in Racks</u>
1A	Evaporation and Acid Recovery	Waste evaporator and condenser; acid fractionator and condenser; evaporator bottoms cooler
1B	Feed System	Two feed tanks and reflux condenser
2A	Final Off-Gas System	Caustic scrubber; two off-gas preheaters; fractionator condensate tank
3B	Calciner Condensate	Calciner condensate tank
3C	Fluid Services	Piping services to racks 5A, 5B, 5C
4A	Pot Storage	Pot storage tank
4C	Fluid Services	Piping services to racks 6A, 6B, 6C
5A	Pot Calciner	Calciner induction furnace and hood
5B	Pot Calciner Head*	Connection head to pot calciner
5-6B	Melter**	Spray calciner-melter and furnace
5-6C	Spray Calciner**	Spray calciner and filter chamber
6A	Melt Receiver	Melt receiver resistance furnace and hood
6B	Melter†	Phosphate glass melter and furnace
6C	Phosphate Glass†	Phosphate glass evaporator and condenser
7A	Decontamination	Decontamination tank
7B	Welder	Welder and tank

* The pot calciner is designed primarily for the "5" position.

** The spray calciner is designed for either the "5" or "6" position, and will be installed in the "6" position at startup.

† The phosphate glass system is designed primarily for the "6" position.

B-Cell, the solidification equipment is in front of two of the windows, and the welding and decontamination equipment is in front of the third window. A photograph of some WSEP equipment in mock-up position is shown in Figure 5. Since all solidification processes are serviced by common off-gas equipment, only one solidification process can be operated at one time. Also, only two positions exist for the three solidification processes so that only two solidification processes may be in operating position at one time. The remote concept for racks permits the third solidifier to be stored until ready for testing.

All equipment racks have a "manipulator face," which is in a plane (usually vertical) accessible to the master-slave manipulators. The face contains the semiremote connector terminations of process pipes. Connections to these pipes are those that (a) include an instrument or valve or other similar items subject to frequent failure, (b) provide for changes in routings of process streams, or (c) provide utility access into or out of process equipment in the racks, or (d) require supply services from other in-cell locations.

The 1A, 1B, and 2A racks each have "cold" service piping through two 12-in. diam "upper" plugs penetrating the wall common with the air lock. Here the services are connected (by direct contact) through tubing jumpers to matching service plugs (not shown in Figure 4) installed diagonally between the air lock and the service gallery. These racks also each have "hot" process piping through 2 12-in. diameter "lower" plugs penetrating the air lock wall into the pipe trench below its cover blocks. Here process pipes are connected between racks or to the waste vaults using semiremote maintenance techniques. A photograph of the 2A rack is shown in Figure 6. The 3B and 4A racks each have two plugs entering cubicles in which "cold" services and medium or low activity level process connections are made from the first floor gallery. The 3C and 4C (service) racks each provide piping connections from the second floor gallery through 1 12-in. diam plug penetrating the gallery wall. The two calciner melt receiver furnaces receive electrical and air services from 2 12-in. diam plugs penetrating the basement gallery walls. The other solidification

FIGURE 5
Design Verification Test Installation

FIGURE 6

Prototype Equipment Rack 2A

Neg. 0631892-1

equipment racks and the decontamination and welding racks have no direct connections to the "cold" areas of the building. They have services and process jumper-connections (semiremote type) from one of the two service racks and from other process racks, respectively. Special electrical, instrument, and mechanical services are supplied from the cell gallery through numerous 4 and 8-in. diam sleeves in the cell walls.

Fully remotable Purex-type jumpers are used for the minimum number of connections that are not accessible to manipulators. Typical uses are for pumps, agitators, replaceable tube bundles, and some off-gas pipes. Most of these connections will be aided by viewing with closed-circuit television through cameras located in 10-in. diam plugs near the top of the cell.

The Waste Solidification Engineering Prototypes (WSEP) will be installed in B cell of the Chemical and Materials Engineering Laboratory (CAMEL), formerly the Fuels Recycle Pilot Plant (FRPP). The CAMEL is now under construction and scheduled for completion late in 1965. Startup operation of the WSEP is planned for the first half of 1966.

The design of the WSEP is complete. Procurement and fabrication is complete except: (1) final onsite assembly of the six-zone resistance-heated glass receiver and alternate pot calciner furnace is nearly done, (2) the three-zone resistance-heated spray calciner furnace has been repaired and is enroute here now, (3) the instrument and electrical service supply plugs are about half fabricated, and (4) fabrication of jumpers requiring field-fitting is awaiting completion of the CAMEL building.

Since the last report period, onsite fabrication of the phosphate glass system has been completed and the melter has been received, both resistance heated melter furnaces have been received, and the welding station has been designed and fabricated.

Design Verification Tests (DVT's) - J. L. McElroy and K. J. Schneider

Following completion of pot calciner DVT's the spray calciner and continuous melter were installed in the 321 Building for testing. Heating

elements in the spray calciner resistance furnace shorted on start-up and a temporary three zone induction heated furnace was installed on the calciner. The induction furnace employs a temperature-controlled susceptor for transferring heat to the calciner. It has been operated satisfactorily at 35 net kW and 800 °C. The 310 SS calciner is 14 in. in diam and has an effective heated length of approximately 5 ft (compared to an overall length of 6 ft) when using the induction furnace. The feed nozzle used thus far has been an external mix pneumatic atomizing nozzle (Spraying Systems Company Set-Up No. 5).

To date, water capacity runs, two powder product runs, and one melt run have been made. A water feed rate of 40 liters/hr was easily attained while operating at a calciner temperature of 700 °C. The powder runs were made with Purex Waste-1 without glass-forming additives (Run 1) and with Purex Waste-2 with additives to give a low melting type waste similar in composition to that of the ORNL rising level glass process (Run 2). The melt run (Run 3) was made with Purex 1WW with phosphoric acid added as a glass former. Feed compositions are shown in Table VIII.

During Run 1 the furnace susceptor was set at 700 °C. A continuous feed rate of 21.6 liters/hr was maintained during the 12-hr run and 100 lb of powder were collected in the 8-in. diam receiver pot. Operation was satisfactory except for calciner pressure surges (up to 15 in. of water) encountered during blow-back.

The second powder run was made to test equipment performance on a low melting point feed (760 °C) by using a calciner furnace temperature of 550 °C. An initial feed rate of 15 liters/hr was gradually reduced to about 10 liters/hr to maintain all internal temperatures above 200 °C during the 13-hr run. A large cake deposit occurred in the bottom of the calciner and an equilibrium 1/4-in., loose powder deposit covered the calciner wall. The cake deposit was apparently caused by a faulty feed nozzle producing some relatively large particles which did not dry thoroughly before reaching the bottom of the calciner. Pressure surges encountered during Run 1 were satisfactorily reduced to 10 in. of water by using lower pressure

TABLE VIII
FEED COMPOSITIONS

Run	1*	2*	3
Feed Type	Purex Waste-1**	Purex Waste-2	Purex - 1WW
gal/ton	80	228	90**
H ⁺	6.25M	2.19M	4.33M
Fe ⁺³	1.16	0.195	0.222
Cr ⁺³	0.015	0.0105	0.044
Ni ⁺²	0.0063	0.0044	0.022
Al ⁺³	0.0013	0.0004	0.111
Na ⁺	0.3601	0.4816	1.057
Hg ⁺⁺	0.001	- -	- -
NO ₃ ⁻	11.0	2.82	5.48
PO ₄ ⁻³	0.0037	0.0026	- -
SO ₄ ⁻²	- -	0.381	0.107
SiO ₃ ⁻²	0.0125	0.0088	- -
MoO ₄ ⁻²	0.0813	0.0285	0.0721
Sr ⁺² + Ba ⁺² (added Ca ⁺²)	0.0438	0.0153	0.0388
ZrO ⁺²	0.0813	0.0285	0.0721
Cs ⁺ (added Na ⁺)	0.05	0.0184	0.044
(Y + RE) ⁺³	0.15	0.0525	0.133
Ru ⁺² (added Mn ⁺²)	0.0713	0.025	0.0632
Te (added SO ₄ ⁻²)	0.008	0.0028	0.0071
Ag ⁺² + Cd ⁺² (added Cu ⁺²)	0.002	0.0007	0.0018
<u>Glass-Forming Additives</u>			
PO ₄ ⁻³	- -	1.58	1.28
Li ⁺	- -	1.05	- -
Al ⁺³	- -	0.327	- -
Na ⁺	- -	1.18	- -
M/P	- -	4.15	2.4
Fission Products as M ⁺²	0.596	0.238	0.596
Sp gr	1.477 at 25 °C	1.35 at 35 °C	1.31 at 42 °C
Volume percent solids	Trace of Si	40 (flocculant)	90 (flocculant very light)

* Operated without the continuous melter.

** Based on fission products. Other metal salts were increased by 2.5 to give a meltable product.

(22 psi versus 45 psi) blow-back steam. Filter performance in both runs was good, with a pressure drop of 2 to 5 in. of water.

Run 3 was made with the spray calciner coupled to the continuous melter. The calciner and melter furnaces were operated at 700 and 1175 °C, respectively. During 33 hr of feeding, an average feed rate of 16 liters/hr was maintained. Although a new atomizing nozzle was used, apparently poor atomization of the feed again caused wet powder to build up in the conical section below the calciner. The buildup was allowed to continue upward until it eventually plugged the lower 2 ft of the calciner chamber. The calciner wall area above the powder buildup was essentially clean.

Filter performance was again excellent and after 58 hr of operating with the three different feeds, the filters had an equilibrium powder deposit of only 1/16 in.

The melter and melter furnace operated satisfactorily except for difficulty in discharging of the very viscous melt. The weir overflow and freeze valve tubes were not recessed sufficiently in their respective heaters to compensate for end heat losses. Thus, flow could not be established through the weir overflow and the melter was drained periodically through the freeze valve (melter drain). Melt batches of approximately 1.5 liters were drained at rates from 1 to 2 ft³/day. Freeze valve flow was successfully stopped with the cooling air provision. Prolonged use of the heaters at maximum power produced failure of both heaters. A liquid level probe using a time domain reflection technique successfully gave a continuous indication of the melt level.

An 8-in., 8-ft long mild steel pot was used as a melt receiver to evaluate performance of mild steel with stainless steel. The bottom of the pot was maintained at 400 °C to minimize internal corrosion and the upper portion was held at 700 °C (about the maximum for mild steel) to keep the melt hot and encourage slumping and filling of the entire pot cross-section. However, these operating conditions produced a 4-ft long stalagmite protruding upward from the bottom of the pot. The 700 °C wall temperature

also produced slightly more oxidation of the pot wall (up to 10 mils) during the 50-hr heating period than expected from laboratory tests.

Pot Storage Station - W. V. DeMier

Design verification and calibration of pot storage and calorimetry station (Rack 4A) was completed. Rack 4A will be used for two purposes: intermediate pot storage, and measurement of heat output of a filled waste pot. A resistance heated pot was used to calibrate the calorimeter thimbles IT-1 and IT-2 at power levels up to about 12 kW. Cooling water ΔT 's of 20 to 30°C were observed at flow rates of 9.5 to 6 liters/min at 12.4 kW (42,000 Btu/hr) using water as the heat transfer medium between pot wall and calorimeter coils. When air, instead of water, was used for the heat transfer medium, the cooling water ΔT 's were too sensitive to pot position to permit reliable calibration.

Computer Programming - E. Shimoda

The GE-412 computer is being coupled to the WSEP processes to provide engineering information for operating use and post-process evaluation. Selected analog signals will be monitored and checked for high and low limits. A complete record of any of the process variables going out of limits will be logged on the alarm typewriter. Calculated quantities based on the analog signals will be logged and tabulated in final form for use during and following a process run. The acquisition of accurate and reliable data will be of value for process evaluation.

Computer programs are being checked for their real-time operating capability during the monitoring of the WSEP DVT runs. Twenty-six process variables are being scanned every twelve seconds and are being used to determine other calculated values. High and low limits have been placed on the analog signals and calculated quantities. The output of the computer is logged every 15 min. A check on computer hardware reliability and computer efficiency is being made by monitoring the present series of DVT runs. Programming and operating experience is also being gained by following the DVT runs with the GE-412 computer.

The main scanning program and other functional programs have been satisfactorily tested and operated during the monitoring of the DVT runs. As different process variables are requested for log-out, the engineering unit conversion program and the calculation program are modified for these changes. Stable analog signals give accurate and reliable readings for use in the programs. However, analog signals which have large fluctuations in them cause some difficulty in obtaining a reliable reading.

HAZARDS OF SHIPPING SOLIDIFIED HIGH LEVEL WASTE

(A. E. Albrethsen and L. C. Schwendiman)

The airborne release of fission products as a consequence of a shipping accident involving high level radioactive wastes and a high temperature fire is an important consideration in the overall evaluation of the accident. Experimental studies directed toward the evaluation of the high temperature fission product release from high level ceramic waste material were continued. Two mechanisms of release are under study: volatilization and mechanical entrainment of particles in the airstream.

In the current experiments samples of phosphate based ceramics were used which simulate the composition of a waste prepared from 20,000 MWd/ton irradiated fuel. The ceramic contains fission product elements in the proper proportions and has a metal oxide M/P ratio of 2.8. The radioisotope whose release was to be studied was added in known amounts to a 15-g sample held in a stainless steel or nickel crucible. The exposed surface area of the ceramic was 5 cm². (It is expected that release rates will be geometry dependent.) Nickel crucibles were used when repeated or prolonged heatings were attempted since stainless steel is strongly attacked by the melt. The sample was dried, baked, and fused to incorporate the isotope into the ceramic matrix. Fusing and heating to the goal temperature of the experiment were accomplished in a controlled atmosphere induction furnace. Any material released passed through a quartz chimney and was collected on a glass fiber filter. Both filter and the washings from the chimney were analyzed.

Results of the releases during the sample preparation heats are shown in Table IX. These releases are significant mainly in that they indicate that losses during sample preparation were only a small fraction of the initial radioisotopes added and this small loss would not significantly affect the results of subsequent heating. A fraction of these initial releases could have occurred before the spike was assimilated because of a higher release potential at that time.

TABLE IX
RELEASE OF RADIOISOTOPES FROM A 15 g SAMPLE
OF SIMULATED WASTE DURING THE SAMPLE PREPARATION HEAT*

Run	Crucible	Preheat Time, min	Temperature, °C	Time, min	Release Fraction
Cs-6	Nickel	80	960	0	2.7×10^{-3}
Cs-6a	Nickel	--	990	60	4.7×10^{-3}
Cs-7	Nickel	80	1020	60	6.9×10^{-3}
Cs-8	SS 304L	70	1000	60	7×10^{-3}
Sr-1	SS 304L	70	975	60	1×10^{-5}
Sr-2	Nickel	65	1000	60	6.2×10^{-5}
Ru-1	SS 304L	75	1000	60	3.5×10^{-4}
Ce-1	SS 304L	70	1000	60	2.9×10^{-5}

* Argon atmosphere was maintained. Preheat time indicates time taken to heat sample to temperature at which sample melted. Cs¹³⁷, Ce¹⁴⁴, Sr⁸⁵, and Ru¹⁰⁶ were isotopes used.

The results of the release experiments are shown in Table X. These tests are reheats of the previously fused samples and represent exposure of solidified waste to a sustained high temperature fire. Repeated tests of the same sample of cesium spiked material, Cs-6a-e, resulted in good agreement between tests. This continuity of results, even after 8 hr of high temperature exposure, as well as agreement with the other cesium runs (Cs-7, Cs-8, and also five previous runs where releases of up to 1%/hr were observed), indicates a satisfactory sample preparation.

These results show that release rates of 1 to 2%/hr can be expected for cesium in the temperature range 1050 to 1200 °C. Even at 900 °C when the ceramic is not molten, releases of about 0.2%/hr can be expected.

TABLE X
RELEASE OF RADIOISOTOPES
FROM 15 g SIMULATED WASTE SAMPLES

Run	Temperature, °C	Time, min	Atmosphere	Release Rate, fraction/hr
Cs-6a*	990	60	Argon	4.7×10^{-3}
Cs-6b	1000	120	Argon	4.8×10^{-3}
Cs-6c	1050	60	Argon	1.1×10^{-2}
Cs-6d	1050	120	Argon	1.1×10^{-2}
Cs-6e	1100	120	Air	1.7×10^{-2}
Cs-7a	900	60	Argon	2.4×10^{-3}
Cs-7b	900	120	Argon	1.9×10^{-3}
Cs-8a	1200	60	Argon	2.6×10^{-2}
Sr-1a	1050	120	Argon	6×10^{-6}
Sr-1b	1050	60	Air	9×10^{-6}
Sr-2a	1100	120	Argon	5×10^{-6}
Sr-2b	900	120	Argon	(none detected)
Ru-1a	1100	60	Air	1.6×10^{-5}
Ce-1a	1100	60	Air	(none detected)

* This run was actually part of sample preparation heat; but it is included again here to indicate continuity of data.

Releases of the other isotopes, Sr^{85} , Ru^{106} , and Ce^{144} , indicate that these isotopes will be released at a rate of about 1/1000 that of cesium under similar conditions. This difference in release rates establishes volatilization as the predominant release mechanism for cesium. Had entrainment been predominant, the release rates of the isotopes would have been nearly equal, as the particles would have essentially the same composition as the source. The relatively high volatility of cesium is also indicated by a comparison of runs Cs-7a-b and Sr-2b where the samples are not molten.

The absence of a detectable release of cerium is probably due to not having a sufficient quantity of the isotope to permit measurement of the very small fraction released. The low release of these isotopes approached the

detection limit and increased concentrations or longer exposure would probably give more precise results.

In order to determine whether or not these release rates can be applied to ceramic waste with other M/P ratios, procedures were developed to make up preparations with different phosphate contents. Successful melts resulting in homogeneous appearing material have been obtained in the range of M/P ratios of 2.0 to 2.8 by using calcined oxide or this same phosphate material (M/P = 2.8) as a base and adding the necessary amount of phosphoric acid before drying and fusing.

WASTE STORAGE AND TREATMENT

(G. J. Alkire and J. M. Atwood)

WASTE SOLIDIFICATION CONDENSATE TREATMENT

Sulfate Fixation - B. W. Mercer and C. J. Touhill

Experiments continued on sulfate fixation from condensates in support of the WSEP program. Efforts were aimed toward obtaining a lead sulfate melt which has desirable formation characteristics and uses $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10 \text{H}_2\text{O}$ (borax) as a fluxing agent. Percentages of PbSO_4 and borax were varied in preparing several melts in batch experiments. The results of these experiments are shown in Table XI. The melts were formed at 900 °C.

TABLE XI

PbSO_4 - BORAX MELT CHARACTERISTICS

<u>% PbSO_4</u>	<u>% Borax</u>	<u>Melt Description</u>
90	10	Semimelt, porous large surface area.
70	30	Encapsulated PbSO_4 melt; white borax type glass; (two phase).
50	50	Two-phase system; upper layer - PbSO_4 melt; lower layer hazy borax glass.
30	70	Two-phase system; upper layer PbSO_4 melt. Lower layer very clear borax glass.

Work was initiated on a continuous feed melter to evaluate lead sulfate melt formation using a simulated Brookhaven National Laboratory (BNL) glass melter condensate ($2.5\text{M H}_2\text{SO}_4$, 3M HNO_3 , $0.1\text{M H}_3\text{PO}_4$). In the first set of experiments PbO and borax were added to the waste in concentrations to yield a melt similar to that formed from 70% PbSO_4 and 30% borax. A 10% excess of PbO over the stoichiometric amount required to react with H_2SO_4 in the waste was added to insure complete reaction with sulfate ion. The resultant slurry was fed to the melter at a rate of about 100 ml/hr for a 6-hr period. The melter temperature was 900°C . Melter off-gas was routed through a condenser and a caustic scrubber. Sulfate evolution was 22%, all of which appeared in the condensate. The melt was composed of two phases and appeared to be quite fluid at 900°C .

Formation of a melt composed of PbSO_4 and PbO in equimolar quantities in the continuous feed melter was attempted at 1000°C with the simulated condensate, but the mixture did not melt completely. A total sulfate evolution of 9% was measured over a 4.5-hr period at a feed rate of about 100 ml of slurry per hour. The condensate contained 2.1% of the evolved sulfate and the scrubber 6.9%.

Incorporation in Asphalt - B. W. Mercer

Studies were initiated on the incorporation of the BNL glass melter condensate into asphalt. The method appears to be simple, safe, and inexpensive for storage of wastes where radioactivity levels are low enough to avoid excessive heat generation or radiation damage. Asphalt has good adhesive and coating properties and is relatively insoluble in water. The leach rate of cesium from asphalt-waste mixes is intermediate between concrete-waste and glass waste mixes

High radioactivity levels are considered to be the primary problem with incorporating BNL glass melter condensate in asphalt. The ORNL asphalt process⁽¹⁾ will be used as an example below to illustrate this

(1) Oak Ridge National Laboratory. Chemical Technology Division Annual Progress Report for Period Ending May 31, 1964, ORNL-3627.

problem. In the ORNL process, wastes are mixed with and evaporated in emulsified asphalt.* Up to about 60% solids (e.g., NaNO_3 , Na_2SO_4 , and NaOH) have been incorporated in asphalt. In general, studies at ORNL indicate that asphalts can be successfully used in radiation environments where radiation dosage does not exceed 10^9 rads.

Radionuclide concentrations in a projected BNL glass melter condensate are shown in Table XII. This condensate (4.4M H_2SO_4 , 5.2M HNO_3 , 0.18M H_3PO_4) is more concentrated than the simulated condensate used in the sulfate melt studies. These concentrations assume 20 gal of condensate from the processing of waste per ton of fuel. Radionuclide concentrations are based on 2% ruthenium volatilization and 0.1% entrainment of other fission products from a Purex Waste-2⁽¹⁾ composition arising from the reprocessing of 20,000 MWd/ton fuel. It is also assumed that all of the sulfate (330 moles), 396 moles of nitrate, and 13 moles of phosphate are contained in the 20 gal of condensate. It is emphasized that these concentrations may be subject to considerable variation. Radionuclide concentrations may be higher by a factor of 5 over those listed in Table XII.

TABLE XII
RADIONUCLIDE CONCENTRATIONS
IN A PROJECTED BNL GLASS MELTER CONDENSATE

Radionuclides	Ci/gal at 1 yr	Ci/gal at 6 yr
Ruthenium	120.0	3.6
Cesium	6.0	3.3
Strontium	2.5	2.0
Yttrium	2.7	2.1
Cerium	11.5	0.1
Promethium	4.7	1.2
Zirconium	0.8	- -
Niobium	1.5	- -
Totals	150.0	12.3

* Type RS-2, defined in Federal Specification SS-A 674b.

(1) C. R. Cooley. Unpublished Data, Pacific Northwest Laboratory, May 6, 1965. (Personal Communication - "Projected Waste Compositions for WSEP Studies")

Estimated radionuclide concentrations in asphalt products, prepared with projected neutralized BNL glass melter condensate, are shown in Table XIII. Since it may be desirable to remove the nitric acid or nitrates

TABLE XIII

ESTIMATED RADIONUCLIDE CONCENTRATIONS IN ASPHALT MIXES
WITH NEUTRALIZED GLASS MELTER CONDENSATE

Radionuclides	Sodium nitrate included 24 gal of asphalt mix per ton of fuel.		Sodium nitrate excluded 14 gal of asphalt mix per ton of fuel.	
	Ci/gal at 1 yr	Ci/gal at 6 yr	Ci/gal at 1 yr	Ci/gal at 6 yr
Ruthenium	100	3.0	171	5.3
Cesium	5.0	2.8	8.6	4.8
Strontium	2.1	1.7	3.6	2.9
Yttrium	2.3	1.7	3.9	3.0
Cerium	9.6	0.1	16.4	0.2
Promethium	3.9	1.0	6.8	1.8
Zirconium	0.6	- -	1.0	- -
Niobium	1.2	- -	2.0	- -
Total	125.0	10.3	213.0	18.0

from the waste because of their detrimental effects, radionuclide concentrations for asphalt products with and without NaNO_3 are listed. A final asphalt product density of 1.5 g/cm^3 and a 60% solids—40% asphalt weight ratio was assumed in all cases. The weights of anhydrous sodium sulfate, sodium nitrate, and sodium phosphate used in the computations (per ton of fuel processed) were 46.9 kg, 33.7 kg, and 2.15 kg, respectively.

Since radioactivity levels in the condensate after 6 yr of aging are near the limit for incorporation in asphalt, possible methods for reducing the radioactivity levels are being studied. These methods include:

1. Storage to permit further decay before incorporation in asphalt.
2. Reduction of radioactivity levels by scavenging and ion exchange.
Recycle separated radionuclides to the glass process.
3. Separation of sulfate (e.g., by $\text{Na}_2\text{SO}_4 \cdot 10 \text{ H}_2\text{O}$ crystallization) from the bulk of the condensate and incorporation in asphalt. Recycle bulk solution containing most of the radioactivity to the glass process.

In-Tank Solidification* - J. Dunn

Exposure of carbon steel and stainless steel steam coils and electrically-heated inconel to three types of concentrated nonboiling underground wastes has continued for over 2500 hr. No appreciable amount of scale and no significant difference in the rate of deposition on the three metals has been detected.

In-plant testing of one 120 kW tubular heater and one 240 kW cartridge unit has been inaugurated. Before conclusive data could be developed, the test of these prototypes was interrupted by failure of an off-gas filter. Testing has been resumed. Meanwhile, the design of the second generation 4 mW concentration unit is being completed by the architect-engineer.

Pumpability has been successfully demonstrated by over two weeks' continuous circulation of a simulated waste slurry concentrated by a factor of 7 as compared to a factor of 4 anticipated in the production plant.

* Not charged to the Division of Reactor Development and Technology.

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