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Transuranium Processing Plant Report of Production, Status, and Plans for the Period October 1, 1978 to September 30, 1980

L. J. King
J. E. Bigelow
E. D. Collins

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TRANSURANIUM PROCESSING PLANT REPORT OF PRODUCTION, STATUS, AND PLANS FOR THE PERIOD OCTOBER 1, 1978 TO SEPTEMBER 30, 1980

L. J. King, J. E. Bigelow, and E. D. Collins

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SUMMARY

This is the 22nd report in a series that is being issued to inform the heavy-element community of the status and future production plans of the Transuranium Element Production Program at ORNL. This report covers the two-year period from October 1, 1978, through September 30, 1980.

During this period, transuranium elements were obtained from 26 irradiated HFIR targets. The products included 86 mg of ^{249}Bk, 686 mg of ^{252}Cf, 3.1 mg of ^{253}Es, and an estimated 1.4 pg of ^{257}Fm. In addition, ~326 mg of high-purity ^{248}Cm was separated from previously purified ^{252}Cf. Several batches of americium and curium were purified and converted to the oxide form, either for use in HFIR targets or for shipment. Approximately 6 g of curium was separated from americium by means of six high-pressure chromatographic ion exchange runs. One hundred seven product shipments were made from TRU; recipients and the amounts of nuclides shipped are listed in Table 2.3. Forty-two standard and two special HFIR targets were fabricated.

During the next 18 months, production totals of 110 mg of ^{249}Bk, 1200 mg of ^{252}Cf, 5.5 mg of ^{253}Es, and 2 pg of ^{257}Fm are anticipated. Also, a total of 225 mg of ^{248}Cm is expected to be made available.

During this report period, a charcoal adsorber system for radioiodine removal was installed, tested, and placed in service. This system serves as a backup to the Hopcalite—charcoal system for adsorption of ^{131}I from the VOG stream.

Seven ^{252}Cf neutron sources were fabricated during this report period. A total of 100 neutron sources have been fabricated previously at TRU. The original and current contents (^{252}Cf and ^{248}Cm) of the existing sources and the individuals to whom the sources are currently loaned are listed in Table 4.1. In addition to neutron sources, nine fission sources were prepared by electroplating ^{252}Cf onto platinum disks or foils.

Special projects during this report period included (1) purification of two batches of isotopically pure ^{240}Pu, (2) fabrication of two special HFIR targets, (3) repurification of the residues of the einsteinium product from Campaign 56, (4) production of ~235 μg of ^{250}Cf by irradiation of ^{249}Bk, (5) radiography of 28 irradiated, stainless steel alloy, fracture-strain specimens, and (6) preparations for the production of 40 μg of ^{254}Es by irradiation of ^{253}Es.

1. INTRODUCTION

This is the 22nd report in a series that is being issued to inform the heavy element community of the status and the future production plans of the Transuranium Element Production Program at ORNL. This report covers the two-year period from October 1, 1978 through September 30, 1980. The transuranium production program has reached a stabilized level at which it is expected to remain in the near future. Long-range plans will be markedly influenced by feed-back from researchers and other users of transuranium elements.

Operations during this report period are summarized and the amounts of materials obtained and shipped are listed. Proposed processing schedules and anticipated yields of various products in the near future are outlined. The original and current contents (^{252}Cf and ^{248}Cm) of existing neutron sources made at the Transuranium Processing Plant (TRU), as well as the individuals to whom these sources are currently loaned, are tabulated. Also, a variety of special projects that required use of the facilities available at TRU are described.

The values of nuclear parameters that were used as input data for the calculations of production rates for transuranium elements, along with a listing of the parameters used to calculate the specific activities of the isotopes that are of interest to TRU, are included in the Appendix of ORNL-5425 (Ref. 1).

2. PROCESSING SUMMARY AND PRODUCTION ESTIMATE

The isotopic concentrations of the various transuranium elements are not constant but are functions of irradiation histories and decay times. One isotope of each element has been selected for use in making material balances for the isotopic mixtures normally handled. Except in special instances, ^{242}Pu, ^{243}Am, ^{244}Cm, ^{249}Bk, ^{252}Cf, ^{253}Es, and ^{257}Fm are the isotopes used for tracing the corresponding elements. Throughout this report, mixtures of isotopes are discussed unless otherwise indicated.

2.1 Processing Summary

Between October 1, 1978, and September 30, 1980, the following operations were accomplished:

1. Two chemical processing campaigns (Nos. 56 and 59) were made to obtain transuranium elements from 26 High Flux Isotope Reactor (HFIR)-irradiated targets plus rework material. Products from these campaigns are listed in Table 2.1.
2. Sixteen packages containing a total of 277 g of curium (204 g of ^{244}Cm) in the oxide form were received from the Savannah River Laboratory (SRL). This material is part of the Californium-I campaign product that was recovered at TRU in the early seventies and shipped to SRL in 1972. The material was returned to TRU for use in HFIR targets as the result of a swap for a similar quantity of curium from the Space Nuclear Systems (SNS) program. During this report period, four packages of the oxide were dissolved and processed to separate the ingrown ^{240}Pu daughter (21 g). Approximately 76 g of curium was obtained and was combined with the Campaign 59 curium product for preparation of HFIR targets.
3. A batch of "light" curium (92.94% ^{244}Cm), obtained from the Fission Products Development Laboratory at ORNL, was purified and converted to the oxide form for use in several special shipments. The oxide product contained a total of 31 g of curium. Approximately 11 g of plutonium (99.943% ^{240}Pu) was obtained as a by-product. Also, a batch of americium oxide obtained from the Savannah River Plant (SRP) was dissolved, purified, and converted to the oxide form for use in HFIR targets. The product oxide contained a total of 132 g of ^{243}Am. All of this work was designated as TRU Campaign No. 57.
4. Six SRP-irradiated ^{241}Am slugs were dissolved and processed to separate 16 g of ^{238}Pu from the americium-curium fraction. This material will be processed further to recover approximately 3 g of curium that contains a high concentration (8%) of ^{243}Cm. This work has been designated as TRU Campaign No. 58.

Table 2.1. Amounts of materials obtained in the major campaigns in the Transuranium Processing Plant during the period October 1, 1978 — September 30, 1980

	Campaign No. 56	Campaign No. 59
Completion date	February 1979	February 1980
Material processed	13 CF-I Cm-HFIR targets, plus rework material	5 TRU Cm-HFIR targets, 8 Cf-I Cm-HFIR targets plus Cf-I curium oxide and rework material.
Amounts obtained:		
^{243}Am, g[a]	3	14
^{244}Cm, g[a]	21 (60)[b]	57 (113)[b]
^{249}Bk, mg	32	54
^{252}Cf, mg	322	364
^{253}Es, mg	0.8[c]	2.3[c]
^{257}Fm, pg	0.6[d]	0.8[d]

[a]Americium and curium are not usually separated from each other.
[b]The amount shown in parentheses is total curium.
[c]Before final purification.
[d]Estimated.

5. A fraction of the Campaign 59 americium-curium product solution, containing about 1.7 g of americium and 6.3 g of curium, was processed by means of six high-pressure chromatographic ion exchange runs to separate the actinides. A product was recovered that contained approximately 75% of the curium and only 17 mg of americium; this represents a separation factor of 300. The purified curium was converted to the oxide form by the oxalate precipitation—calcination technique.
6. Three batches (Nos. 25, 26, and 27) of ^{248}Cm were separated from the parent ^{252}Cf. The purification of Batch 25 was completed and 106 mg of ^{248}Cm was obtained. Batches 26 and 27, containing approximately 220 mg of ^{248}Cm, await final purification.

7. Forty-two HFIR targets were fabricated from curium oxide and/or americium oxide in the form of mixed oxide-aluminum pellets that had been pressed to 80% of the theoretical density of the pellet core. Actinide loadings and isotopic compositions are shown in Table 2.2.

8. One hundred seven shipments were made. Recipients and the amounts of nuclides shipped are listed in Table 2.3.

2.2 Irradiation and Processing Proposals

Two chemical processing campaigns per year are planned to obtain transuranium elements from irradiated HFIR targets. The estimated production of transcurium elements from the campaigns that are scheduled through March 1982 are outlined in Table 2.4. Projected estimates for the remainder of FY 1982 and FY 1983 are based on current trends.

2.3 Estimates of the Availability of Transcurium Elements

The amounts of transcurium elements expected from each campaign are shown in Table 2.4. During the next 18 months, we expect to recover a total of 110 mg of ^{249}Bk, 1200 mg of ^{252}Cf, 5.5 mg of ^{253}Es (in a mixture of isotopes), and 2 pg of ^{257}Fm. The following steps were used to estimate these amounts: (1) calculation of the amounts of transcurium elements in each group of targets at the time of reactor discharge by means of our computer code, (2) addition of the assumed amounts of rework feed, and (3) application of the assumed chemical yield factors and net decay factors for the assumed recovery times to the amounts of total feed (targets plus rework). The assumed chemical yields and recovery times are based on past performance data [the most recently revised data are listed in Table 2.3 of ORNL-5305 (Ref. 2)].

Curium-248, a valuable research material, is formed by alpha decay of ^{252}Cf. On September 30, 1980, TRU held the inventory of purified californium shown in Table 2.5. At appropriate times, a group of packages and/or unneeded pellets or neutron sources will be processed to separate the californium and curium. The curium thus obtained is considered to be

Table 2.2. Summary of HFIR targets fabricated in the Transuranium Processing Plant during the period October 1, 1978 — September 30, 1980

Source of material	Campaign 54	Campaign 56	Campaign 57A	Campaign 57B	Campaign 59	Campaign 54/59[a]
No. of targets fabricated	8	7	7	7	12	1
Avg. actinide content, g/target	9.22	8.37	9.22	9.51	9.10	9.36
Isotope	Atom % (neglecting impurities)					
^{240}Pu	1.087	0.297[b]	0.061	0.176	0.564[c]	1.87
^{241}Am		0.300	0.012	0.425	0.199	0.308
^{243}Am	20.81	18.09	97.67	90.00	10.75	15.59
^{244}Cm	28.91	29.24	2.09	8.70	43.98	35.55
^{245}Cm	0.314	0.335	0.025	0.103	0.445	0.381
^{246}Cm	41.86	43.50	0.132	0.576	37.51	39.53
^{247}Cm	1.124	1.231	0.002	0.011	0.977	1.05
^{248}Cm	5.90	7.00	0.001	0.006	5.58	5.72
Total	100.005	99.993	99.993	99.997	100.005	99.999

[a]Target composed of 17 pellets from Campaign 54 and 18 pellets from Campaign 59.

[b]One of the Campaign 56 targets (R43) was completed at a later date and contained more ^{240}Pu (0.527%) and less ^{244}Cm (29.01%).

[c]Five of the Campaign 59 targets (R69 through R73) were completed at a later date and contained more ^{240}Pu (0.844%) and less ^{244}Cm (43.70%).

Table 2.3 Distribution of heavy elements from the Transuranium Processing Plant during the period October 1, 1978 — September 30, 1980

Major nuclide	Date shipped	TRU file number	Shipped to: Recipient	Site
^{240}Pu, g				
0.134	01-10-79	1004	IRML[a]	HEDL
0.167	11-02-79	1032	R. W. Hoff	LLNL
0.049	11-02-79	1033	C. W. Reich	EG&G Idaho
29.01	11-06-79	1068	IRML[a]	LANL and HEDL
29.360				
^{242}Pu, g				
0.151	12-11-79	1075	S. Katcoff	BNL
^{241}Am, g[b]				
17.64	02-16-79	988	Isotopes Sales	ORNL
^{243}Am, g				
0.10	02-16-79	1016A	Isotopes Sales	ORNL[c]
2.03	02-22-79	1014B	IRML[a]	LLNL
0.16	03-09-79	1014A	R. W. Hoff	LLNL
0.05	03-15-79	1017	C. W. Reich	EG&G Idaho
2.3	03-27-79	1029	IRML[a]	LLNL
5.94	04-05-79	1020	Operations Div.	Karlsruhe
20.0	05-31-79	986B	L. R. Morse	U. of Liege
0.10	08-01-79	1019	Isotopes Sales	BCNM, Belgium
10.14	11-06-79	1018	IRML[a]	LANL
2.08	09-26-80	1105	R. L. Hahn	ORNL
42.90				
Curium (mixed), g				
142.04	10-13-78	987	A. R. Boulogne	SRL
0.040	02-01-79	1006	L. W. Reynolds	SRL
0.002	05-02-79	1030	S. E. Dismuke	ORNL
0.57	09-04-79	1047	Isotopes Sales	ORNL[c]
0.032	09-11-79	1048	G. W. Beall	ORNL
0.010	10-16-79	1062A	S. Katz	ORNL
0.010	01-14-80	1062C	S. Katz	ORNL
2.093	03-03-80	1046A	IRML[a]	ORNL
10.75	03-05-80	1045	R. W. Hoff	LLNL
0.002	04-22-80	1091	M. M. Abraham	ORNL
155.55				

Table 2.3. (continued)

Major nuclide	Date shipped	TRU file number	Shipped to: Recipient	Site
^{243}Cm (56%), mg				
5.0	01-29-79	1008A	J. J. Thompson	Lovelace Found.
10.0	02-02-79	1008B,C	J. J. Thompson	Lovelace Found.
0.1	02-02-79	1009	W. T. Carnall	ANL
1.0	02-02-79	1010	R. A. Penneman	LANL
(1.1 ng)	11-15-79	1073	J. F. Emery	ORNL
1.0	07-02-80	1090A	M. M. Abraham	ORNL
5.2	09-26-80	1011	IRML[a] for	HAIE[d]
22.3				
^{245}Cm (99%), μg				
92	01-25-79	991	R. W. Hoff	LLNL
2.2	06-05-79	1037	J. K. Dickens	ORNL
94.2				
^{248}Cm (97%), mg				
20.04	05-31-79	986A	L. R. Morse	Univ. of Liege
0.52	05-31-79	1034A	IRML[a]	Yale Univ.
13.42	06-14-79	985B	R. G. Haire	ORNL
0.507	06-29-79	1034B	IRML[a]	Yale Univ.
0.101	07-30-79	1042	J. H. Hamilton	Darmstadt
0.802	09-18-79	1034C	IRML[a]	Yale Univ.
0.097	10-08-79	1064	J. M. Peele[c]	ORNL
0.489	10-09-79	1034E	Isotopes Sales	GSI-Darmstadt
19.95	11-12-79	1055	W. T. Carnall	ANL
19.95	11-12-79	1057	R. W. Hoff	LLNL
0.036	11-28-79	1039	D. W. Hayes	SRL
19.95	11-28-79	1056	N. M. Edelstein	LBL
23.8[e]	12-18-79	1071	R. W. Hoff	LLNL
0.478	01-10-80	1034F	Isotope Sales	GSI-Darmstadt
19.95	02-12-80	1059	R. G. Haire	ORNL
140.090				
^{249}Bk, mg				
6.296	03-05-79	1022	W. T. Carnall	ANL
6.296	03-05-79	1023	N. M. Edelstein	LBL
6.296	03-06-79	1024	R. W. Hoff	LLNL
6.693[f]	05-25-79	1035	R. G. Haire	LANL
6.374[f]	05-25-79	1036	R. G. Haire	ORNL
3.0[f]	07-09-79	1040A	J. W. Ward	LANL
0.001	08-03-79	1038	Isotopes Sales	India
8.879	05-20-80	1085	W. T. Carnall	ANL
8.879	05-20-80	1087	R. W. Hoff	LLNL
7.419	06-02-80	1086	N. M. Edelstein	LBL
9.164	07-05-80	1089	R. G. Haire	ORNL
69.297				

Table 2.3. (continued)

Major nuclide	Date shipped	TRU file number	Shipped to: Recipient	Site
^{249}Cf, mg				
17.538[f]	11-02-78	1000	R. G. Haire	ORNL
0.245	01-09-79	1001	C. W. Reich	EG&G Idaho
2.56	01-19-79	996	W. T. Carnall	ANL
2.56	01-19-79	997	N. M. Edelstein	LBL
2.56	01-22-79	998	R. W. Hoff	LLNL
1.0[f]	07-09-79	1040B	J. W. Ward	LANL
1.23	12-03-79	1072	J. K. Dickens	ORNL
0.001	06-30-80	1094	Isotope Sales	IPL[g]
27.694				
^{250}Cf (85%), mg				
0.232	08-20-79	1051	J. G. Conway	LBL
^{252}Cf, mg				
0.0118 (NSD-105)	12-08-79	980	E. H. Gupton	ORNL
0.010	01-17-79	1005	IRML[a]	Germany
2.623 (NS-100)	02-27-79	929	V. Spiegel	NBS
0.0117	03-21-79	1027	IRML[a]	Karlsruhe
0.0112	03-21-79	1028	IRML[a]	ORNL
1.909 (NSD-106)	05-04-79	989	S. Untermyer	HEDL
42.414	05-23-79	975	A. R. Boulogne	SRL
0.0026	07-30-79	1031	IRML[a]	HEDL
42.900	08-17-79	1041	A. R. Boulogne	SRL
37.312	09-18-79	1052	A. R. Boulogne	SRL
36.764	10-04-79	1053	A. R. Boulogne	SRL
36.499	10-15-79	1054	A. R. Boulogne	SRL
38.018	11-09-79	1069	W. H. Brotherton, Sr.	SRL
37.741	01-04-80	1070	W. H. Brotherton, Sr.	SRL
0.206 (NZD-31)	01-24-80	1079	F. J. Muckenthaler	ORNL
0.001	01-25-80	1065	IRML[a]	ORNL
21.832 (NSD-107)	02-05-80	1074	J. F. Schulze	SNL
0.088 (NSD-78)	04-07-80	1063A	J. H. Eaves	UNC Ind.
0.00137 (SR-Cf-260C)	04-07-80	1063B	J. H. Eaves	UNC Ind.
0.0275	04-24-80	1092	IRML[a]	ORNL
0.567	06-18-80	1080	R. J. Gehrke	EG&G Idaho
0.00016 (FS-3)	07-03-80	1099	J. T. Mihalczo	ORNL
1.240 (NZD-44)	07-17-80	951	R. C. Hagenauer	NBL[h]
0.00045 (FS-4)	07-22-80	1100	J. T. Mihalczo	ORNL
29.715	08-12-80	1101	R. B. Pagett	SRL
14.189 (NSD-102)	09-10-80	943A	R. J. Cloutier	ORAU
15.729 (NSD-103)	09-10-80	943B	R. J. Cloutier	ORAU
359.824				

Table 2.3. (continued)

Major nuclide	Date shipped	TRU file number	Shipped to: Recipient	Site
^{253}Es (mixed), μg				
110	02-13-79	1012	W. T. Carnall	ANL
414	02-13-79	1013	R. G. Haire	ORNL
451	02-08-80	1081	W. T. Carnall	ANL
248	02-20-80	1082A	R. G. Haire	ORNL
400	02-29-80	1082B	R. G. Haire	ORNL
5	06-27-80	1096	R. W. Hoff	LLNL
1628				
^{254}Es, μg				
0.0009	10-15-79	1066	R. G. Haire	ORNL
3	11-27-79	1060	M. M. Abraham	ORNL
0.22	06-19-80	1097	R. W. Hoff	LLNL
3.2209				
^{257}Fm, pg				
1	06-27-80	1098	R. W. Hoff	LLNL

[a]Isotopes Research Materials Laboratory (ORNL). In some instances material was forwarded to another site.
[b]Not a TRU product. Material purified and returned to inventory.
[c]For dispensing small orders.
[d]Joint US/UK Higher Actinides Irradiation Experiment.
[e]Material contained more ^{244}Cm (0.165%) than typical high-purity ^{248}Cm.
[f]Contains some material previously allocated to LANL and ORNL.
[g]Isotope Products Laboratories.
[h]New Brunswick Laboratory of the DOE at Argonne, IL.

Table 2.4. Estimated future production of transcurium elements

Time period	Processing campaign	Products of campaigns				^{252}Cf production[b]		Date products available
		^{249}Bk (mg)	^{252}Cf (mg)	^{253}Es[a] (μg)	^{257}Fm (pg)	During the period (mg)	Cumulative (mg)	
Through September 1980							3792[b]	
October 1980 — September 1981	10 Cf-I Cm-HFIR Targets 3 TRU Cm-HFIR Targets	45	500	2600(0)	1			November 1980
	8 Cf-I Cm-HFIR Targets 2 TRU Cm-HFIR Targets	34	370	1500(0)	0.6	870	4662	April 1981
October 1981 — March 1982	13 TRU Cm-HFIR Targets	31	330	2400(0)	0.5	330	4992	January 1982
April 1982 — September 1982						350	5342	
FY 1983						700	6042	

[a]Amounts from initial separation. Amounts "milked" from californium product fraction after decay period are given in parentheses.

[b]Californium produced in SRP irradiations is not included in production totals. A total of 720 mg was recovered from 164 SRP slugs and 21 SRP tubes processed between November 1970 and January 1973.

high-purity ^{248}Cm; the typical isotopic composition is 97% ^{248}Cm, 3% ^{246}Cm, and 0.01% ^{244}Cm. The ^{246}Cm is produced by the decay of ^{250}Cf, which is present in the californium. We expect to make available 150 mg of the high-purity ^{248}Cm in FY 1982 and 75 mg in early FY 1983.

Table 2.5. Inventory of purified californium-252

Container		Content on September 30, 1980	
Type	Number	^{252}Cf (mg)	^{248}Cm (mg)
Stored packages	30	720	384
^{252}Cf pellets	8	24	29
Neutron sources	83	143	329
		887	742

3. PROCESSES AND EQUIPMENT

A new vessel off-gas (VOG) charcoal adsorber system has been installed in a pit south of the TRU building and has been tested and placed in service. This system, illustrated schematically in Fig. 3.1, consists of two parallel trains, each containing a small electrical-resistance heater, a flow rate element, housings for two standard, replaceable charcoal beds, and a HEPA filter. The new system is being used as a "backup" to the Hopcalite-charcoal iodine retention system, which is located upstream in the VOG. The filter and charcoal beds were not installed in one train so that it could be used as a bypass path during periods between campaigns when there is no ^{131}I entering the VOG and the Hopcalite-charcoal system is bypassed.

4. CALIFORNIUM NEUTRON SOURCES

Some of the recovered californium is incorporated into neutron sources, which are subsequently loaned to researchers. Data for existing neutron sources fabricated at TRU are listed in Table 4.1. Most of the sources were fabricated into one of the four standard models illustrated in Fig. 4.1 of ORNL-4921 (Ref. 3) and are designated in the table by a three-letter prefix.

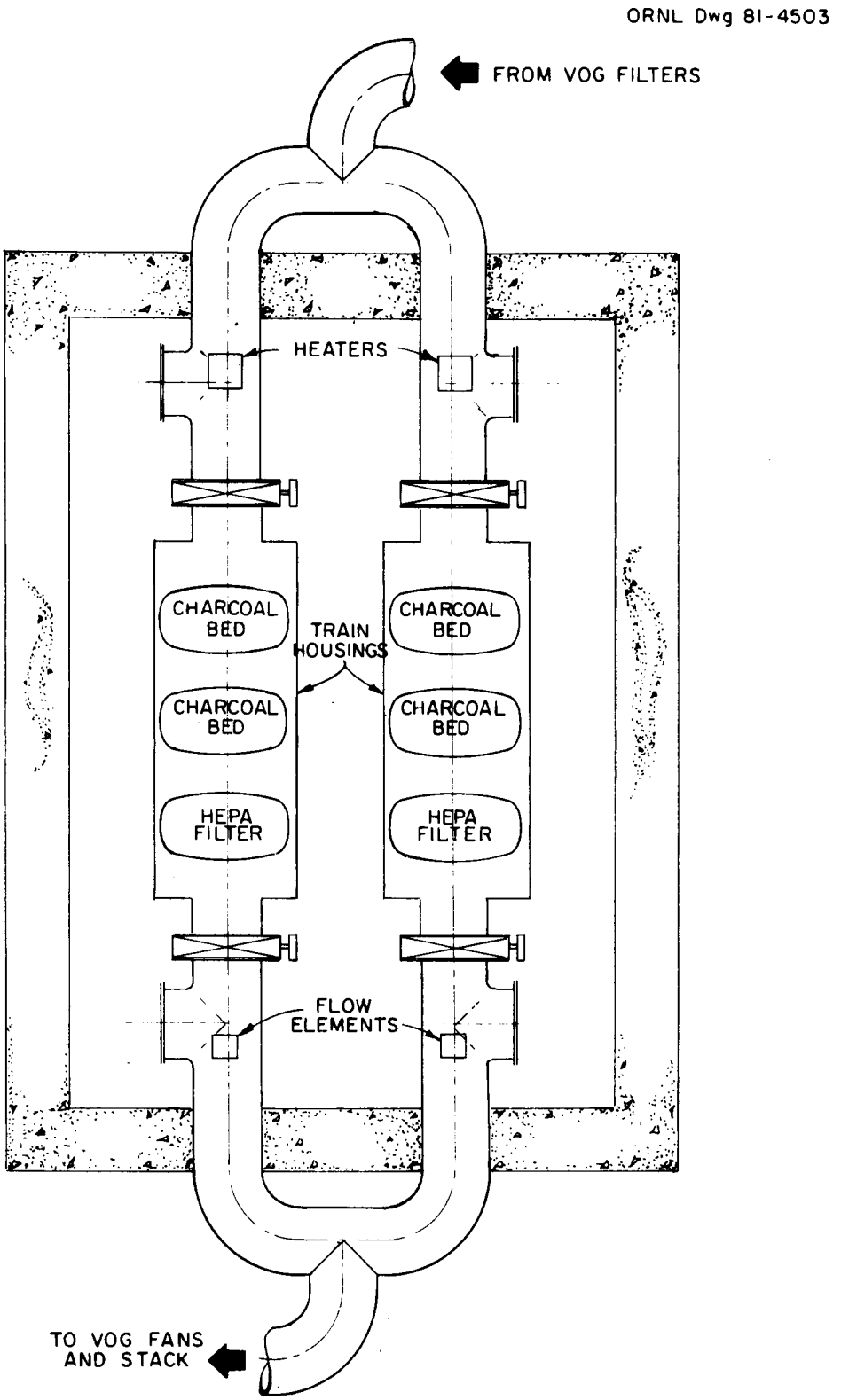

Fig. 3.1. Schematic diagram of vessel off-gas (VOG) charcoal adsorber system.

Table 4.1. Data for neutron sources prepared at TRU

Source	Date of calib.	^{252}Cf Content at calib. (μg)	Content as of 9/30/80 ^{252}Cf (μg)	Content as of 9/30/80 ^{248}Cm (μg)	On loan to: Individual	On loan to: Site
NS-1[a]	08-28-68	316	13	b	K. L. Swinth	PNL
NS-2	08-23-68	275	12	b	c	
NS-3	05-13-69	~90	~5	b	J. D. Burger	ORAU
NS-4	07-09-69	883	47	798	C. F. Masters	LANL
NS-5[d]	08-14-69	1049	57	950	C. W. Ricker	ORNL
NS-6	11-21-69	747	43	671	R. W. Hoff	LLNL
NS-7	01-21-70	789	48	707	F. R. Chattin	ORNL-TRU
NS-8	12-17-69	1839	109	1650	H. Berger	ANL
NSD-9	04-17-70	1720	111	1547	N. D. Wogman	PNL
NSS-10	03-11-70	113	7	b	J. P. Balagna	LANL
NS-11	03-10-70	8	1	b	R. R. Fullwood	LANL
NSS-12	06-30-70	1868	127	1697	R. W. Hoff	LLNL
NSD-13	03-19-71	4649	382	4081	H. O. Menlove	LANL
NSS-14	06-29-70	4615	314	4197	M. C. Davis	Northwestern U
NS-15[e]	06-25-70	864	59	782	A. W. Blackstock	LANL
NSS-17	08-31-71	4886	452	4228	L. W. Dahlke	SNL-Livermore
NS-18[d]	06-24-70	960	65	869	K. H. Valentine	ORNL
NSS-19	06-26-70	493	34	447	J. E. Bigelow	ORNL-TRU
NSD-20	07-01-70	630	43	573	J. E. Powell	SNL
NSS-21	10-21-70	18	1	b	F. Cross	PNL
NSD-24	10-15-70	6	<1	b	c	
NS-25	11-09-70	58	4	b	F. J. Muckenthaler	ORNL
NSD-26	02-11-71	14	1	b	H. O. Menlove	LANL
NSD-27	01-29-71	2528	201	2271	c	
NSD-28	02-12-71	11	1	b	E. E. Hicks	Rocky Flats
NSD-29	09-10-71	11393	1062	9852	S. G. Snow	Y-12
NSD-30	03-31-71	876	73	776	c	
NZD-31	11-23-71	1731	170	1545	F. J. Muckenthaler	ORNL
NZD-34	11-23-71	1924	189	1717	W. G. Spear	HEDL
NZD-35	11-23-71	1896	186	1692	N. Clark	U of Costa Rica
NS-36[d]	03-23-71	2070	171	1823	Y. D. Harker	EG&G Idaho

Table 4.1. (continued)

Source	Date of calib.	^{252}Cf Content at calib. (μg)	Content as of 9/30/80 ^{252}Cf (μg)	Content as of 9/30/80 ^{248}Cm (μg)	On loan to: Individual	On loan to: Site
NSD-37	09-04-71	9838	913	8511	R. W. Perkins	PNL
NSD-38	06-16-71	102	9	b	H. O. Menlove	LANL
NSD-40	04-27-72	1154	127	997	J. P. Balagna	LANL
NSD-41	11-08-71	5117	475	4302	c	
NSD-42	11-02-71	4434	420	3802	c	
NSD-43	04-20-72	4839	523	4111	c	
NZD-44	05-15-72	10429	1162	8922	R. C. Hagenauer	New Brunswick Lab
NSD-45	08-18-71	1776	163	1538	K. L. Swinth	PNL
NSD-46	04-23-72	62	69	542	H. O. Menlove	LANL
NSD-47	07-14-71	200	18	181	P. L. Johnson	Mound
NSD-48	07-14-71	194	17	176	A. C. England	ORNL
NSD-49	07-14-71	199	18	180	L. J. Esch	KAPL
NS-50	08-23-71	138	13	129	S. G. Carpenter	ANL-NRTS
NSD-51	11-02-71	365	35	320	J. H. Eaves	Un. Nucl. Ind.
NSD-52	09-02-71	280	26	242	E. D. Clayton	PNL
NSD-53	10-25-71	1051	101	916	L. J. Esch	KAPL
NS-54	01-19-73	3187	424	3334	V. Spiegel	NBS
NSD-55	04-19-72	4	<1	b	L. J. Esch	KAPL
NSD-56	04-19-72	124	14	105	M. M. Bretscher	ANL
NSD-57	04-14-72	973	106	833	J. P. Balagna	LANL
NZD-58	05-15-72	10849	1208	9193	c	
NS-59[d]	07-13-72	53	6	b	G. E. Hanson	LANL
NSD-60	04-11-72	21	2	b	H. W. Dickson	ORNL-DOSAR
NSD-61	01-19-73	5225	696	4319	L. J. Esch	KAPL
NSS-62	03-27-73	3755	525	3081	J. E. Bigelow	ORNL-TRU
NSD-63	04-21-72	847	93	729	H. O. Menlove	LANL
NSD-64	07-19-73	193	29	157	H. O. Menlove	LANL
NS-65	07-09-73	114	17	92	L. Green	BAPL
NSD-66	08-02-73	3449	528	2833	J. E. Powell	SNL
NSD-67	06-07-76	13501	4360	8847	H. G. Rieck	PNL

Table 4.1. (continued)

Source	Date of calib.	^{252}Cf Content at calib. (μg)	Content as of 9/30/80 ^{252}Cf (μg)	Content as of 9/30/80 ^{248}Cm (μg)	On loan to: Individual	On loan to: Site
NSD-68	06-07-76	16838	5437	11034	H. G. Rieck	PNL
NSD-69	06-07-76	16775	5417	10993	H. G. Rieck	PNL
NSD-70	06-10-76	22748	7362	14939	H. G. Rieck	PNL
NSD-71	07-15-76	21319	7075	14357	H. G. Rieck	PNL
NSD-72	07-15-76	16602	5509	11180	H. G. Rieck	PNL
NSD-73	09-11-73	13545	2129	11416	c	
NSD-74	09-11-73	4416	694	3722	c	
NS-75	10-01-73	1919	307	1645	J. H. Elliott	LLNL
NSD-76	03-09-74	434	78	380	c	
NSD-77	03-09-74	433	78	380	c	
NSD-78	03-09-74	429	77	350	J. H. Eaves	Un. Nucl. Ind.
NS-79	10-02-74	1650	343	1293	V. Spiegel	NBS
NSD-80	06-03-74	5966	1126	4805	c	
NSD-81	06-03-74	6364	1200	5119	c	
NS-82	05-19-75	14264	3333	9906	G. Tessler	BAPL
NS-83	09-24-75	11783	3114	8383	G. Tessler	BAPL
NS-84	09-30-75	12674	3274	8730	G. Tessler	BAPL
NS-85	10-22-75	12181	3331	8882	G. Tessler	BAPL
NS-86	11-17-75	2620	731	1950	V. Spiegel	NBS
NSD-87	10-15-75	22387	6103	16276	c	
NSD-88	08-28-75	9528	2510	6693	R. L. Ullrich	ORNL
NSD-89	04-23-75	12599	3051	9622	c	
NZS-90	01-16-75	0.87	<1	b	J. R. Smith	ANC
NSD-91	09-26-75	15	4	b	L. J. Esch	KAPL
NS-92	06-24-76	2960	968	1963	V. Spiegel	NBS
NSD-93	01-29-74	500	87	397	J. P. Balagna	LANL
NSD-94	03-09-77	1544	607	903	F. M. Clikeman	Purdue
NSD-95	03-09-77	1537	605	899	F. M. Clikeman	Purdue
NSD-96	03-09-77	1194	469	698	F. M. Clikeman	Purdue
NSD-97	03-09-77	1399	550	818	F. M. Clikeman	Purdue

Table 4.1. (continued)

Source	Date of calib.	^{252}Cf Content at calib. (μg)	Content as of 9/30/80 ^{252}Cf (μg)	Content as of 9/30/80 ^{248}Cm (μg)	On loan to: Individual	On loan to: Site
NSD-98	09-30-75	8000	2157	5753	J. L. Fuller	HEDL
NSD-99	09-21-77	715	324	394	C. A. Strand	HEDL
NS-100	11-04-77	3664	1712	1887	V. Spiegel	NBS
NSD-101	05-24-76	24136	7716	15658	c	
NSD-102	09-03-80	14189	13917	7566	R. J. Cloutier	ORAU
NSD-103	09-03-80	15729	15427	8387	R. J. Cloutier	ORAU
NSD-104	08-10-78	944	539	409	f	
NSD-105	08-15-78	11	6	b	E. H. Gupton	ORNL
NSD-106	10-12-77	2754	1266	1539	G. P. Gottshalk	HEDL
NSD-107	01-30-80	21832	18327	4118	J. F. Schulze	SNL
MRC-Cf-46[g]	11-13-79	28	22	b	c	
SR-Cf-167[h]	05-26-71	3975	339	3624	c	

[a] This source is encapsulated in aluminum.

[b] This source is not suitable for recovery of ^{248}Cm.

[c] This source is held at ORNL and is available for reissue.

[d] This source is encapsulated in Type 405 stainless steel.

[e] This source has an inner capsule of Type 405 stainless steel and an outer capsule of Type 304L stainless steel.

[f] This source is being held for J. P. Cusimano of the Idaho Center for Radiological and Environmental Sciences.

[g] Fabricated by Monsanto Research Corporation.

[h] This source was fabricated in standard Savannah River SR-Cf-100 series hardware.

Non-standard sources are designated simply "NS- ". The three-letter prefix used for a standard source indicates whether it is singly or doubly encapsulated and whether it is fabricated from type 304L stainless steel or from Zircaloy-2. The characteristics of standard source capsules are listed in Table 4.2 of ORNL-4921 (Ref. 3).

4.1 Sources Fabricated During October 1978 — September 1980

Seven ^{252}Cf neutron sources were fabricated during this report period. One of these (NS-100) was fabricated in a non-standard form specified by the user. The other six (NSD-102 through NSD-107) were doubly encapsulated in the standard form.

4.2 Used Sources Returned to TRU

A number of neutron sources are returned to TRU when the projects for which they were requested are completed or when replacement sources are ordered to make up for decay of the ^{252}Cf. The returned sources are available for reassignment until the appropriate time for reprocessing to recover the ingrown ^{248}Cm. During this report period, eighteen sources were returned to TRU. Currently, nineteen sources are in the "available" category and are so designated in Table 4.1.

4.3 Electroplated ^{252}Cf Fission Sources

Procedures were developed to allow the electroplating of various amounts of purified ^{252}Cf from dry isopropanol solutions onto platinum foils or disks. Nine fission sources, ranging in size from 0.16 to 339 μg, of ^{252}Cf were prepared. A modified electroplating cell was designed, built, and tested. In this cell, a brass heat sink was used to minimize the formation of gas bubbles in the plating solution, and an insulating mask was used to confine the californium deposit to a circular area of the desired size. The anode-to-cathode plating voltage has ranged from 600 to 1100 V and, in some cases, the appropriate plating time was determined by trial platings of ^{238}U. After completion of the plating, the deposits were flamed to red heat to enhance adherence of the californium to the platinum.

5. SPECIAL PROJECTS

The primary functions of TRU are (1) to fabricate targets for irradiation in the HFIR to produce transuranium elements and (2) to isolate and purify transuranium elements for use by research workers. However, the facilities that are available[4] are also used for a variety of other purposes, such as nonroutine production, special preparations, and special irradiations in HFIR. In each case, a unique service can be provided to assist a research program at ORNL or another site.

5.1 Purification of ^{240}Pu

Two batches of isotopically pure ^{240}Pu were isolated during the purification of aged ^{244}Cm in Campaigns 55 and 57. These two batches, which contained about 20 and 10 g of ^{240}Pu, respectively, were purified further by means of the nitrate-based anion exchange process and were converted to the oxide form by means of the oxalate precipitation–calcination technique. Both batches were transferred to the ORNL Isotopes Research Materials Laboratory for dispensing. About 10 g was destined for use in a precision reactivity measurement in the "Big 10" reactor at Los Alamos National Laboratory (LANL), about 8 g was committed to Hanford Engineering Development Laboratory (HEDL) for fast neutron dosimetry, and the remainder was made available for miscellaneous uses and sales.

Approximately 250 mg of the ^{240}Pu from the Campaign 57 batch was purified more extensively by means of both anion and cation exchange runs. The remaining radiochemical impurity in the final product was predominantly ^{238}Pu, which represented about 1% of the activity. The isotopic analysis is shown in Table 5.1. This material was divided into two batches that were shipped to Lawrence Livermore National Laboratory (LLNL) and EG&G Idaho for use in studies of the gamma-ray spectrum of ^{240}Pu.

Table 5.1. Isotopic Analysis of ^{240}Pu Sample[a]

Isotope	Atom %
^{238}Pu	0.014
^{239}Pu	0.023
^{240}Pu	99.930
^{241}Pu	0.003
^{242}Pu	0.029
^{244}Pu	0.001

[a]Date of analysis: July 24, 1979 (sample PU-PP-257A).

5.2 Fabrication of Special Targets

Two special HFIR targets (R39 and R61) were fabricated for the ORNL Operations Division. Target R61 contained 4 g of isotopically separated ^{118}Sn, encapsulated in a quartz ampul, which was carefully sized to fit the aluminum target rod tubing. Target R39 contained a similar amount of ^{118}Sn plus a second ampul containing 1 g of ^{54}Fe. These targets were irradiated in the HFIR flux trap to make some high-specific-activity ^{119m}Sn and ^{55}Fe.

5.3 Repurification of Campaign 56 Einsteinium

At the request of the Transplutonium Program Committee, all the residues resulting from the Campaign 56 einsteinium product were collected, concentrated, and recovered. These residues included most of the material that had been shipped to ORNL researchers. The residues were concentrated by evaporation and were purified by ion exchange techniques. The final product contained 2.97 μg of ^{254}Es and 3.1 ng of ^{255}Es. These amounts represented about 75% of the material contained in the original Campaign 56 einsteinium product.

5.4 Production of ^{250}Cf

Approximately 235 μg of ^{250}Cf was produced by irradiation of ^{249}Bk in the HFIR Hydraulic Rabbit Facility and was recovered and purified at TRU. Prior to the irradiation, approximately 1.2 mg of ^{249}Bk was purified, using

a micro-separations column, to remove the ingrown ^{249}Cf. The purified ^{249}Bk was blended with magnesium and loaded onto Dowex 50 resin beads, which were dried, calcined, and mixed with aluminum powder. The mixture was pressed into three pellets that were heat treated to remove volatile impurities and then encapsulated in a HFIR rabbit.

The rabbit capsule was irradiated for 20 h and allowed to cool 9 h before it was transferred to Shielded Cave B at TRU via the hydraulic transfer tube. The ^{250}Bk in the irradiated rabbit caused a radiation reading of 8 mR/h at the face of the cave window. The rabbit capsule was opened by sawing off both ends and pushing out the pellets.

The aluminum pellet matrix was dissolved in a caustic solution, from which the magnesium-berkelium microspheres were recovered by filtration. The microspheres were dissolved from the filter frit by small additions of 1 M HNO_3. The solution was diluted to 0.2 M HNO_3 and was processed by means of a high-pressure ion exchange run to separate the californium from the berkelium and most of the fission products. The neutron probe failed during the run; however, the run was still well-executed since the movement of the berkelium band could be easily followed by means of the gamma probe which was used to detect the intense radiation from ^{250}Bk (even 35 h after discharge). The californium fraction was concentrated and purified by means of a cation exchange cleanup run. The product solution was evaporated in a quartz cone and packaged for shipment to LBL. The final product consisted of 274 μg of californium, with the following isotopic composition (as of August 23, 1979): 4.79% ^{249}Cf, 86.78% ^{250}Cf, 7.42% ^{251}Cf, 1.01% ^{252}Cf, <0.001% ^{253}Cf, and <0.02% ^{254}Cf.

After decay of the ^{250}Bk, the ^{249}Bk residue was recovered and purified. The amount of ^{249}Bk recovered was 718 μg.

5.5 Radiography of Stainless Steel Specimens

Twenty-eight irradiated, stainless steel alloy, fracture-strain specimens were radiographed remotely, using the TRU target fabrication facilities. This service was performed because the TRU facilities contain

an x-ray machine capable of operating at 80 kV. The machine normally used for post-irradiation examination (50 kV) was not adequate for these examinations. A special effort was required to prevent contamination of the specimens with ^{244}Cm or ^{252}Cf while they were in the TRU cells.

5.6 Preparation for Production of 40 μg of ^{254}Es

Under normal conditions, the ground-state isomer of ^{254}Es (half-life = 276 d) would be very difficult to produce by neutron irradiation in the HFIR because the isomer has a thermal neutron fission cross section of 3000 b; thus, the effective half-life in the HFIR would be only about 1.3 d. The production of ^{254}Es relative to ^{253}Es possibly may be enhanced via capture and fission occurring in the epithermal region if the thermal neutrons can be filtered out with a material such as cadmium. Calculations have predicted that the production ratio of ^{254}Es to ^{253}Es in a standard HFIR target could be increased by a factor of 10.

However, currently available values for the thermal and epithermal capture cross sections of ^{253}Es leading to ^{254}Es are not consistent with the observed production of ^{254}Es. Thus, our present effort is directed toward making a new measurement of these capture cross-sections in the HFIR, using the hydraulic rabbit facility. This task is vastly more complex than it would be in a reactor operated at a lower flux. A HFIR rabbit with a cadmium insert that should meet the exacting requirements has been designed, fabricated, and leak-tested. This rabbit is now ready for a test irradiation.

6. DECAY AND NEUTRON CROSS-SECTION DATA

The values that we are currently using for transuranium element decay data and for cross-section data in planning irradiation-processing cycles, calculating production forecasts, and assaying products are tabulated in the appendix of ORNL-5415 (Ref. 1).

7. REFERENCES

1. L. J. King, J. E. Bigelow, and E. D. Collins, Transuranium Processing Plant Semiannual Report of Production, Status, and Plans for Period Ending December 31, 1977, ORNL-5415 (August 1978).

2. L. J. King, J. E. Bigelow, and E. D. Collins, Transuranium Processing Plant Semiannual Report on Production, Status, and Plans for Period Ending December 31, 1976, ORNL-5305 (October 1977).

3. L. J. King, J. E. Bigelow, and E. D. Collins, Transuranium Processing Plant Semiannual Report on Production, Status, and Plans for Period Ending June 30, 1973, ORNL-4921 (March 1974).

4. L. J. King, J. E. Bigelow, and E. D. Collins, Transuranium Processing Plant Semiannual Report of Production, Status, and Plans for Period Ending June 30, 1972, ORNL-4833 (January 1973).

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