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HISTORY AND COSTS OF WASTE
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HISTORY AND COSTS OF WASTE STORAGE AT HAPO

INTRODUCTION

The radioactive fission products formed during irradiation of the uranium fuel in the reactors are separated from the uranium and plutonium in the Chemical Processing Department's separations plants. Most of these fission products are removed in aqueous solutions as high-level radioactive waste and are subsequently stored in large underground tanks.

The purpose of this report is to record the history of HAPO process waste storage, together with the developments which have significantly affected waste storage volumes and costs since start-up in 1944.

SUMMARY

From the four tank farms (T, U, B, and C), which originally provided a storage capacity of 26,363,000 gallons, process waste storage facilities have since grown to eleven tank farms, having a total capacity of 90,107,000 gallons. A capital investment of over \$38,000,000⁽¹⁾ is represented. The stored waste inventory on March 1, 1958, was 49,322,000 gallons.

Since most of the tank farms, particularly the older ones, have been used interchangeably for storage purposes, the figure \$0.423 per gallon (average cost per gallon for all tanks) was arbitrarily selected as a basis for computing storage costs.

In 1944-45, the wastes from the processing of each ton of uranium through the bismuth phosphate process occupied about 10,600 gallons and cost about \$4,500 to store. If this uranium had been irradiated to today's exposures, the waste would have occupied about 17,000 gallons and cost about \$7,200 to store. As a result of more efficient operations, process improvements, and the inception of waste self-concentration, waste volumes and storage costs have been reduced by a factor of about 42. The installation of the two-cycle process in Purex in June, 1958, is expected to effect a reduction in salt waste by two to threefold ultimately, with a corresponding decrease in final waste stored to approximately 275 gallons (\$116) per ton of production. If, however, concentration techniques are applied to coating waste to effect similar reductions, final stored Purex waste may eventually approach 150 gallons, or \$63, per ton of production.

The over-all trend in waste storage at HAPO, expressed as cumulative average waste gallons per ton of uranium processed for all separations plants, is depicted in Figure I. Figure II shows individual plant performance, adjusted for reductions realized from cribbing, evaporation, scavenging, and self-concentration and which were effected after the solutions were stored.

DISCUSSION

Tank Farms

Since 1944, a total of 145 underground tanks have been constructed in eleven groups,

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or farms. These tanks are constructed of reinforced concrete, with mild steel liners being used to retain the liquid wastes. The capacity of these tanks ranges from 54,500 to 1,000,000 gallons, the cumulative capacity being about 90,107,000 gallons.

The cumulative cost of this storage capacity is \$38,090,000, or an average of \$0.423 per gallon. This "value" was arbitrarily used in calculating the effects of operating improvements in the subsequent discussion.

The pertinent data concerning these tank farms are presented in Table I.

T and B Plants

In the bismuth phosphate process the following types of wastes were generated in the 221, or Canyon, Building and sent to underground storage⁽²⁾:

1. Alkaline coating removal waste, containing small amounts of fission products, which was combined with first-cycle decontamination waste for storage. Stack drainage, initially combined with second decontamination-cycle waste, was later combined with first decontamination-cycle waste in May, 1951.
2. Metal waste from extraction, containing essentially all of the uranium, about 90% of the original fission activity, and 0.5 to 1% of the plutonium loss.
3. By-product cake solution and waste solution from the first decontamination cycle, containing about 10% of the original fission activity and 2% of the plutonium.
4. Second decontamination-cycle waste, containing less than 0.1% of the fission activity and about 1% of the plutonium. Canyon cell drainage waste, previously disposed to a dry well via the 361 settling tank, was combined with the second decontamination waste stream subsequent to May, 1951.

In the 224, or Concentration, Building, fission activity ($< 0.001\%$ of that in the starting metal) of the waste was low enough to permit ground disposal. The flow was directed through a settling tank, where the bulk of the fission and product activity settled out with precipitated phosphates and lanthanum fluoride, and then to a reverse or dry well. When it was discovered that the wells were filling up with sand, presumably flowing into the well casing through the lower perforations, the wells were replaced with buried sumps. The underground storage tanks for Canyon Building wastes were arranged in cascade groups of three so that suspended solids, containing the bulk of the radioactive fission products, could collect in the first tank of each series.

The first production run was started in T Plant on December 26, 1944, and in B Plant on April 13, 1945. The waste volumes in gallons/TU (gallons per ton of uranium processed) were extremely high. For example, during 1944-45 at T Plant when the feed material averaged .38 MWD/T (megawatt days per ton, relative value), a run was limited by batch size and the stored waste produced amounted to 10,602 gallons/TU (\$4,485). If, however, the feed had been 1.20 MWD/T (equivalent to

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current metal) the plutonium content of a charge would have been increased 10%, the uranium per charge would have been reduced approximately 57%, and the waste produced would have increased to approximately 17,016 gallons/TU (\$7,198). Although the latter condition did not occur, it is presented so that a more realistic comparison can be made with subsequent solvent extraction processes.

While some improvements were incorporated which effected minor waste volume reductions, the first significant development occurred in September, 1947, when the cribbing of second decontamination-cycle supernatants was started at T Plant. The program was later adopted at B Plant in February, 1948. Prior to this time all second cycle wastes had been stored in underground tanks. The mechanics of ground disposal were similar to that for Concentration Building waste, i.e., after settling in an underground storage tank, the supernatant was pumped to cribs. The remaining solids, containing nearly all of the initial fission activity but only a fraction (9%) of the original volume, were held in storage.

In June, 1949, the concept of concentrating first decontamination-cycle wastes by evaporation was proposed. After determining that the approach was economically feasible, facilities for this purpose were installed. The cost of 242-T Evaporator (Project C-369) was \$559,000 and operation commenced May 1, 1951. 242-B Evaporator (Project C-423), which began operation December 14, 1951, was constructed for a cost of \$589,000.

During the lifetime of 242-T, over 8,638,000 gallons of first-cycle feed were processed and an over-all 82.1% reduction in volume was realized. The storage space reclaimed by this technique totaled more than 7,089,000 gallons. Based on operating costs for the first eight months of operation⁽³⁾ plus a prorated cost of the facility (59% for first-cycle and 41% for Uranium Recovery wastes), the cost per gallon of recovered space was \$0.102. Subsequently, the equipment processed 5,899,000 gallons of Uranium Recovery waste, recovering 2,092,000 gallons of storage at a cost of \$0.183/gallon⁽⁴⁾. The facility was shut down in July, 1955.

Some 6,027,000 gallons of first-cycle feed were processed in the 242-B Evaporator, achieving a volume reduction of 80.9%. As in the case of the 242-T Evaporator, the over-all effectiveness was achieved by making two passes. Usually the first pass gave about 70% reduction, later followed by a second (bottoms from first evaporation) which were concentrated approximately 30%. Since this facility was also later used for evaporating Uranium Recovery wastes, it was estimated that the cost of space recovered (4,874,000 gallons) amounted to \$0.113/gallon⁽³⁾ (prorated cost of the facility: 48% for first-cycle and 52% for Uranium Recovery). Before shutdown at the end of October, 1954, over 2,298,000 gallons of space were recovered from Uranium Recovery wastes at a cost of \$0.216/gallon⁽⁴⁾. Total space recovered by both evaporators amounted to 16,353,000 gallons, valued at \$6,917,319 on a replacement basis of \$0.423 per gallon, at an estimated expense of \$2,153,000.

While both evaporators have remained inactive since shutdown, the possibility of using the equipment to concentrate coating waste has been contemplated. However, until such time as the need for additional space for this type of waste becomes more acute, this approach is not economically attractive. It is estimated that sufficient space for coating waste storage currently exists to last until 1965 for Purex and beyond 1970 for Redox⁽⁵⁾.

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In May, 1953, approval was obtained from Radiological Sciences to pump a limited volume of first-cycle supernatant to ground (trenches) on a specific retention basis. Specific retention refers to the ability of a dry column of soil to retain liquid without penetration of the liquid to the water table. In June, 1954, approval was obtained to dispose of evaporator bottoms in a similar manner. During the period December, 1953, to December, 1954, 4,807,000 gallons of first-cycle supernatants and 1,938,000 gallons of first-cycle evaporator bottoms were discharged to ground at an estimated cost of \$45,600 or \$0.007 per gallon⁽⁶⁾. This cost is to be compared with a value of \$2,853,135 for the recovered storage space, based on a replacement cost of \$0.423 per gallon.

While disposal of first-cycle wastes on a specific retention basis was expedient at the time due to limited storage space, efforts were directed toward minimizing the quantity of activity sent to ground yet retaining the desirable feature of high-volume disposal. Although scavenging techniques had been tested previously at the Uranium Recovery Plant, success at T Plant with first-cycle waste was not demonstrated until late 1954. After difficulty with poor decontamination (attributed to interference from ions in the coating waste) was overcome by segregating the two wastes, routine scavenging of first-cycle waste started December 31, 1954. Until the shutdown of T Plant in August, 1956, approximately 3,144,000 gallons of scavenged supernatants were discharged to the TY Caverns. The effective reduction in volume, as discharged from the building, was approximately 88%.

Briefly summarizing bismuth phosphate plants performance: During twelve years of operation, waste volumes were effectively reduced by a factor of 3.25 - from 17,016 gallons/TU to 5,240 gallons/TU with a corresponding decrease in waste storage cost from \$7,198/TU to \$2,217/TU.

Uranium Recovery Plant

It is not intended to discuss the operation of the Uranium Recovery Plant at length in this report. Nevertheless, the waste picture would be incomplete without at least a brief look at the massive contribution of the Uranium Recovery waste scavenging program.

Although the volumes of waste per ton of production varied with the type feed, estimates of 9,200 gals./TU (unconcentrated) and 5,500 gals./TU (concentrated) are considered to be reasonably accurate. Subsequent processing in the evaporators reduced the volume to about 3,600 gals./TU, comparable to the original volume of metal waste discharged by the bismuth phosphate plants. However, the design capacity of the two waste evaporators was only 720,000 gallons per month while the waste generated by the Uranium Recovery Operation ranged as high as 1,676,000 gallons per month. Consequently, it became apparent that new underground waste tanks would be required to accommodate these waste surpluses unless another solution was found.

The imminent shortage was alleviated by the laboratory development of a waste scavenging technique which removed long-lived fission products and permitted ground disposal of the resulting and relatively inactive supernatants. Following incorporation of this change in the Uranium Recovery flowsheet in October, 1954, over 29,156,000 gallons of "In-Plant" scavenged wastes were disposed to ground.

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Prior to October, 1954, the Uranium Recovery wastes had been stored in an untreated condition. In November, 1955, scavenging of these wastes was started at the 241-CR facility, resulting in an additional 11,659,000 gallons of "In-Farm" scavenged supernatants being disposed to ground. Thus over-all, approximately 41,000,000 gallons of space were recovered at an estimated cost of \$0.049/gallon for "In-Plant" and \$0.057/gallon for "In-Farm."⁽⁷⁾ Total scavenging costs for Uranium Recovery wastes amounted to approximately \$2,093,207 and represented reclaimed tank storage valued at an estimated \$17,264,745.

Redox Plant

Responsibility for the Redox Plant was accepted by the Separations Section on August 16, 1951, and after several months of operability testing, initial dissolving of a full charge of 100% HAPO level slugs was started January 9, 1952. During the first year of operation, combined salt and coating wastes (segregation of wastes was not practiced until 1955) averaged 4,378 gallons/TU. At an average cost of \$0.423/gallon, waste storage costs amounted to \$1,852/TU.

In April, 1953, a study was performed to determine the practicability of self-concentrating wastes in the first two cascades of S Farm by disposing of vapor condensate instead of refluxing to the tanks⁽⁸⁾. Concluding that the technique was feasible and that the resulting condensates could be safely cribbed, suitable condensers were installed and the first benefits of self-concentration were realized in August, 1953. Combined with process improvements, e.g., concentrated flowsheet, made during the year, the total net effect was to reduce waste volumes approximately 30% below 1952 performance.

During subsequent years, with greater self-concentration being achieved and additional process improvements incorporated in the flowsheet, the trend of waste volumes continued downward. Significant among the latter were: (1) Initiation of first stage backcycling in December, 1954, which effected approximately 30% reduction; (2) Adoption of full scale backcycling in March, 1956, which effected an additional 23% reduction and; (3) Reduction of dissolver rinses and line flushes in 1956-57 which cut coating waste volumes in half and lowered over-all volumes by about 10%.

In computing the self-concentration presented in Table IV, an attempt was made to credit the period in which the waste was generated and stored in preference to the year when the reduction actually occurred. For example, 277,000 gallons of space were reclaimed by self-concentration in Tank 101-SX during 1956 and 1957 yet the last production waste received by the tank was during September, 1955. Accordingly, the boil-off obtained the last two years was credited to 1955 and 1954 when the tank was being filled.

In summary, the combined effects of self-concentration and process improvements during the six-year life of the Redox Plant successfully reduced waste volumes and storage costs by a factor of 7.4 - from 4,378 gallons/TU (\$1,852/TU) to 594 gallons per TU (\$251/TU). If future plans are realized, it is estimated that present salt waste volumes will be ultimately reduced by a factor of 2. With similar reduction in coating waste volumes possible by concentration, for example in the 242-T

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Evaporator, it is conceivable that future final waste volumes from Redox may approach 300 to 250 gallons/TU (\$127 to \$106).

Purex Plant

At the completion of operability testing and the processing of cold uranium runs in latter 1955, Purex Plant came on the line as a production facility in January, 1956. High initial waste volumes precluded self-concentration, resulting in two tanks (101-A and 102-A) being partially filled with wastes which never boiled. In May, 1956, the salt waste was routed to a third tank (103-A) and as a result of volume reductions plus temporary segregation of carbonate and organic wastes, sufficient self-heat was generated to start boiling in Tank 103-A on July 5, 1956. Boiling accelerated at a rapid rate, attaining a boil-off peak in June, 1957, of 10 gallons per minute. When boil-off greatly exceeded input, water additions became necessary (in February, 1957) to maintain liquid in the tank at a reasonable level. To date, over 2,650,000 gallons of water have been added to the one tank.

Primarily as a result of the significant self-concentration, the final stored volumes were reduced from 856 gallons/TU in 1956 to 402 gallons/TU in 1957, with a corresponding decrease in storage costs from \$362/TU to \$170/TU. Of the latter figure, 74% is attributed to coating waste which does not benefit from self-concentration.

Looking ahead, present plans are to install a two-cycle process in Purex in June of this year. One of the advantages expected from this change is an ultimate reduction in salt waste by a factor of 2 to 3, decreasing combined waste output to approximately 275 gallons/TU (\$116). Success in this attempt plus similar improvements in coating waste, e.g., concentration in the 242-B Evaporator, could further reduce over-all final waste volumes to approximately 150 gallons/TU (\$63).

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- (1) Personal communication from J. V. Walton to R. E. Roberts, January 6, 1958.
- (2) HW-10475-C, "Hanford Technical Manual Section C," author not stated, May 1, 1944.
- (3) HW-23478, "Eight Month Operational Report - Evaporation Facilities for Waste Solutions," A. Bradway, Jr., January 28, 1952.
- (4) Personal communication from R. E. Middaugh to R. E. Roberts, January 6, 1958.
- (5) HW-54570, "Waste Storage Requirements for Chemical Processing Department," R. E. Roberts, January 28, 1958.
- (6) HW-34281, "First Cycle Supernatant Ground Disposal," D. E. Peterson, December 31, 1954.
- (7) HW-47832, "Waste Scavenging Costs," M. J. Stedwell, January 17, 1957.
- (8) HW-27884, "Separations Plant Engineering Report No. 62 - Self-Concentration In S Farm Waste Storage Tanks," V. P. Madsen, May 25, 1953.

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TABLE ITANK FARMS

<u>Farm</u>	<u>Tanks/ Farm</u>	<u>Capacity/Tank (Gallons)</u>	<u>Capacity/Farm (Gallons)</u>	<u>Year Constructed</u>	<u>Cost/Farm**</u>	<u>Cost/Gallon</u>
T	16	54,500 (4) 530,000 (12)	6,617,000*	1943-44	\$3,087,000	\$0.467
U	16	54,500 (4) 530,000 (12)	6,578,000*	1943-44	2,969,000	0.451
B	16	54,500 (4) 530,000 (12)	6,590,000*	1943-44	3,019,000	0.458
C	16	54,500 (4) 530,000 (12)	6,578,000*	1943-44	2,938,000	0.447
BX	12	530,000	6,360,000	1946-47	2,208,000	0.347
TX	18	758,000	13,644,000	1947-48	5,859,000	0.429
BY	12	758,000	9,096,000	1948-49	2,651,000	0.291
S	12	758,000	9,096,000	1950-51	3,961,000	0.435
TY	6	758,000	4,548,000	1951-52	1,846,000	0.406
SX	15	1,000,000	15,000,000	1953-54	3,983,000	0.266
A	<u>6</u>	1,000,000	<u>6,000,000</u>	1954-55	<u>5,569,000</u>	<u>0.928</u>
Totals	145		90,107,000		\$38,090,000	\$0.423 Average

* Actual Capacity

** Includes original tank farm cost plus improvements, including instrumentation, agitation systems, and transfer lines from separation plants. A Farm also includes estimated cost of remotely maintained stainless steel condensers (\$1,380,000) currently being installed. Operating and maintenance costs of approximately \$200,000 per year for the entire complex were not included.

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TABLE II
BISMUTH PHOSPHATE PLANTS

Year	Plant	Relative MWD/T	Runs	Tons	Waste Stored (Gallons X 10 ³)			Net Gals./Ton	Cost/ton of Final Waste Stored at \$0.423/gal.
					Metal Waste	First Cycle	2nd Cycle & 224 Sludge		
1944-45	T	.38	252	334	1328	1265	948	10,602	\$4485
1944-45	T	1.20	252	128	538	925	715	17,016	7198 (Estimated)
1944-45	B	.39	210	302	1124	982	728	9,384	3969
1946	T	.50	244	291	1210	1125	867	11,003	4654
1946	B	.40	391	573	2412	1894	1400	9,958	4212
1947	T	.41	206	306	1363	1049	526 (1)	9,601	4061
1947	B	.41	225	345	1482	1162	861	10,159	4297
1948	T	.41	263	388	1523	1152	113	7,186	3040
1948	B	.42	272	398	1626	1148	184 (2)	7,432	3144
1949	T	.55	347	393	1738	1272	142	8,020	3392
1949	B	.55	311	356	1569	1130	122	7,924	3352
1950	T	.80	561	424	1894	1916	219	9,502	4019
1950	B	.80	583	460	1994	1953	229	9,078	3840
1951	T	.94	776	560	2401	1067	302	6,732	2848
1951	B	.98	729	508	2044	2067	282	8,648	3658
1952	T	1.17	461	295	1301	224	125	5,593	2366
1952	B	1.17	195	118	542	111	60	6,042	2556
1953	T	1.00	322	246	997	150	89	5,024	2125
1954	T	.47	743	1019	3915	462 (6)	204	4,496	1902
1955	T	.46	929	1266	4938	683	255	4,641	1963
1955	T	1.20	929	580	2436	416	187	5,240	2217 (Estimated)
1956	T	.52	49	45	401	68	41	11,333 (7)	4794

- (1) Cribbing of T Plant second-cycle supernatant started in September, 1947.
- (2) Cribbing of B Plant second-cycle supernatant started in February, 1948.
- (3) 242-T Evaporator started operation on May 1, 1951 and effectively reduced first-cycle waste volumes 82%.
- (4) 242-B Evaporator started operation on December 14, 1951 and effectively reduced first-cycle waste volumes 81%.
- (5) B Plant shut down in October, 1952.
- (6) In-plant scavenging of first-cycle wastes started December 31, 1954, effectively reducing first-cycle volumes 88%.
- (7) Waste volumes were high due to extensive flushing prior to shutdown in August, 1956.

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TABLE III

242 B AND T EVAPORATORS PERFORMANCE

Facility	First-Cycle Waste (Gals. X 10 ³)		%	Cost/Gal.		TBP Wastes (Gals. X 10 ³)		%	Cost/Gal.	
	Feed	Space Recovered		Efficiency	Recovered	Feed	Space Recovered		Efficiency	Recovered
242-B	6027	4874	80.9		\$0.113(1)	6407	2298	35.9		\$0.216(2)
242-T	8638	7089	82.1		0.102(3)	5899	2092	35.5		0.183(4)

(1)	\$0.055/gal. estimated operating cost plus \$0.058/gal. prorated cost of facility
	$\left(\frac{48\% \times \$589,000}{4,874,000} \right) = \$0.113/\text{gal.}$
(2)	\$0.083/gal. estimated operating cost plus \$0.133/gal. prorated cost of facility
	$\left(\frac{52\% \times \$589,000}{2,298,000} \right) = \$0.216/\text{gal.}$
(3)	\$0.055/gal. estimated operating cost plus \$0.047/gal. prorated cost of facility
	$\left(\frac{59\% \times \$559,000}{7,089,000} \right) = \$0.102/\text{gal.}$
(4)	\$0.073/gal. estimated operating cost plus \$0.110/gal. prorated cost of facility
	$\left(\frac{41\% \times \$559,000}{2,092,000} \right) = \$0.183/\text{gal.}$

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TABLE IV

REDOX PLANT

Year	Relative MWD/T	Waste Volumes (Gallons X 10 ³)			Net Gals./Ton	Cost/Ton of Final Waste Stored at \$0.423/gallon
		Coating	Salt	Self Concentration		
1952	1.19	822	3599	0	3599	\$1,852
1953	1.18	1431	4923	569	4354	1,287
1954	1.26	1579	4984	1554	3430	919
1955	0.93	2426	4690	1709	3731	651
1956	0.83	2406	3455	996	3154	555
1957	1.11	1829	2144	1336	1086	251

(1) Coating and salt wastes were not segregated until 1955.

TABLE V

PUREX PLANT

Year	Relative MWD/T	Waste Volumes (Gallons X 10 ³)			Net Gals./Ton	Cost/Ton of Final Waste Stored at \$0.423/gallon
		Coating	Salt	Self Concentration		
1956	1.04	780	2274	896	2158	\$ 362
1957	1.12	1307	3356	2890	1773	170

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FIGURE 1

CUMULATIVE AVERAGE WASTE VOLUMES
PER TON OF URANIUM PROCESSED
(All Separations Plants)

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FIGURE II

**DATE
FILMED**

11 / 15 / 93

END