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Cost of Producing U_3O_8 From Ammonium Bicarbonate In Situ Leach Solution by the Multiple-Compartment Ion-Exchange System

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8796

Cost of Producing U_3O_8 From Ammonium Bicarbonate In Situ Leach Solution by the Multiple-Compartment Ion-Exchange System

By Masami Hayashi and Henry Dolezal

UNITED STATES DEPARTMENT OF THE INTERIOR
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COST OF PRODUCING U_3O_8 FROM AMMONIUM BICARBONATE IN SITU LEACH SOLUTION BY THE MULTIPLE-COMPARTMENT ION-EXCHANGE SYSTEM

by

Masami Hayashi[1] and Henry Dolezal[2]

ABSTRACT

The Bureau of Mines estimated the cost for a uranium ion-exchange recovery system using five grades of U_3O_8 leach solution producing 815,570 pounds of U_3O_8 per year from an ammonium bicarbonate in situ leach solution. The system flowsheet consisted of four unit operations: (1) Multiple-compartment ion-exchange (MCIX) absorption; (2) MCIX elution; (3) precipitation of the uranium as yellow cake, filtering, calcining, and packaging; and (4) waste disposal.

The total fixed capital cost of a system treating 2,000 gallons per minute of 0.1-gram-per-liter-U_3O_8 leach solution was estimated as $6,888,000. For a basic case of an MCIX system depreciating in 9 years, unit production cost of U_3O_8 was $3.51 per pound. A decrease in feed solution grade from 0.4 to 0.03 gram per liter increased the production cost exponentially. Shorter depreciating periods significantly increased the production cost particularly for the lower grade feed solutions.

INTRODUCTION

A new low-cost system using multiple-compartment ion-exchange (MCIX) columns for recovering uranium from mine water, clear solutions, and slime slurries was developed by the Bureau of Mines.[3] Subsequently, the Bureau of Mines made additional studies to better quantify the design criteria for MCIX columns.[4]

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Both authors are with the Salt Lake City Metallurgy Research Center, Bureau of Mines, Salt Lake City, Utah.

[3] George, D. R., J. R. Ross, and J. D. Prater. Byproduct Uranium Recovered with New Ion Exchange Technique. Min. Eng., v. 20, January 1968, pp. 1-5. Ross, J. R., and D. R. George. Recovery of Uranium From Natural Mine Waters by Countercurrent Ion Exchange. BuMines RI 7471, 1971, 17 pp.

[4] Traut, D. E., I. L. Nichols, and D. C. Seidel. Design Criteria for Uranium Ion Exchange in a Fluidized System. Trans. AIME, v. 260, March 1976, pp. 24-28.

During 1976, the Bureau of Mines Salt Lake City Metallurgy Research Center continued experimental studies to determine MCIX column design requirements for the absorption of uranium from ammonium bicarbonate solutions similar to those produced by in situ leaching operations. Design criteria were also developed for the elution of the loaded resin with ammonium chloride eluant in separate MCIX columns. The results of these experimental studies have been published; these data were used to prepare the present estimate of costs for treating ammonium bicarbonate leach solutions by an integrated system using countercurrent fluidized bed MCIX absorption and elution columns.[5]

DESCRIPTION OF THE PROCESS

A process was designed to recover 2,330 pounds per day of U_3O_8 from a 2,000-gallon-per-minute leach solution stream containing 0.1-gram-per-liter U_3O_8. Using this process, evaluations were made for five capacities of different grades of U_3O_8 leach solution each producing 815,570 pounds per year U_3O_8. The resin absorbed 99 percent of the uranium in the feed stream, and the recoveries for all five grades were assumed to be independent of the initial concentration. The system flowsheet consists of four unit operations: (1) MCIX absorption; (2) MCIX elution; (3) precipitation of the uranium as yellow cake, filtering, calcining, packaging; and (4) waste disposal. A simplified flowsheet of the basic system processing 2,000 gallons per minute leach solution is shown in figure 1. Equipment exposed to corrosive solutions is of either rubber-covered or stainless steel construction.

Pregnant solution containing 0.1 gram per liter U_3O_8 from the ammonium bicarbonate in situ leach operation is collected in storage tanks and circulated through the system at 2,000 gallons per minute. Uranyl carbonate is exchanged between the leach liquor and a strong base anion resin in four 6.5-foot-diameter MCIX columns at a flow of 15 gallons per square foot per minute with an aqueous-to-resin ratio (A:R) of 400:1; a resin loading of 3.3 pounds per cubic foot was used. The column consists of fourteen 1-foot-high compartments separated by orifice plates. Eluted resin is fed into the top compartment of the absorption column and descends countercurrently to the leach solution flow.

The loaded resin is discharged from the bottom of the absorption column and transferred to a screen above the elution column where it is washed and dewatered, then it is fed into a 4.5-foot-diameter MCIX elution column consisting of fifteen 1-foot-high compartments. The loaded resin is eluted with ammonium chloride at an eluant flow rate of 2.7 gallons per square foot per minute at an A:R of 6:1. Overflow from the elution column contains 5 grams of U_3O_8 per liter. Eluted resin containing 0.19 pound U_3O_8 per cubic foot is washed and dewatered on a screen and recycled to the loading columns. The resin inventory in the integrated MCIX circuit is 1,450 cubic feet; resin losses are 363 cubic feet per year.

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[5] Traut, D. E., I. L. Nichols, and D. C. Seidel. Design Requirements for Uranium Ion Exchange From Ammonium Bicarbonate Solutions in a Fluidized System. BuMines RI 8280, 1978, 27 pp.

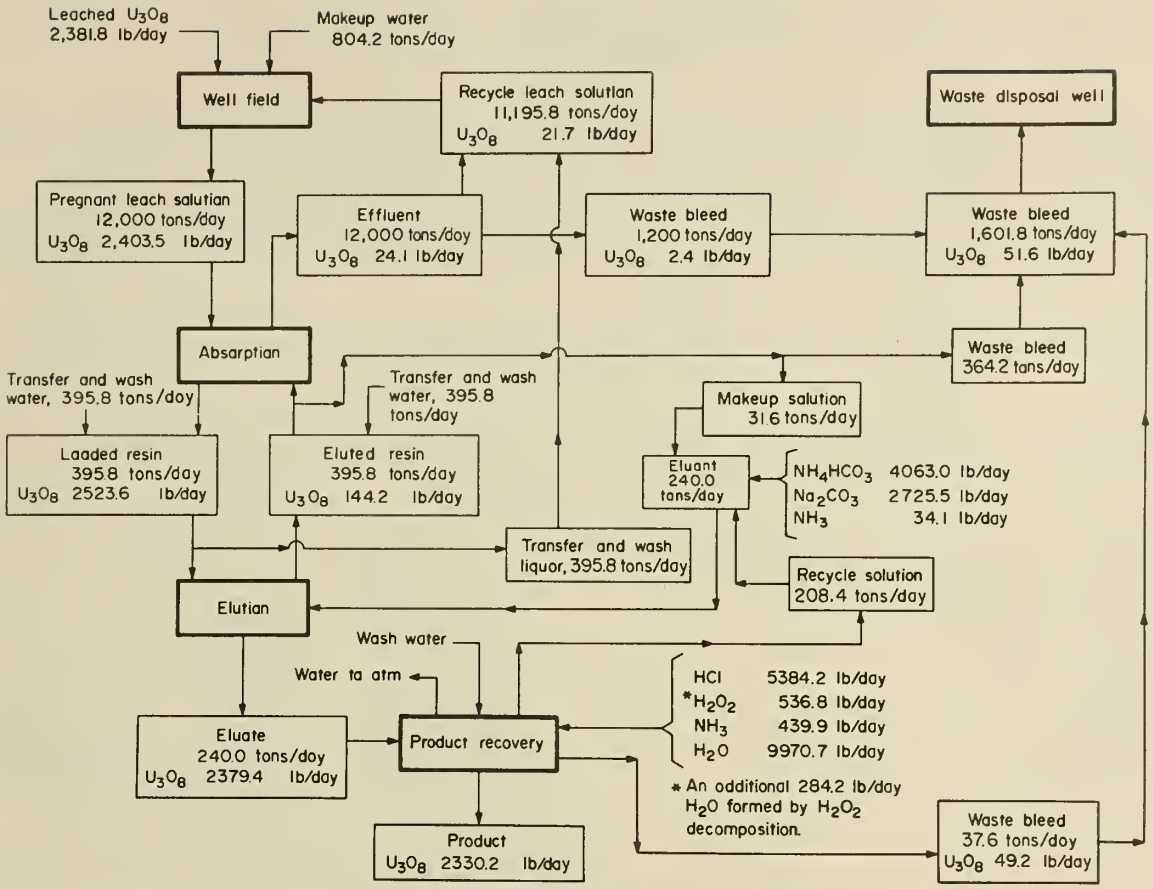

FIGURE 1. - Material balance for ion-exchange system to process 2,000 gal/min of leach solution containing 0.1 g/l U_3O_8.

Uranium is recovered from the eluate by acidifying the solution to pH 1 with hydrochloric acid and precipitating with ammonia and hydrogen peroxide. The slurry of uranium peroxide is thickened, filtered, washed, and calcined to U_3O_8 at 550° C. The chemical requirement for precipitation is 0.185 pound NH_3 and 0.23 pound H_2O_2 per pound of U_3O_8.

Solution wastes derived from washes and bleed-offs are disposed of in 3,000-foot-deep wells.

COST ESTIMATES

Preliminary cost estimates were made of a uranium MCIX recovery system processing five different solution feed grades and depreciated over 5, 9, 12.5, and 20 years to determine the relative effects of these variables. A study estimate prepared from a flowsheet and a minimum of equipment design data was made to estimate costs for a system based on 2,000 gallons per minute of 0.1-gram-per-liter-U_3O_8 leach solution producing 815,570 pounds U_3O_8 per year for 9 years of production. Estimates for the other capacities treating leach solution streams of 500, 1,000, 4,000, and 6,000 gallons per minute containing 0.4, 0.2, 0.05, and 0.033 gram per liter of U_3O_8, respectively, were obtained by scaling from this basic design.

Capital Costs

Capital costs, including direct construction costs, indirect costs, interest during construction, cost of facilities and utilities, and working capital costs, were calculated for the second quarter of 1978 (Marshall and Swift Index 540), and should be accurate to ±30 percent. Fixed capital cost summary for the uranium ion-exchange recovery system treating 2,000 gallons per minute of 0.1 gram per liter leach solution is given in tables 1-5.

TABLE 1. - Fixed capital cost summary for uranium ion-exchange recovery system--absorption

	NUMBER	MATERIAL COST, $	LABOR COST, $	TOTAL COST, $
DIRECT CONSTRUCTION COST				
ABSORPTION FEED TK	2	34600.	5200.	39800.
PUMP, SS	4	31400.	3100.	34500.
EDUCTOR,SS	4	23800.	2400.	26200.
TRANSFER PUMP, SS	2	3000.	300.	3300.
SCREEN	1	2800.	400.	3200.
IX-COLUMN,LOADING	4	457500.	68600.	526100.
TOTAL, E		553100.	80000.	633100.
FOUNDATIONS	.070(MATERIAL COST TOTAL, E)			38700.
STRUCTURES	.070			38700.
BUILDINGS	.400			221200.
INSULATION	.000			0.
INSTRUMENTATION	.150			83000.
ELECTRICAL WORK	.100			55300.
PIPING	.500			276600.
PAINTING	.015			8300.
MISCELLANEOUS	.100			55300.
TOTAL	1.405			777100.
TOTAL DIRECT CONSTRUCTION COST, DC				1410200.
INDIRECT COST, CONTINGENCY, AND FEE, I	.690(DC)			973000.
INTEREST DURING CONSTRUCTION	.120(DC+I)			286000.
TOTAL CONSTRUCTION COST				2669200.
INITIAL REAGENTS				
IX RESIN	1275.3			133900.
TOTAL				133900.
TOTAL FIXED CAPITAL COST				2803100.

TABLE 2. - Fixed capital cost summary for uranium ion-exchange recovery system--elution

		NUMBER	MATERIAL COST, $	LABOR COST, $	TOTAL COST, $
DIRECT CONSTRUCTION COST					
EDUCTOR,SS		1	6000.	600.	6600.
ELUTION PUMP, SS		4	6000.	600.	6600.
SCREEN		1	2800.	400.	3200.
MAKE-UP TANK, SS		1	64300.	6400.	70700.
IX COLUMN,ELUTION		1	80100.	12000.	92100.
TOTAL, E			159200.	20000.	179200.
FOUNDATIONS	.070	(MATERIAL COST TOTAL, E)			11100.
STRUCTURES	.070				11100.
BUILDINGS	.400				63700.
INSULATION	.000				0.
INSTRUMENTATION	.150				23900.
ELECTRICAL WORK	.100				15900.
PIPING	.500				79600.
PAINTING	.015				2400.
MISCELLANEOUS	.100				15900.
TOTAL	1.405				223600.
TOTAL DIRECT CONSTRUCTION COST, DC					402800.
INDIRECT COST, CONTINGENCY, AND FEE, I		.690(DC)			277900.
INTEREST DURING CONSTRUCTION		.120(DC+I)			81700.
TOTAL CONSTRUCTION COST					762400.
INITIAL REAGENTS					
IX RESIN		174.7			18300.
TOTAL					18300.
TOTAL FIXED CAPITAL COST					780700.

TABLE 3. - Fixed capital cost summary for uranium ion-exchange recovery system--product recovery

		NUMBER	MATERIAL COST, $	LABOR COST, $	TOTAL COST, $
DIRECT CONSTRUCTION COST					
PPT TANK, SS		3	192800.	19300.	212100.
THICKENER (RC)		1	10300.	1000.	11300.
DIAP.PUMP		1	800.	100.	900.
DRUM FILTER,SS		2	27100.	8100.	35200.
AUX EQUIP (FILTER)		1	10800.	1100.	11900.
HEARTH DRYER		1	17000.	1700.	18700.
VENTURA SCRUBBER		1	1100.	100.	1200.
PUMP, SS		4	4100.	400.	4500.
NH3 SPHERICAL TANK		1	40200.	4000.	44200.
STORAGE TANK(AL)		1	4900.	500.	5400.
TOTAL, E			309100.	36300.	345400.
FOUNDATIONS	.080	(MATERIAL COST TOTAL, E)			24700.
STRUCTURES	.060				18500.
BUILDINGS	.450				139100.
INSULATION	.000				0.
INSTRUMENTATION	.100				30900.
ELECTRICAL WORK	.070				21600.
PIPING	.500				154600.
PAINTING	.015				4600.
MISCELLANEOUS	.100				30900.
TOTAL	1.375				424900.
TOTAL DIRECT CONSTRUCTION COST, DC					770300.
INDIRECT COST, CONTINGENCY, AND FEE, I		.690(DC)			531500.
INTEREST DURING CONSTRUCTION		.120(DC+I)			156200.
TOTAL CONSTRUCTION COST					1458000.
MOBILE EQUIPMENT					
FORK LIFT (DRUM)		1	10600.		10600.
CONTINGENCY					1100.
TOTAL					11700.
TOTAL FIXED CAPITAL COST					1469700.

TABLE 4. - Fixed capital cost summary for uranium ion-exchange recovery system--waste disposal

		NUMBER	MATERIAL COST, $	LABOR COST, $	TOTAL COST, $
DIRECT CONSTRUCTION COST					
SURFACE EQUIPMENT		1	284600.	42700.	327300.
TOTAL, E			284600.	42700.	327300.
FOUNDATIONS	.000	(MATERIAL COST TOTAL, E)			0.
STRUCTURES	.000				0.
BUILDINGS	.000				0.
INSULATION	.000				0.
INSTRUMENTATION	.000				0.
ELECTRICAL WORK	.000				0.
PIPING	.000				0.
PAINTING	.000				0.
MISCELLANEOUS	.000				0.
TOTAL	.000				0.
TOTAL DIRECT CONSTRUCTION COST, DC					327300.
INDIRECT COST, CONTINGENCY, AND FEE, I		.690(DC)			225800.
INTEREST DURING CONSTRUCTION		.120(DC+I)			66400.
TOTAL FIXED CAPITAL COST					619500.

TABLE 5. - Fixed capital cost summary for uranium ion-exchange recovery system

	FIXED CAPITAL WITHOUT INTEREST	INTEREST DURING CONSTRUCTION	FIXED CAPITAL WITH INTEREST
ABSORPTION	2517100.	286000.	2803100.
ELUTION	699000.	81700.	780700.
PRODUCT RECOVERY	1313500.	156200.	1469700.
WASTE DISPOSAL	553100.	66400.	619500.
TOTAL FOR UNITS	5082700.	590300.	5673000.
FACILITIES	492900.	59200.	552100.
UTILITIES	591900.	71000.	662900.
TOTAL FIXED CAPITAL	6167500.	720500.	6888000.

TOTAL CONSTRUCTION FACTOR COSTS

FOUNDATIONS	74500.
STRUCTURES	68300.
BUILDINGS	424000.
INSULATION	0.
INSTRUMENTATION	137800.
ELECTRICAL WORK	92800.
PIPING	510800.
PAINTING	15300.
MISCELLANEOUS	102100.
TOTAL	1425600.

TOTAL NUMBER OF MEN = 26.0

Direct Construction Cost

Direct construction costs consist of the delivered cost of equipment, labor cost to erect the equipment, material and labor costs for construction of special equipment at the plantsite, and the cost of additional construction required to support, house, and protect the equipment and make it operable. Equipment costs are obtained from direct quotes by suppliers, records of similar construction, equipment catalogs, and published cost estimating data. Delivery costs based on weight, type of equipment, and average distance to suppliers are added.

Construction costs, which include foundations, structures, buildings, etc., are estimated by factors applied to the total delivered cost of the equipment requiring such construction. These factors vary with the types of unit operation and have been accumulated from detailed consideration of requirements as new types of unit operations are encountered.

Indirect Cost

The indirect cost is taken to be 69 percent of the direct cost and approximates the addition of 13.5 percent for field indirect expense plus the following percentages of successive resulting subtotals: 7.5 for engineering plus 7.5 for administration and overhead, 20 for contingencies, and 7.5 for contractor's fee. The field indirect expense covers field supervision, inspection, temporary construction, equipment rental, and payroll overhead.

Interest

Interest cost during the construction period is the sum of direct and indirect construction costs multiplied by a factor that is actually 0.7 times the product of interest rate and construction period in years. From a combination of information in the literature and a review of actual construction records, it appears that the average amount upon which interest is paid over the construction period is about 70 percent of the contract price.

Special Supplies and Equipment

Costs for mobile equipment and initial reagents, which can be purchased at the end of construction, are added to the total construction cost to obtain the total fixed capital cost for each unit operation.

Plant Facilities

Plant facilities cost, which includes buildings and equipment for office, laboratory, shops, and warehouses, plus fencing, roads, railroad spurs, fire protection facilities, and safety equipment, is estimated as 10 percent of the total fixed capital cost of the production units of the plant.

Utilities

Plant utilities cost, which includes the cost of construction and equipment necessary to conduct utilities to the plant from an outside source and to distribute them to the various buildings or operating units of the plant, is estimated as 12 percent of the total fixed capital cost of production units.

Working Capital

Working capital is estimated as the sum of 1 month's supply of raw materials (annual cost of materials divided by 12), 1 month's out-of-pocket expense (total annual operating cost less depreciation divided by 12), and 2 months' product inventory (total annual operating cost divided by 6).

Operating Costs

Annual operating costs were based on 350 operating days per year and were estimated in two ways: (1) On the basis of charges against individual unit operations, and (2) on the basis of charges against the entire plant. In estimating operating costs for unit operations, each unit is treated as though it were an independent operation charged with a prorated share of the operating costs of plant utilities and general plant facilities. In the estimated operating cost for the total plant, the fixed cost for utilities and facilities is a part of the total indirect cost.

To break down the operating cost into costs for individual unit operations, the fixed costs for utilities and facilities are determined independently. Labor, maintenance, overhead, and indirect costs for the plant utilities are estimated as 2 percent of the utility capital cost without interest during construction plus 5 percent of the utility capital cost with interest. This amount is subtracted from the indirect cost for the total plant and added to the fixed costs for utilities. An estimated 30 percent of the resulting total annual operating cost for plant utilities is charged to plant facilities (which also consume utilities), and the balance is distributed between the various utilities on the basis of consumption plus estimated relationships between consumption and cost for each utility. This establishes increased rates at which the utilities are charged to unit operations.

The operating cost for plant facilities is distributed to unit operation on the same basis (cost of labor, maintenance, and operating supplies) as the indirect operating cost. For this reason, it is not necessary to estimate the total operating cost of the plant facilities. The fixed cost for facilities plus the utility cost charged to facilities are added to the remaining portion of the indirect costs for the total plant. Dividing the new total by the sum of labor, maintenance, and operating supplies yields a new factor by which indirect costs for unit operations are determined. Annual operating costs for individual unit operations are given in tables 6-7. Costs for the entire plant are given in table 8.

TABLE 6. - Annual operating cost, $, of absorption, elution, and product recovery unit operations for uranium ion-exchange recovery system

UNIT OPERATION	ABSORPTION	ELUTION	PRODUCT RECOVERY
DIRECT COST			
MATERIALS			
IX RESIN	33500.	4600.	0.
NH3	0.	1100.	13900.
NH4HCO3	0.	256000.	0.
SODA ASH	0.	28600.	0.
H2O2	0.	0.	83200.
HCL	0.	0.	165800.
TOTAL	33500.	290300.	262900.
UTILITIES			
ELECTRICITY, 440 V,(LOW)	25200.	3500.	9800.
NATURAL GAS, CONSUMED	0.	0.	5100.
WATER, PROCESS	50300.	50300.	300.
TOTAL	75500.	53800.	15200.
DIRECT LABOR			
LABOR 8.000/MAN HOUR	104800.	104800.	206300.
SUPERVISION .150	15700.	15700.	31000.
TOTAL, D	120500.	120500.	237300.
PLANT MAINTENANCE			
LABOR	47700.	13600.	26300.
SUPERVISION .200	9500.	2700.	5300.
MATERIALS	71500.	20400.	39400.
TOTAL, M	128700.	36700.	71000.
PAY OVERHEAD .300(PAYROLL)	53300.	41000.	80700.
OPERATING SUPPLIES,S .200(M)	25700.	7300.	14200.
TOTAL DIRECT COST	437200.	549600.	681300.
INDIRECT COST			
ADM & OHEAD .47993(D+M+S)	131900.	78900.	154800.
FIXED COST			
TAXES AND INSURANCE .020	50300.	14000.	26300.
DEPRECIATION 9.000 YR	311500.	86700.	163300.
TOTAL	361800.	100700.	189600.
TOTAL ANNUAL COST	930900.	729200.	1025700.

TABLE 7. - Annual operating cost, $, of waste disposal unit operation for uranium ion-exchange recovery system

UNIT OPERATION	WASTE DISPOSAL
DIRECT COST	
MATERIALS	
IX RESIN	0.
NH3	0.
NH4HCO3	0.
SODA ASH	0.
H2O2	0.
HCL	0.
TOTAL	0.
UTILITIES	
ELECTRICITY, 440 V,(LOW)	7200.
NATURAL GAS, CONSUMED	0.
WATER, PROCESS	0.
TOTAL	7200.
DIRECT LABOR	
LABOR 8.000/MAN HOUR	16600.
SUPERVISION .150	2500.
TOTAL, D	19100.
PLANT MAINTENANCE	
LABOR	11100.
SUPERVISION .200	2200.
MATERIALS	16600.
TOTAL, M	29900.
PAY OVERHEAD .300(PAYROLL)	9700.
OPERATING SUPPLIES,S .200(M)	6000.
TOTAL DIRECT COST	71900.
INDIRECT COST	
ADM & OHEAD .47993(D+M+S)	26400.
FIXED COST	
TAXES AND INSURANCE .020	11100.
DEPRECIATION 9.000 YR	68800.
TOTAL	79900.
TOTAL ANNUAL COST	178200.

TABLE 8. - Annual operating cost, $, for uranium ion-exchange recovery system

	ANNUAL CONSUMPTION		UNIT COST	OPERATING COST, $	PCT
DIRECT COST					
MATERIALS					
IX RESIN	362.5	CUFT	105.00	38100.	1.33
NH3	165896.5	LB	.09	15000.	.52
NH4HCO3	1422050.0	LB	.18	256000.	8.94
SODA ASH	953925.0	LB	.03	28600.	1.00
H2O2	5367.9	CWT	15.50	83200.	2.91
HCL	50253.0	CWT	3.30	165800.	5.79
TOTAL				586700.	20.49
UTILITIES					
ELECTRICITY	1164.0528	MKWHR	30.00	34900.	1.22
NATURAL GAS, CONSUMED	1412.2	MCF	2.00	2800.	.10
WATER, PROCESS	66710.0	MGAL	.34	22700.	.79
TOTAL				60400.	2.11
DIRECT LABOR					
LABOR 8.000/MAN HOUR				432500.	15.10
SUPERVISION .150				64900.	2.27
TOTAL, D				497400.	17.37
PLANT MAINTENANCE					
LABOR				98700.	3.45
SUPERVISION .200				19700.	.69
MATERIALS				147900.	5.16
TOTAL, M				266300.	9.30
PAYROLL OVERHEAD .300(PAYROLL)				184700.	6.45
OPERATING SUPPLIES, S .200(M)				53200.	1.86
TOTAL DIRECT COST				1648700.	57.57
INDIRECT COST					
ADMINISTRATION AND OVERHEAD .400(D+M+S)				326800.	11.41
FIXED COST					
TAXES AND INSURANCE .020				123200.	4.30
DEPRECIATION 9.000 YR				765300.	26.71
TOTAL				888500.	31.02
TOTAL ANNUAL OPERATING COST				2864000.	100.00

The cost of raw materials includes the shipping cost and is the same for both estimating methods. For these estimates no costs are assigned to the makeup reagents for the in situ leach solution so that only the ion-exchange processing cost is determined.

Utility requirements are calculated for the unit operations and totaled for the integrated plant. Rates for the integrated plant are those charged by the utility companies and were assumed to be $30.00 per thousand kilowatt-hours for electricity, $2.00 per thousand cubic feet for natural gas, and $0.34 per thousand gallons for process water. For the unit operations, the previously explained added charges make the utility rates higher: $39.28 per thousand kilowatt-hours for electricity, $3.63 per thousand cubic feet for natural gas, and $1.51 per thousand gallons for process water. Makeup water required for the in situ leach operation was not charged to the ion-exchange systems.

Direct labor includes operating labor and supervision. Labor cost is based on a wage rate of $8.00 per hour. Labor requirements were estimated on the basis of 4.2 men for each position requiring continuous operation. Supervision is taken as 15 percent of the labor cost.

Plant maintenance consists of maintenance labor, supervision, and maintenance materials. Labor is estimated as 2 percent of the total fixed capital cost without interest for unit operations without costs for initial reagents. Supervision is 20 percent of the labor cost, and material cost is assumed to be 1.5 times the labor cost.

Payroll overhead is estimated as 30 percent of the cost of labor and supervision for operation and maintenance. Operating supplies are assumed equal to 20 percent of the cost of maintenance.

Indirect costs include the cost of maintaining the plant facilities and utilities, the expense of accounting, control and research laboratories, engineering, plant protection and safety, warehousing, shipping, and the executive and administrative offices. These costs for the general plant are estimated as 40 percent of the cost of labor, maintenance, and operating supplies. For the unit operations, other prorated charges make the percentage a little higher.

Taxes and insurance are estimated as 2 percent of the fixed capital cost without interest.

Estimated Costs

A summary of costs and operating personnel for the basic system processing 2,000 gallons per minute of 0.1-gram-per-liter-U_3O_8 leach solution is shown in table 9. A comparison of costs for five modifications of the system each producing 815,570 pounds U_3O_8 per year but using different feed solution grades and capacities is given in table 10; straight-line depreciation over periods of 5, 9, 12.5, and 20 years are assumed for each modification. The effect of feed solution grade on unit production cost is shown in figure 2. Variation of unit production cost with depreciation life of the MCIX recovery system is shown in figure 3 for the feed grades considered.

TABLE 9. - Summary of costs and operating personnel for uranium ion-exchange recovery system

	NUMBER OF OPERATORS	CAPITAL COST, $	ANNUAL OPERATING COST, $	ANNUAL OPERATING COST, PCT	UNIT PRODUCTION COST, $/ LB U3O8
ABSORPTION	6.3	2803100.	930900.	32.50	1.14141
ELUTION	6.3	780700.	729200.	25.46	.89410
PRODUCT RECOVERY	12.4	1469700.	1025700.	35.81	1.25765
WASTE DISPOSAL	1.0	619500.	178200.	6.22	.21850
TOTAL, T		5673000.			
INITIAL REAGENTS, IR = 152200.					
FACILITIES,.100(T-IR)		552100.			
UTILITIES,.120(T-IR)		662900.			
TOTAL FIXED CAPITAL		6888000.			
WORKING CAPITAL		701000.			
TOTAL CAPITAL	26.0	7589000.	2864000.	100.00	3.51165

TABLE 10. - Estimated capital and operating costs, depreciated over 5, 9, 12.5, and 20 years, for five grades of uranium leach solutions

Solution feed		Depreciation, year	Fixed capital	Working capital	Operating cost	Unit production cost, per lb U_3O_8
Gal/min	U_3O_8, g/l					
500	0.4	5	$4,401,000	$648,000	$2,686,000	$3.29
		9	4,401,000	588,000	2,329,000	2.86
		12.5	4,401,000	565,000	2,192,000	2.69
		20	4,401,000	543,000	2,060,000	2.53
1,000	.2	5	5,233,000	696,000	2,931,000	3.59
		9	5,233,000	625,000	2,505,000	3.07
		12.5	5,233,000	597,000	2,342,000	2.87
		20	5,233,000	571,000	2,185,000	2.68
2,000	.1	5	6,888,000	795,000	3,426,000	4.20
		9	6,888,000	701,000	2,864,000	3.51
		12.5	6,888,000	666,000	2,650,000	3.25
		20	6,888,000	631,000	2,443,000	3.00
4,000	.05	5	10,181,000	991,000	4,412,000	5.41
		9	10,181,000	853,000	3,580,000	4.39
		12.5	10,181,000	800,000	3,263,000	4.00
		20	10,181,000	749,000	2,957,000	3.63
6,000	.033	5	13,452,000	1,186,000	5,392,000	6.61
		9	13,452,000	1,002,000	4,291,000	5.26
		12.5	13,452,000	932,000	3,872,000	4.75
		20	13,452,000	865,000	3,468,000	4.25

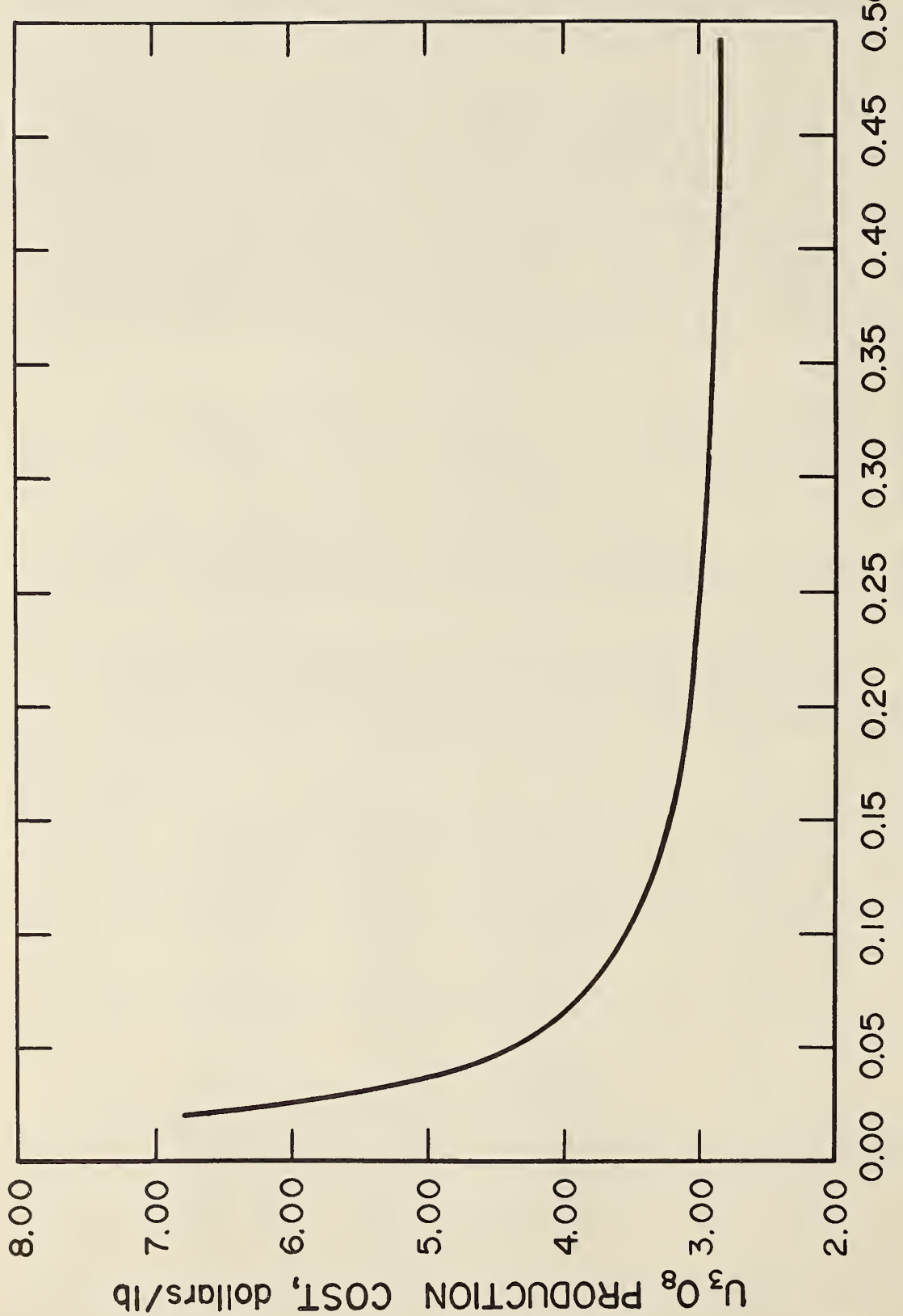

FIGURE 2. - Effect of solution feed grade on unit production cost of U_3O_8.

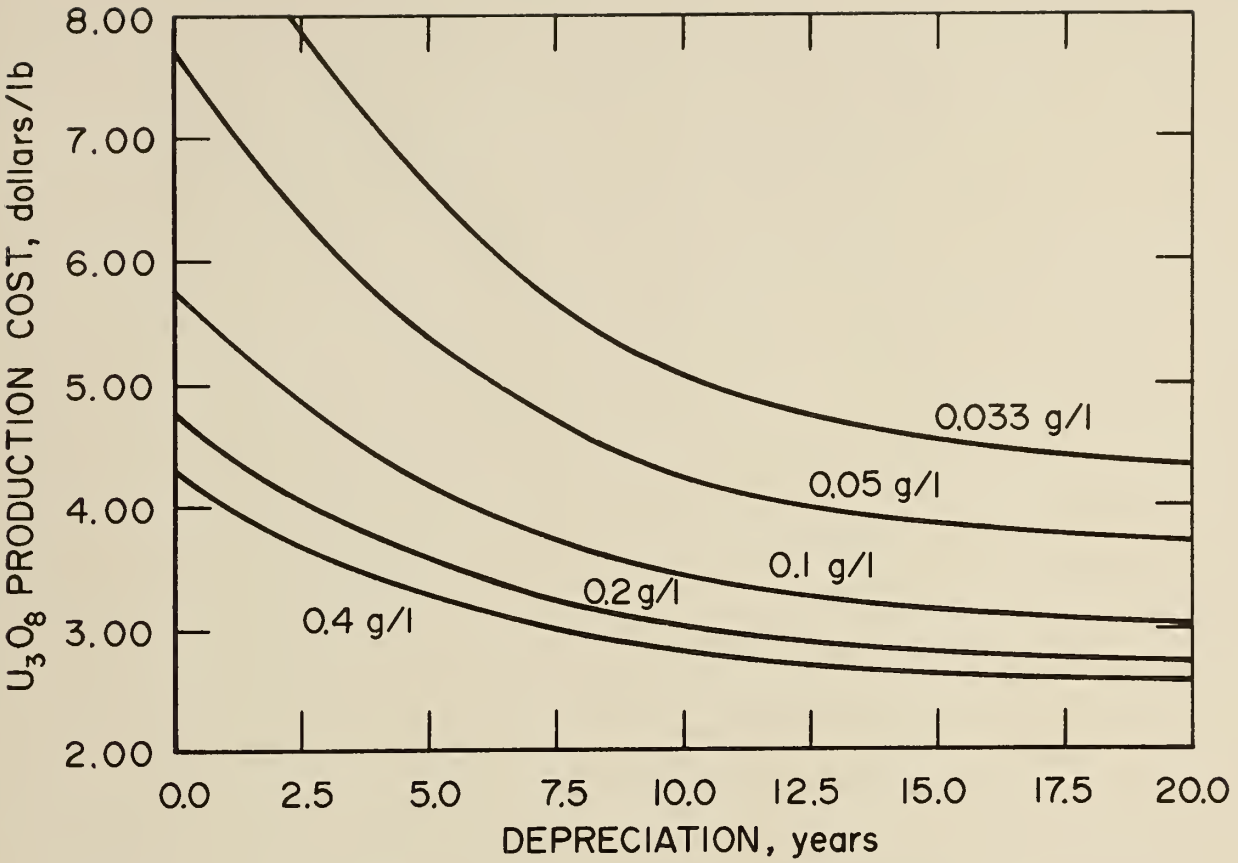

FIGURE 3. - Effect of depreciation of uranium ion-exchange system on unit production cost of U_3O_8

CONCLUSIONS

Cost estimates for production of 815,570 pounds of U_3O_8 per year from ammonium bicarbonate in situ leach solution containing from 0.033 to 0.4 gram per liter U_3O_8 show that the feed solution grade has a significant effect on capital requirement and unit production cost. A system processing 500 gallons per minute of 0.4-gram-per-liter-U_3O_8 solution requires a fixed capital of $4,401,000 compared with $13,452,000 for a system treating 6,000 gallons per minute of 0.033-gram-per-liter-U_3O_8 solution. Based on 9 years' depreciation, the annual operating cost is $2,329,000 and the unit production cost per pound of U_3O_8 is $2.86 for the system treating 0.4-gram-per-liter-U_3O_8 solution. The annual operating cost and unit production cost of U_3O_8 based on 9 years' depreciation increase exponentially to $4,291,000 and $5.26, respectively, for the system treating 0.033-gram-per-liter U_3O_8 solution.

The effect of the operating life of a system on production cost is also significant, particularly for systems treating lower grade feed solutions. The unit production cost per pound of U_3O_8 for a system processing feed solution containing 0.4 gram per liter U_3O_8 based on 20 years of depreciation of $2.53 compared with $3.29 for 5 years. For a system processing 0.033-gram-per-liter-U_3O_8 feed solution, the unit production cost is $4.25 based on 20 years' depreciation and $6.61 for 5 years' depreciation.

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