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URANIUM RECOVERY FROM ORE BY A HIGGINS ION-EXCHANGE CONTACTOR AT GRAND JUNCTION PILOT PLANT

C. W. Hancher
I. R. Higgins
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Washington 25, D. C.

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C. W. Hancher
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CONTENTS

		Page
1.0	ABSTRACT	1
2.0	INTRODUCTION	1
3.0	FEED PREPARATION	1
4.0	EFFECT OF FLOW RATE ON LOADING SECTION PERFORMANCE	2
5.0	EFFECT OF FLOW RATE ON STRIPPING SECTION PERFORMANCE	4
6.0	PRODUCT CONCENTRATION, PURITY, AND QUALITY	6
7.0	EQUIPMENT PERFORMANCE	7
8.0	BIBLIOGRAPHY	8
9.0	APPENDIX	9

TABLES AND FIGURES

Table 3.1	Composition of Feed	2
Table 4.1	Loading Section Performance	3
Table 4.2	Calculated HETS for Loading Section	4
Table 5.2	Calculated HETS for Stripping Section	4
Table 5.1	Stripping Section Performance	5
Table 6.1	Uranium Concentrate Composition	6
Table 9.1	Loading Section Data, 12 tons ore/day	12
Table 9.2	Stripping Section Data, 12 tons ore/day	16
Table 9.3	Pulsing Pressure Data for 12 Ton Per Day and 16 Ton Per Day Test	20
Table 9.4	Loading Section Data, 16 tons ore/day	21
Table 9.5	Stripping Section Data, 16 tons ore/day	24
Figure 9.1	Schematic Diagram of 12 in. dia. Higgins Ion Exchange Contactor Used in Grand Junction Tests	10
Figure 9.2	12-in.-dia Higgins Ion-exchange Contactor	11

1.0 ABSTRACT

The 12-in.-dia Higgins continuous ion-exchange contactor satisfactorily processed 180 tons of Dysart ore over an operating period of 13 days. The uranium loss ranged from 0.001 to 0.004 g of U_3O_8 per liter with an average loss of 0.002 g/liter (0.2% loss). The final uranium product quality exceeded that normally produced. The maximum sustained processing rate was 16 tons of ore per day with all units in the system operating at 200% of design capacity.

2.0 INTRODUCTION

The objective of this study was to test the Higgins continuous ion-exchange column for recovery of uranium from sulfate leach liquors of western ores. The inherent advantages of the continuous ion exchange compared with fixed-bed or basket equipment lead to significant savings for this application [1,2] because of reduced resin inventory and lower chemical consumption. The scope of the study included determination of uranium losses and the uranium concentration profile at steady state as a function of feed rate, product concentration and purity, time required to establish steady state, and equipment performance.

In a prior test at Grand Junction, October 1955, a 5-day run was made in the 12-in.-dia Higgins ion-exchange contactor developed at Oak Ridge National Laboratory. The slurry feed rate was 5 gal/min (about 6 tons of ore per day with 10% slime solids) and the uranium recovery was 99.3% with an average product concentration of 4.3 g/liter as U_3O_8.[3] The low product concentration was due to a high pressure drop in the system, which was corrected prior to the second test.

The second test was made in September 1956. It included two runs, of seven and six days duration, respectively.

3.0 FEED PREPARATION

The feed was prepared by the standard acid Resin-in-Pulp procedure.[4] The ore used was Dysart's Shaft ore from the Rio de Oro deposit in northern New Mexico. The solids after sand-slime separation were -200 mesh, with 8-10% solids in the feed to the contactor. The density of the feed was 1.05 g/ml. The ore as mined contained 0.16% U_3O_8, 77.4% SiO_2, 7.7% Al_2O_3, and 0.05% molybdenum as the major constituents (dry basis) (Table 3.1).[3] The leached ore pulp liquor in passing through the sand-slime separation had removed from it 85% of the original weight of ore. Therefore, the insoluble fraction of the ore passing through the ion-exchange bed was about 15% of the original weight of the ore.

Table 3.1 Composition of Feed

Dysart Shaft Ore	Amount (wt %)	Feed Liquor	Amount
U_3O_8	0.166	U_3O_8 (g/liter)	0.82-1.09
P_2O_5	0.10	$SO_4^=$	10-20
V_2O_5	0.12	Density (g/ml)	1.05
SiO_2	74.40	Solids (wt %)	8-10 (-200 mesh)
Mo	0.047		
CO_2	2.90		
Total SO_4	2.90		
Sol. SO_4	2.21		
Al_2O_3	7.70		
MgO	0.31		
CaO	4.32		

4.0 EFFECT OF FLOW RATE ON LOADING SECTION PERFORMANCE

The flow rates studied were 7 and 10 gal/min with uranium loss remaining essentially constant at 0.001 to 0.004 g of U_3O_8 per liter (Table 4.1). The loading section was 8 ft high.

The uranium concentration profile was determined as a function of flow rate by sampling the liquid phase along the height of the loading bed. In the loading column at 7 gal/min flow rate the uranium concentration reached steady state in 5 ft of bed while at 10 gal/min 7 ft was required. The HETS was calculated to be 1.2 ft at 7 gal/min and 1.5 ft at 10 gal/min (Table 4.2). The design of this column was based on an HETS of 1.8 ft, a flow rate of 5 gal/min (430 gal/hr·ft^2), and a feed concentration of 0.5 g of U_3O_8 per liter. Operation was satisfactory at 10 gal/min (860 gal/hr·ft^2) with a feed concentration of 1.0 g of U_3O_8 per liter and an HETS of 1.5 ft.

The flow ratio of the feed to resin remained constant at approximately 85 volumes of liquor to 1 volume of resin. This was based on the objective of a resin loading of 65 g of uranium per liter of resin. The maximum uranium loading that could be obtained is about 70 g/liter.

Table 4.1 Loading Section Performance

Feed slurry density: 1.05 g/ml

Solids: 8-10%

Resin: Permutit SK, 10-20 mesh

U loading on resin: 65 g/liter

Pulse frequency: 1 per 5 min

Fraction	U Conc. in Aqueous Phase (g U_3O_8/liter)	
	12 tons ore/day[a]	16 tons ore/day[b]
Feed	0.96	0.92
F-2	0.94	0.78
F-3	0.18	0.55
F-4	0.016	0.37
F-5	0.002	0.10
F-6	0.001	0.08
F-7	0.001	0.001
F-8	0.001	0.001
Waste	0.001	0.002

[a] Feed flow rate of 7 gpm (580 gal/hr/ft^2); feed wash flow rate of 0.90 gpm.

[b] Feed flow rate of 10 gpm (860 gal/hr/ft^2); feed wash flow rate of 1.2 gpm.

Table 4.2 Calculated HETS for Loading Section

Feed Rate (gpm)	Liquid/Resin Flow Ratio	Effective[a] Bed Height (ft)	NETS	HETS	
				Actual	Design
7	87	5	3.9	1.2	1.8
10	83	6	3.9	1.54	1.8

[a] Actual depth of ion-exchange bed in the loading section was 8 ft.

5.0 EFFECT OF FLOW RATE ON STRIPPING SECTION PERFORMANCE

The uranium was stripped from the resin at concentrations of 12.1 (Table 5.1) and 10.3 g of U_3O_8 per liter at flow rates of 12 and 16 tons of ore per day. At the 12 tons of ore per day feed rate the HETS for the stripping section was 4.7 ft whereas the design HETS was 2.7 ft. The large HETS was due to the once-an-hour backwash of the slip-water takeoff screen which made it difficult to operate efficiently (Table 5.2)

Two factors were chosen to optimize the performance of the strip section: maximum product concentration and minimum uranium loss to the waste stream. Increasing the stripping and stripping wash rates from 0.2 to 0.4 gpm and from 0.2 to 0.7 gpm, respectively, reduced the losses in the waste stream from 0.05 to 0.008 g/liter as U_3O_8. The addition of a 0.25 M H_2SO_4 scrub at 0.1 gpm further reduced the uranium losses to 0.001 to 0.002 g/liter as U_3O_8. The sulfuric acid scrub performed two functions: (1) it released a resin equivalent of nitrate ion for greater scrubbing efficiency and (2) it left the resin in the sulfate form, in which the equilibrium coefficient favors the adsorption of any $UO_2(SO_4)_3^{4-}$ ion that might be in the liquid phase.

Table 5.1 Stripping Section Performance

U loading on resin: 65 g/liter

Resin pulse height: 3-6 in.

Pulse frequency: 5 min

Slip-water ratio: 4.2/1.0

Strip: 1 M NH_4NO_3--0.1 M HNO_3

Acid Wash: 0.5 M H_2SO_4

Slurry feed: Density - 1.05 g/ml
Solids - 8-10%

Stream	Ore Rate 12 tons/day, 104% Material Balance, 101% Flow Balance		Ore Rate 16 tons/day, 102% Material Balance, 98.7% Flow Balance	
	Flow Rate[a] (gpm)	U Conc. (g U_3O_8/liter)	Flow Rate[a] (gpm)	U Conc. (g U_3O_8/liter)
Strip	0.45	---	0.45	---
Strip wash	0.57	---	0.58	---
Acid wash	0.08	---	0.16	---
Waste	8.20	0.002	11.25	0.003
Slip-water	0.30	---	0.40	---
Product	0.60	12.10	0.90	10.30

[a] 7 gpm = 580 gal/hr/ft^2; 10 gpm = 860 gal/hr/ft^2

Table 5.2 Calculated HETS for Stripping Section

Feed Rate (gpm)	Effective Bed Height (ft)	NETS	HETS (ft)	
			Actual	Design
7	7	1.5	4.7	2.7

6.0 PRODUCT CONCENTRATION, PURITY, AND QUALITY

The precipitated and dried uranium-concentrate cake was 76.1 to 80.1% U_3O_8. The product liquor from the ion-exchange column was precipitated in seven batches by the addition of MgO and dried, giving a total of about 360 lb of uranium. The product specification was attained for total uranium, vanadium, molybdenum, boron, copper, arsenic, phosphate, chloride, bromide, and iodine (Table 6.1). The specifications for fluoride and sulfate were not met; however, this is a function of the process chemistry and reflects the normal experience for the R.I.P. basket system.

Table 6.1 Uranium Concentrate Composition

Component	Amount (%)[a]							
	Specific.	Ppt 1	Ppt 2	Ppt 3	Ppt 4	Ppt 5	Ppt 6	Ppt 7
U_3O_8	75.0	77.1	76.1	80.1	77.7	79.8	79.8	77.1
V_2O_5	1.5	0.05	0.03	0.02	0.006	0.02	0.02	0.02
PO_4	1.5	0.79	0.88	1.02	1.29	1.03	1.11	1.11
Mo	0.45	0.39	0.14	0.11	0.11	0.16	0.17	0.14
B	0.022	0.00047	0.00036	0.00017	Nil	Nil	Nil	Nil
Cl, Br, I	0.075	0.0004	0.0005	0.0005	0.0003	0.0004	0.0003	0.0004
F	0.075	0.22	0.12	0.14	0.10	0.13	0.14	0.15
Cu	1.3	0.06	0.04	0.05	0.15	0.01	0.14	0.11
As	0.6	0.064	0.021	0.014	0.012	0.025	0.014	0.029
SO_4	11.0	15.4	15.2	12.2	14.7	11.3	13.2	14.4
NH_3		1.83	2.00	1.98	1.99	1.58	1.53	2.12
Fe		0.10	0.14	0.14	0.29	0.15	0.18	0.22

[a] Each precipitate batch is for approximately 48 hr of contactor operation and contained about 50 lb of uranium.

7.0 EQUIPMENT PERFORMANCE

The mechanical and hydraulic performance of the equipment was very satisfactory. Two flow problems resulted from operation of the system at 200% of design capacity: (1) an undersized feed pump which limited the feed rate to 10 gal/min and (2) an undersized screen on the line for discharge of slip-water. A third problem was the occasional need for backwashing the feed screen to remove wood chips; however, the pulsing action of the column tended to clear the screen without backwashing. The separation of wood fibers was a separate operation and involved considerable attention because the proper automatic equipment was not provided.

The pressure required for feeding the leach-pulp liquor was 14 to 24 psig (20 psig average) at 10 gal/min.

The pressure at the middle of the loading section was also measured, 15 psig average at 7 gal/min and 20 psig average at 10 gal/min. This indicated that the pressure drops were comparable for the inlet and outlet screens. The principal value of this pressure measurement was to indicate which screen was being plugged.

The strip-feed pumping pressure varied from 7 to 15 psig (10 psig average) at 1.0 gal/min and 11 to 18 psig (16 psig average) at 1.2 gal/min. The interval pressure in the strip column was 9 psig average at 1.0 gal/min and 13 psig average at 1.2 gal/min, which indicated that the major pressure drop was across the discharge screen and for this screen it was approximately equivalent to pressure drops in the loading section screens.

The Higgins column operates as a series of fixed beds which are moved periodically. This movement of the bed results in overall performance of the unit as a continuous countercurrent device. The movement of the bed is accomplished by a high flow rate of water and the slip-water ratio, i.e., the ratio of the volume of water to volume of resin moved, is a function of the resin mass inertia and the wall-to-resin friction.

The slip-water ratio decreased from 6.4/1 to 3.2/1 during the (12-ton/day) operation (water/resin volume) and was approximately 3.3/1 for the 16-ton/day operation. This probably reflects the cleaning action of the resin in the column, which decreased the friction pressure drop. During the prior test the pulse pressure was approximately 60 psig to move the resin with a slip-water ratio of 4.0/1.0. Thirty per cent of this total drop was across a 4-in.-dia connecting line between the two sections. When this line was replaced by a 6-in.-dia line, the total contactor pressure drop was reduced to 45 psi.

The pulsing frequency for the movement of resin was on a 5-min cycle. The volume of resin moved was governed by the resin-loading capacity. At the 12-ton/day rate the resin volume moved was 0.43 gal/pulse, which is equivalent to 0.086 gal/min of resin flow. At 16 tons/day the resin volume moved was 0.60 gal/pulse, equivalent to 0.12 gal/min of resin flow.

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9.0 APPENDIX

The 12-in.-dia column is shown in Figs. 9.1 and 9.2. Detailed tables of data are attached.

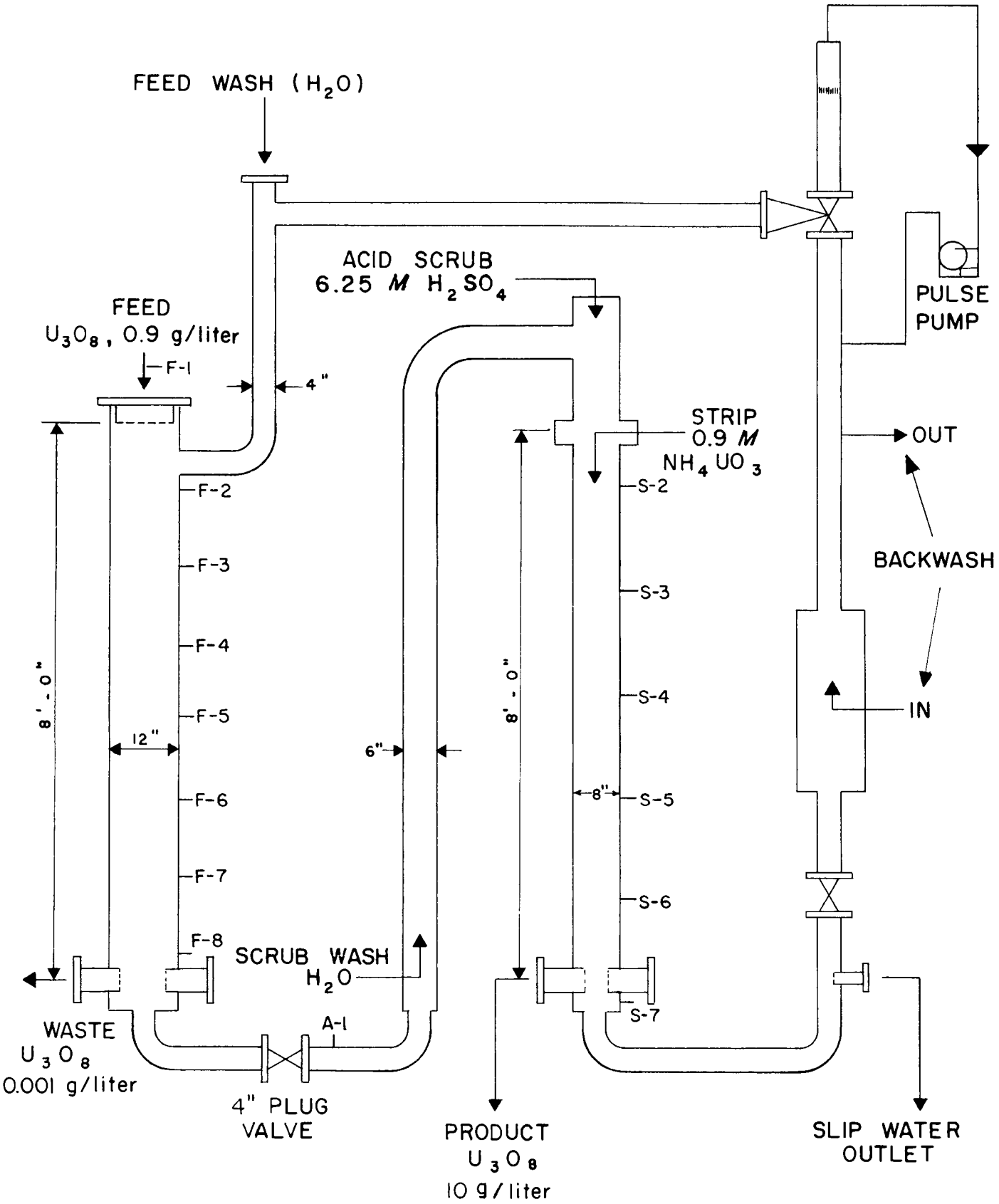

Fig. 9.1. Schematic Diagram of 12 in. dia. Higgins Ion Exchange Contactor Used in Grand Junction Tests. Resin Capacity ~ 13 ft.^{3}

Fig. 9.2. 12-in.-dia Higgins Ion-Exchange Contactor.

Table 9.1

Loading Section Data, 12 tons ore/day

Feed flow rate: 7 gpm

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/7/56	11:00 PM	1.07	7.8	0.98			0.34				0.004	0.003	20	11
9/8/56	1:00 AM	1.12	8.0	0.91							0.006	0.003	22	9
	3:00	1.12	8.3	0.88			0.58				0.003	0.004	20	15
	5:00	1.12	8.3	0.88							0.004	0.005	23	17
	7:00	0.79	8.0	0.85			0.64				0.003	0.005	21	16
	9:00	0.76	8.0	0.90							0.002	0.006	21	15
	11:00	0.67	7.5	0.76			0.39				0.001	0.004	20	15
	1:00 PM	0.69	7.3	0.82							0.001	0.044	18	15
	3:00	0.65	8.0	0.82			0.16				0.001	0.042	21	14
	5:00	0.63	7.5	0.87							0.001	0.14	21	14
	7:00	0.65	8.3	0.94	0.56		0.21	0.007	0.002	0.001	0.002	0.027	22	14
	10:00	0.69	8.0	0.89			0.22				0.004	0.075	21	15
	12:00	0.61	9.0	0.90			0.36				0.003	0.086	22	16
9/9/56	3:00 AM	0.86	8.3	0.84							0.006	0.020	22	16
	5:00	0.89	8.3	0.86							0.005	0.590	21	17
	7:00	0.90	8.0	0.96			0.37				0.004	0.067	22	16
	9:00	0.89	8.5	0.98							0.004	0.100	21	16
	11:00	0.86	8.0	0.96			0.35				0.003	0.056	21	16
	1:00 PM	0.90	8.0	0.92							0.005	0.054	23	15
	3:00	0.86	8.8	0.97			0.38				0.002	0.120	22	16
	5:00	0.85	8.3	0.94							0.003	0.049	24	16

Table 9.1 (Cont'd)

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/9/56	7:00 PM	0.86	8.3	0.90			0.23				0.002	0.150	21	16
	9:00	0.84	8.0	0.88							0.002	0.050	22	16
	11:00	0.85	8.3	0.93			0.23				0.001	0.032	22	16
9/10/56	1:00 AM	0.92	8.5	0.89			0.15				0.001	0.027	21	16
	3:00	0.92	8.3	0.87							0.001	0.074	21	15
	5:00	0.91	8.3	0.85			0.09				0.002	0.047	20	16
	7:00	0.87	7.8	0.84							0.002	0.047	17	16
	9:00	0.86	7.5	0.99			0.28				0.003	0.048	19	16
	11:00	0.85	8.3	0.83							0.002	0.043	17	16
	1:00 PM	0.85	8.0	0.86			0.21				0.002	0.059	18	16
	3:00	0.85	8.3	0.88	0.84	0.59	0.21	0.02	0.003	0.002	0.001	0.043	16	16
	5:00	0.88	8.3	0.87			0.22				0.001	0.043	21	16
	7:00	0.88	8.3	0.87			0.21				0.001	0.015	21	16
	9:00	0.84	8.0	0.86							0.001	0.008	19	16
	11:00	0.91	8.0	0.88							0.001	0.010	17	14
9/11/56	1:00 AM	0.91	8.0	0.66			0.13				0.001	0.011	17	12
	3:00	0.88	7.8	0.84							0.001	0.011	16	11
	5:00	0.90	8.0	0.88			0.098				0.001	0.008	20	11
	7:00	0.90	8.0	0.90							0.001	0.006	20	12
	9:00	0.90	8.0	0.97			0.24				0.001	0.001	17	11
	11:00	0.90	8.0	0.94							0.001	0.006	16	11
	1:00 PM	0.90	8.3	0.96			0.34				0.001	0.008	18	11
	3:00	0.90	8.0	0.99	0.94		0.36	0.044	0.002	0.001	0.001	0.013	16	11

Table 9.1 (Cont'd)

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/11/56	5:00 PM	0.90	8.0	0.98							0.004	0.010	15	11
	7:00	0.90	8.3	0.96							0.002	0.010	15	11
	9:00	0.88	7.8	0.93	0.93	0.65	0.32	0.38	0.004	0.002	0.003	0.009	15	11
	11:00	0.88	7.8	0.93							0.002	0.016	15	11
9/12/56	1:00 AM	0.88	8.0	0.98			0.44				0.001	0.009	16	11
	3:00	0.88	7.6	0.97							0.002	0.008	16	11
	5:00	0.90	8.0	0.95			0.48				0.002	0.008	16	11
	7:00	0.90	8.0	0.95			0.50				0.002	0.012	16	12
	9:00	0.90	8.3	0.88							0.003	0.001	17	12
	11:00	0.90	8.0	0.93			0.50				0.002	0.005	16	12
	1:00 PM	0.90	8.3	1.03	0.93		0.370	0.27	0.002	0.001	0.001	0.003	16	12
	3:00	0.88	7.6	0.94	0.93						0.003	0.002	16	13
	5:00	0.88	7.8	0.95			0.26				0.001	0.007	16	12
	7:00	0.88	7.8	0.91			0.28				0.001	0.002	15	12
	9:00	0.90	8.3	0.93							0.001	0.001	15	9
	11:00	0.90	8.3	0.92	0.92		0.22				0.001	0.001	15	9
9/13/56	1:00 AM	0.90	8.3	0.96							0.001	0.001	15	10
	3:00	0.90	8.3	0.74			0.063				0.001	0.001	16	10
	5:00	0.90	8.3	0.91							0.001	0.001	14	10
	7:00	0.87	7.3	0.99							0.001	0.001	16	11
	9:00	0.90	7.5	1.09			0.30				0.001	0.002	16	11
	11:00	0.88	7.5	1.09							0.015	0.001	17	12
	1:00 PM	0.88	7.8	1.00			0.37				0.001	0.002	15	10

Table 9.1 (Cont'd)

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/13/56	3:00 PM	0.90	8.0	0.96	0.96		0.18	0.016	0.001	.001	Nil	0.001	13	9
	5:00	0.92	8.3	0.94							Nil	0.001	15	10
	7:00	0.94	8.3	0.83			0.12				Nil	0.001	15	10
	9:00	0.90	8.3	0.75							.001	0.001	16	10
	11:00	0.88	8.3	1.117			0.14				Nil	Nil	16	10
9/14/56	1:00 AM	0.88	8.0	0.81							Nil	Nil	16	10
	3:00	0.90	8.0	0.82			0.31				Nil	0.001	14	10
	5:00	0.90	8.3	0.84										

*Distance from feed point.

Table 9.2

Stripping Section Data, 12 tons ore/day

Strip: 0.9 M $NaNO_3$--0.1 M HNO_3
Acid Scrub: 0.25 M H_2SO_4

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/7/56	11:00 PM	0.21	0.27	Not in use	0.63	2.0		1.94			0.64	6.37		6	5
9/8/56	1:00 AM	0.19	0.24		0.72	2.0		10.90			0.54	7.93		17	10
	3:00	0.21	0.26		0.78	2.0						9.40		7	6
	5:00	0.21	0.27		0.72	2.0					3.99	8.44		7	6
	7:00	0.24	0.27		0.69	2.0		6.32			3.63	11.67		6	5
	9:00	0.24	0.27		0.79	2.0					5.29	12.84		7	6
	11:00	0.22	0.29		0.84	2.0		17.64			9.89	14.59		7	7
	1:00 PM	0.21	0.33		0.92	2.0	3.45				12.22	14.27		7	7
	3:00	0.24	0.37		0.85	1.5	3.78	22.79			11.71	15.60		6	10
	5:00	0.22	0.33		0.95	2.0	2.00	18.79			10.71	16.35		6	7
	7:00	0.26	0.36		1.05	1.5	1.52	10.21			13.25	12.62		7	7
	9:00	0.25	0.35		0.99	2.0	1.73	10.29			6.79	9.54		8	8
	11:00	0.29	0.42		0.95	1.5	1.48	6.24			6.66	8.62		7	8
9/9/56	1:00 AM	0.29	0.50		0.88	1.5	1.30				7.48	8.52		6	7
	3:00	0.28	0.51		0.98	2.0	0.74				5.60	9.19		8	8
	5:00	0.35	0.49		0.98	2.0	0.48	4.06			8.41	10.50		9	8
	7:00	0.34	0.48		0.98	1.5	0.96	6.39		14.05		10.66		7	9
	9:00	0.36	0.47		0.45	2.0	0.62			14.06		10.91		8	10
	11:00	0.29	0.51		0.50	2.0	0.83	2.96		11.37		12.81		10	11
	1:00 PM	0.43	0.54		0.55	2.0	0.54			7.41		11.66	2.06	11	8
	3:00	0.44	0.56		0.45	2.0	0.47	4.16		11.64		10.60		12	12

Table 9.2 (Cont'd)

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/9/56	5:00 PM	0.41	0.54	Not in use	0.50	2.0	.88	4.85		10.53		12.43		13	8
	7:00	0.44	0.62		0.50	2.0	.64			10.75		11.64		14	10
	9:00	0.46	0.61		0.60	2.0	.75	7.60		9.43		10.59	1.33	16	12
	11:00	0.44	0.60		0.60	2.0	.46			12.15		9.57		17	14
9/10/56	1:00 AM	0.41	0.59		0.50	1.5	1.11	2.14		14.55		10.61		15	15
	3:00	0.48	0.62		0.55	1.5	1.05			13.50		11.48		22	16
	5:00	0.46	0.60		0.55	2.0	0.72	3.62		9.10		9.68		12	13
	7:00	0.44	0.56		0.55	2.0	0.36	1.99		5.52		9.53	1.10	20	17
	11:00	0.44	0.57		0.45	1.5	0.74			10.16		10.78	1.05	21	11
	1:00 PM	0.51	0.53		0.45	1.5	0.34			10.36		9.94	0.99	13	11
	3:00	0.48	0.41		0.40	2.0	0.38			7.40		8.65	0.85	12	11
	5:00	0.41	0.62		0.63	1.75	0.29			7.64		9.29	0.91	15	15
	7:00	0.40	0.52		0.60	2.00	0.53			9.22		11.42	0.49	18	17
	9:00	0.40	0.54		0.50	1.75	0.42			11.51		15.06	0.35	22	22
	11:00	0.44	0.51		0.55	1.25	0.53	2.45		9.27		13.97	0.28	19	20
9/11/56	1:00 AM	0.41	0.52		0.55	1.50	0.52			10.16		12.66	0.28	14	16
	3:00	0.43	0.51		0.50	2.00	0.27	3.53		10.36		11.01	0.16	11	13
	5:00	0.43	0.55		0.60	1.30	0.31			6.49		9.29	0.18	12	12
	7:00	0.44	0.55		0.70	1.75	0.059	1.54		6.49		8.14	0.39	15	16
	9:00	0.43	0.53		0.50	2.00	0.26	1.40		6.30		7.77	0.38	17	19
	11:00	0.43	0.53		0.60	2.00	0.31			4.67		6.06	0.27	15	19
	1:00 PM	0.37	0.48		0.60	2.25	0.40	1.78		7.10		10.04	0.31	17	19
	3:00	0.43	0.51		0.60	2.25	0.28	2.37	5.32	8.73	11.25	11.05	0.31	13	13

Table 9.2 (Cont'd)

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/11/56	5:00 PM	0.34	0.54		0.40	2.25	0.13			7.77		10.53	0.31	12	14
	7:00	0.37	0.63		0.60	2.25	0.13			12.45		13.06	0.28	8	10
	9:00	0.38	0.56	0.073	0.80	2.50	0.25	4.46	7.43	11.49	14.12	12.96	0.27	10	12
	11:00	0.37	0.57	0.100	0.70	2.75	0.24	11.00				12.98	0.059	10	12
9/12/56	1:00 AM	0.37	0.57	0.092	0.70	2.00	0.17			8.42		11.43	0.13	9	11
	3:00	0.35	0.56	0.083	0.60	2.25	0.17	2.60		9.03		10.95	0.22	10	12
	5:00	0.35	0.56	0.083	0.70	2.00	0.18			7.44		12.26	0.19	11	11
	7:00	0.37	0.56	0.083	0.65	2.50	0.11	2.15				10.27	0.25	10	11
	9:00	0.29	0.58	0.083	0.60	2.00	0.076	1.83		7.16		9.50	0.21	10	11
	11:00	0.40	0.52	0.073	0.70	1.75	0.14	2.22		8.15		11.33	0.20	9	18
	1:00 PM	0.37	0.48	0.100	0.55	2.00	0.087	1.54		7.72		11.62	0.20	9	20
	3:00	0.37	0.52	0.064	0.70	1.75	0.20	2.87	5.77	12.08	17.70	14.10	0.19	9	12
	5:00	0.37	0.52	0.092	0.50	2.00	0.34			11:02		13.45	0.16	9	11
	7:00	0.35	0.50	0.100	0.60	2.00	0.25	2.26		9.55		14.73	0.17	10	12
	9:00	0.32	0.48	0.092	0.40	1.75	0.35			8.54	16.06	13.63	0.16	7	10
	11:00	0.38	0.52	0.073	0.50	2.00	0.32	2.15	4.32	10.44		15.00	0.044	7	10
9/13/56	1:00 AM	0.29	0.51	0.083	0.65	1.75	0.18			7.79		14.28	0.16	7	10
	3:00	0.37	0.50	0.083	0.55	1.75	0.36	2.37		10.39		14.90	0.16	8	12
	5:00	0.30	0.49	0.083	0.55	2.00	0.19	2.00		7.93		14.52	0.15	7	10
	7:00	0.41	0.47	0.092	0.55	2.25	0.16			9.12		14.11	0.20	7	8
	9:00	0.40	0.50	0.092	0.60	2.25	0.087		1.38	4.59		9.24	0.15	7	8
	11:00	0.40	0.53	0.120	0.55	2.25	0.080			6.56		10.32	0.14	7	10
	1:00 PM	0.40	0.51	0.083	0.65	2.00	0.054		0.90	5.71		9.61	0.13	10	8

Table 9.2 (Cont'd)

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/13/56	3:00 PM	0.38	0.53	0.073	0.45	2.00	0.047					13.43		7	7
	5:00	0.37	0.46	0.100	0.65	2.00	0.062	2.43	4.66	3.00	17.26	16.61	0.007	8	7
	7:00	0.37	0.52	Not in use	0.70	2.00	0.092			12.47		12.97	0.009	7	5
	9:00	0.37	0.51		0.55	1.75	0.099		2.70	9.62		12.69	0.014	7	7
	11:00	0.35	0.54		0.70	2.00	0.098			9.42		10.70	0.006	7	7
9/14/56	1:00 AM	0.35	0.54		0.60	1.75	0.340		2.66	7.82		14.93	0.13	7	7
	3:00	0.33	0.53		0.65	2.00	0.55			15.02		13.02	0.010	7	7
	5:00	0.33	0.55		0.65	2.00	0.18		6.49	14.57		10.94	0.11	7	7

Distance from strip inlet point in stripping column.

Table 9.3

Pulsing Pressure Data for 12 Ton Per Day and 16 Ton Per Day Test

Date	Time	Pulse Time	Pulse Frequency	Pulse Amplitude			Pulse Resin Volume	Pulse Water Volume	Pulse Pressure	Feed Rate
				6 in. pipe	8 in. pipe	12 in. pipe				
		sec.	min.	inch	inch	inch	gallon	gallon	psig	ton/day
9-8-56	1:00 AM	14	5	3.0	1.7	0.75	0.36	2.00	57	12
	1:00 PM	12	4	2.5	1.4	0.62	0.31	2.00	46	
9-9-56	1:00 AM	14		3.5	2.0	0.87	0.42	1.50	47	
	1:00 PM	15		4.1	2.3	1.00	0.52	2.00	47	
9-10-56	1:00 AM	15		3.5	2.0	0.87	0.43	1.50	43	
	1:00 PM	14	5						44	
9-11-56	1:00 AM	13							46	
	1:00 PM	14						2.25	41	
9-12-56	1:00 AM	14						2.00	40	
	1:00 PM	15						2.00	37	
9-13-56	1:00 AM							1.75	35	
	1:00 PM			4.0	2.2	1.0	0.48	2.00	41	
9-14-56	1:00 AM			4.5	2.5	1.1	0.59	1.75	39	16
	1:00 PM			3.5	2.0	0.87	0.43	2.0	40	
9-15-56	1:00 AM	16		4.0	2.2	1.0	0.48	2.0	36	
	1:00 PM	17						2.5	39	
9-16-56	1:00 AM	17						2.0	45	
	1:00 PM	18		4.5	2.5	1.1	0.59	2.3	34	
9-17-56	1:00 AM	19		4.0	2.2	1.0	0.48	2.3	39	
	1:00 PM	20		4.5	2.5	1.1	0.59	2.5	40	
9-18-56	1:00 AM	20		4.5	2.5	1.1	0.59	2.3	43	
	1:00 PM	21		4.0	2.2	1.0	0.48	2.0	45	
9-19-56	1:00 AM	21		4.5	2.5	1.1	0.59	2.5	40	

Table 9.4

Loading Section Data, 16 tons ore/day

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/14/56	7:00 AM	0.95	7.5	0.85			0.019				Nil	0.001	27	15
	9:00	1.0	10.5								0.001	0.005	40	
	11:00	1.1	9.0	0.96			0.33				Nil	0.002		16
	1:00 PM	1.2	11.2											
	3:00	1.2	9.8											
	5:00	1.2												
	7:00		Sand											
	9:00													
	11:00													
9/15/56	1:00 AM	0.84	6.8										27	9
	3:00	1.0	8.0										27	11
	5:00	1.0	8.2										25	12
	7:00	1.0	8.4										22	15
	9:00	1.1	8.2	0.87							0.001	0.001	24	15
	11:00	1.0	9.9	0.96							0.001	0.002	24	14
	1:00 PM	1.0	9.8	0.92	0.78		0.37	0.010	0.080	0.001	0.001	0.003	24	14
	3:00	1.1	9.3	1.00							0.001	0.007	24	15
	5:00	1.1	9.0	1.14							0.001	0.006	25	15
	7:00	1.1	9.0	0.94							0.001	0.006	25	15
	9:00	1.0	9.0	0.94										
	11:00			Pump Packing							0.001	0.004	45	17

Table 9.4 (Cont'd)

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/16/56	1:00 AM	1.1	9.0	0.87										
	3:00	1.2	11.0	0.84							0.001	0.004	43	13
	5:00	1.2	11.0	0.96							0.001	0.002	58	19
	7:00	1.1	9.0	1.04							0.001	0.002	40	16
	9:00	1.1	10.8	1.12							0.001	0.004	41	20
	11:00	1.2	9.0	1.08			0.47				0.001	0.004	44	15
	1:00 PM	1.1	9.5	0.98	0.94	0.72	0.38	.062	0.006	0.001	0.001	0.003	38	15
	3:00	1.1	11.1	0.96							0.001	0.005	38	17
	5:00	1.1	10.5	1.01							0.002	0.005	50	20
	7:00	1.1	11.3	0.92			0.75				0.005	0.001	42	20
	9:00	1.1	11.0	0.81							0.005	0.006	42	18
	11:00	1.1	9.3	0.78			0.78				0.003	0.005	39	21
9/17/56	1:00 AM	1.1	10.0	0.86							0.002	0.003	37	20
	3:00	1.1	10.5	0.89			0.28				0.001	0.002	37	20
	5:00	1.1	10.5	0.84							0.001	0.003	35	20
	7:00	1.2	9.5	0.90			0.40				0.001	0.008	35	20
	9:00	1.2	9.8	0.90			0.40				0.001	0.008	38	18
	11:00	1.2	9.3	0.90			0.43				0.001	0.007	42	18
	1:00 PM	1.2	10.5	1.02	1.02	0.80	0.44	0.095	0.009	0.003	0.003	0.006	40	20
	3:00	1.2	10.5	1.06							0.003	0.005	40	15
	5:00	1.2	11.3	1.01			0.61				0.002	0.005	42	21
	7:00	1.2	10.5	0.94	0.95	0.78		0.25	0.026	0.005	0.001	0.006	40	21
	9:00	1.2	10.0	0.86							0.002	0.004	40	22
	11:00	1.2	10.5	0.76			0.39				0.001	0.003	42	23
											0.001	0.002	39	21

Table 9.4 (Cont'd)

Date	Time	Flow Rate (gpm)		Flowing Stream U Concentration (g U_3O_8/liter)									Operating Pressure (psig)	
		Feed Wash	Waste	Feed	1 ft*	2 ft*	3 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Waste	Feed Pump	Column Midpoint
9/18/56	1:00 AM	1.2	11.3	0.82							0.001	0.004	32	24
	3:00	1.2	10.8	0.95			0.39				0.001	0.005	40	22
	5:00	1.2	11.3	0.90							0.001	0.005	35	22
	7:00	1.2	12.0	1.03			0.72				0.001	0.007	40	22
	9:00	1.2	11.0	1.10							0.002		40	20
	11:00	1.2	11.5	1.00	0.86	0.71	0.35	0.10	0.02	0.003	0.003		40	24
	1:00 PM	1.2	12.0	0.81							0.002	0.006	42	24
	3:00	1.2	11.5	0.86	0.87	0.75	0.67	0.38	0.14	0.024	0.003	0.012	42	22
	5:00	1.2	11.8	0.92									40	24
	7:00	1.2	11.0	0.93			0.75				0.008	0.052	39	21
	9:00	1.2	11.0	1.04							0.043	0.060	32	19
	11:00	1.2	9.8	0.79			0.14				0.003	0.060	30	17
9/19/56	1:00 AM	1.2	10	1.03							0.003	0.039	35	19
	3:00	1.2	9.0	0.79							0.002	0.025	35	18
	5:00	off												
	7:00	1.2	9.3	1.00			0.39				0.03	0.002	40	16
	9:00	1.2	9.4	0.91							0.001	0.077	40	20
	11:00													
	1:00 PM													
	3:00													
	5:00	Shutdown Feed Wash and Strip Contactor												
	7:00													
	9:00													
	11:00													

*Distance from feed point.

Table 9.5

Stripping Section Data, 16 tons ore/day

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/14/56	7:00 AM	0.69	0.49	Pump-out	1.20	2.0	1.14			14.32		11.19	0.002	8	6
	9:00														
	11:00	0.74	0.57		1.51	2.0	0.78		6.33	15.30		10.38	0.019	8	2
	1:00 PM	0.65	0.66		1.51									17	13
	3:00	Sand-out													
	5:00														
	7:00														
	9:00														
	11:00	Start-up													
9/15/56	1:00 AM													8	4
	3:00													5	3
	5:00													6	5
	7:00													7	7
	9:00	0.40	0.46		0.85	2.0	0.32			11.11		11.74	0.028	8	7
	11:00	0.38	0.57		1.08	1.8	0.20		5.30	8.23		8.18	0.028	9	7
	1:00 PM	0.43	0.57		1.05	1.8	0.50			12.73		10.54	0.023	10	9
	3:00	0.45	0.57		1.08	2.0	0.17			8.04		9.22	0.014	10	11
	5:00	0.43	0.54	0.22	1.17	3.0	0.35			13.34		13.55	0.050	12	10
	7:00	0.43	0.53	0.15	1.27	2.3	1.40			9.02		11.10	0.097	12	10
	9:00	0.45	0.60	0.15	1.12	1.5	0.40			11.11		11.74	0.051	11	19
	11:00	0.47	0.58	0.15	1.30	1.8							0.028	8	5
														9	5

Table 9.5 (Cont'd)

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/16/56	1:00 AM	0.43	0.50	0.07	1.14	2.0	6.50		5.30	8.23		8.18	0.028	12	10
	3:00	0.47	0.55	0.15	1.15	2.0	0.17			12.73		10.54	0.023	12	10
	5:00	0.45	0.56	0.15	1.05	2.0	0.35			8.04		9.22	0.014	12	9
	7:00	0.45	0.54	0.07	1.15	2.0	0.35			13.34		13.55	0.050	12	9
	9:00	0.45	0.54	0.17	1.16	2.5	0.31				5.63	12.66	0.097	12	10
	11:00	0.45	0.53	0.15	1.44	2.3	0.38		4.31		6.64	10.79	0.058	12	10
	1:00 PM	0.45	0.57	0.07	1.35	2.5	0.30		5.88	9.16	10.14	12.24	0.14	12	9
	3:00	0.45	0.56	0.22	1.18	1.8	0.16				8.92	11.67	0.058	13	11
	5:00	0.45	0.57	0.15	1.28	2.3	0.15				7.31	8.45	0.029	13	9
	7:00	0.45	0.57	0.15	1.20	2.0	0.15				9.16	11.12	0.017	11	9
	9:00	0.45	0.59	0.17	1.25	2.0	0.21				8.56	11.28	0.008	11	10
	11:00	0.45	0.53	0.18	1.30	2.3	0.21				8.79	10.42	0.010	13	11
9/17/56	1:00 AM	0.45	0.57	0.15	1.15	2.5	0.37				11.13	12.03	0.016	14	12
	3:00	0.45	0.58	0.13	1.19	2.3	0.56				12.35	10.94	0.038	13	11
	5:00	0.45	0.57	0.15	1.19	2.3	0.74				11.33	10.27	0.038	10	9
	7:00	0.45	0.56	0.15	1.20	2.0	0.52				5.55	10.09	0.056	11	9
	9:00	0.45	0.53	0.18	1.34	2.3								10	9
	11:00	0.45	0.57	0.15	1.23	2.5	0.21		4.90		8.02	9.91	0.057	10	8
	1:00 PM	0.45	0.57	0.11	1.16	3.0	0.27		4.19	6.77	2.64	11.44	0.020	11	9
	3:00	0.45	0.56	0.07	1.23	2.5	0.22				10.64	10.96	0.017	16	14
	5:00	0.45	0.56	0.07	1.28	2.0	0.19		3.22		8.26	11.71	0.017	12	9

Table 9.5 (Cont'd)

Date	Time	Flow Rate (gpm)					Flowing Stream Concentration (g U_3O_8/liter)							Operating Pressure (psig)	
		Strip Rate	Strip Wash	Acid Scrub	Product	Slip Water	2 ft*	4 ft*	5 ft*	6 ft*	7 ft*	Product	Midpoint Water Wash Section	Strip Pump	Stripping Column Midpoint
9/17/56	7:00 PM	0.45	0.56	0.15	1.15	2.5	0.24			6.49	10.45	11.79	0.017	12	10
	9:00	0.45	0.57	0.18	1.18	2.5	0.50				13.69	14.13	0.012	14	11
	11:00	0.45	0.55	0.11	1.16	2.5	0.73		7.88		14.79	12.50	0.016	15	11
9/18/56	1:00 AM	0.45	0.56	0.15	1.19	2.0	0.66				8.12	10.86	0.025	13	10
	3:00	0.45	0.57	0.15	1.12	1.8	0.67		6.27		10.27	10.20	0.025	15	12
	5:00	0.45	0.57	0.07	1.29	2.8	1.12				11.28	9.61	0.029	15	11
	7:00	0.45	0.57	0.15	1.34	2.5	0.82		7.69		11.49	11.29	0.044	14	11
	9:00	0.45	0.57	0.07	1.15	3.0	1.78					12.01		14	10
	11:00	0.45	0.58	Pump-out	1.07	1.0								12	9
	1:00 PM	0.45	0.58		1.08	2.0	0.53		15.32	14.89	5.99	12.02	0.16	13	10
	3:00	0.45	0.58		1.15	2.0	4.49				13.45	11.35	0.36	12	12
	5:00	0.45	0.58		1.34	2.0								14	10
	7:00	0.45	0.58		1.44	2.3	1.96		11.69	12.96	6.57	4.20	0.23	15	12
	9:00	0.45	0.58		1.44	2.3						5.67		15	9
	11:00	0.45	0.58		1.19	2.3	0.44		3.32		7.07	10.22	0.092	17	10
9/19/56	1:00 AM	0.45	0.60		1.07	2.3	0.63			15.00		13.50	0.11	17	10
	3:00	0.45	0.61		1.02	2.0	2.54		14.36		25.64	14.07	0.102	18	11
	5:00	Off													
	7:00	0.42	0.64		1.28	2.8	1.22					12.54	0.091	18	12
	9:00	0.44	0.61		1.11	2.8		10.59		15.55					
	11:00														
	1:00 PM														
	3:00														
	5:00	Shut-down Feed Wash and Strip Contactor													
	7:00														

*Distance from strip inlet point in stripping column.