RADIAN CORPORATION

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TASK 2 REPORT:

DOCUMENTATION OF WORK DONE IN SUPPORT OF THE REGIONAL COPPER/NICKEL STUDY

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SECTION 1
INTRODUCTION

This report describes the engineering work performed to support a part of the Regional Copper-Nickel Study being conducted by the Environmental Quality Council of the State of Minnesota. The work described and results presented represent work on Task 2, "Smelter Model Development." The smelter model is a series of estimates which allow the emissions from a future copper/nickel smelter to be predicted. The particular type of smelter is one which would process ore from the Duluth Gabbro ore body.

Six subtasks were completed under Task 2. There are:

- Smelter sulfur balance,
- Limestone scrubber cost estimate,
- Limestone scrubber water use estimate,
- Electrostatic precipitator cost estimate,
- NO_x emissions evaluation, and
- Estimate of particulate emissions.

In the following sections, the purpose of each of these subtasks is described, the assumptions made are given, and the results are presented with the appropriate references.

These sections are intended as documentation of the work performed. They do not contain information from other tasks performed for the Regional Copper-Nickel Study and should not be used without the additional supporting information available to the study.

SECTION 2
SMELTER SULFUR BALANCE

The sulfur material balance estimates presented in this section were completed so that an atmospheric model could be developed of the expected SO_2 emissions from a copper/nickel smelter. Two smelter flowsheets were developed which are feasible for processing the copper/nickel concentrates which are expected to be produced from Duluth Gabbro ore. Figures 1 and 2 are the flowsheets used for the smelter model. Figure 1 employs a flash smelting furnace whereas Figure 2 uses a roaster/electric furnace combination. Both flowsheets represent technically feasible smelting approaches. Neither, however, are expected to be the exact smelter configuration ultimately used.

The basis used for both material balances is as follows:

- 635,245 metric tons per year of concentrate assaying 25.9% sulfur (164,341 metric tons S/year),
- 92% copper recovery,
- 0.005% sulfur in anode copper, and
- 55% copper matte produced.

The quantity and concentration of sulfur in process streams other than the concentrate and anode copper were based on availalbe literature data, data provided by smelting companies, and estimates made by the author.

Tables 1 and 2 present the two smelter sulfur balances and the attached notes list the assumptions made and appropriate references. It should be emphasized that Tables 1 and 2 are the best estimates possible using available smelter data. The estimates of fugitive emissions were made based on observations in five primary copper, one primary copper/nickel, and thirteen other nonferrous smelters. They are, however, estimates. No accurate measurements of fugitive emissions in copper or nickel smelters have been reported in the literature.

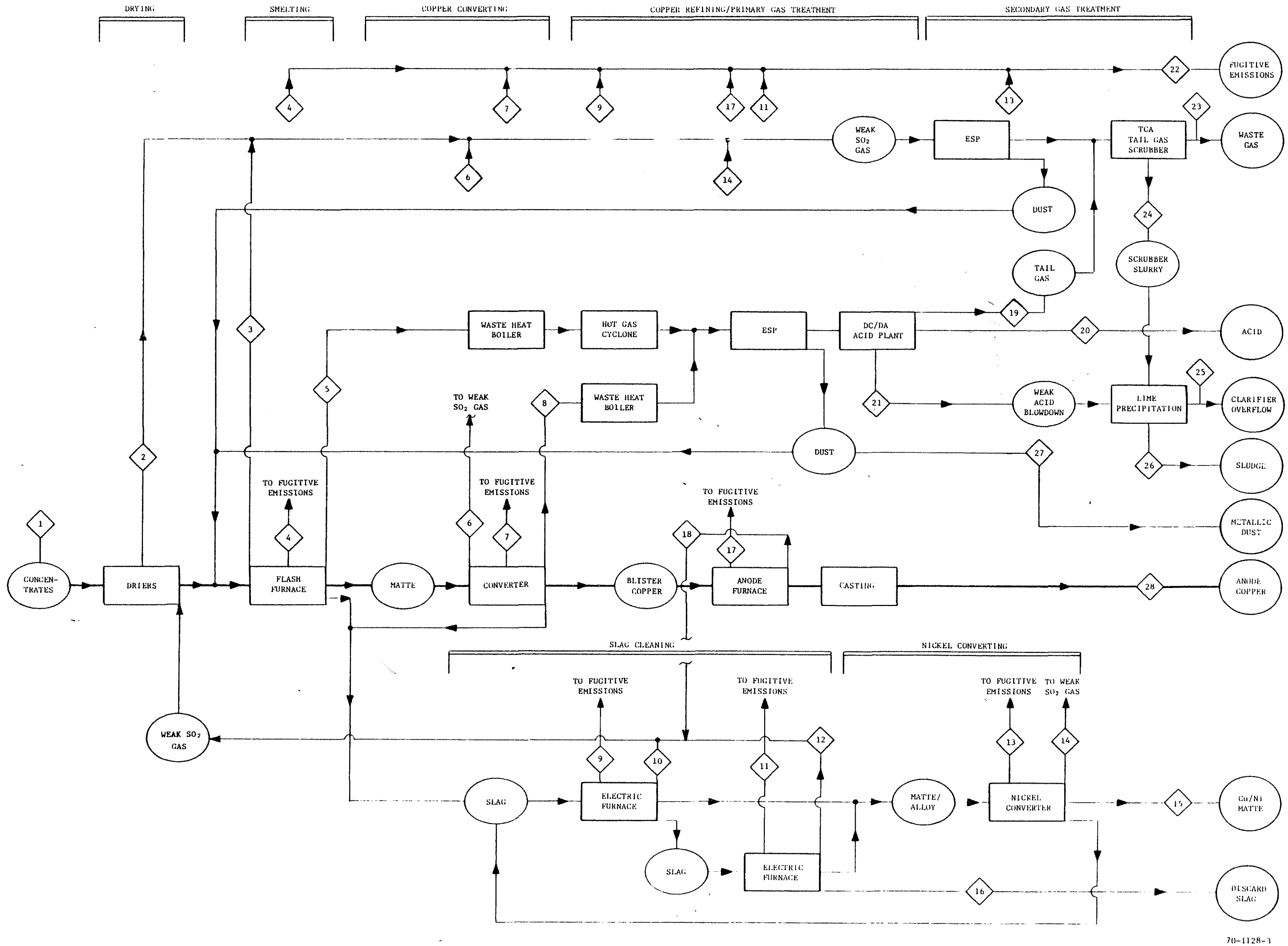

Figure 1. Flowscheme for a copper/nickel smelter using a flash smelting furnace.

TABLE 1. TOTAL SULFUR BALANCE FLASH SMELTING FURNACE

	1	2	3	4	5	6	7	8	9	10	11	12	13
Stream Name	Concentrate	Drier Offgas	Flash Furnace Vent Gas (Slag/Matte Taps)	Flash Furnace Fugitives	Flash Furnace Process Gas	Secondary Converter Hoods	Converter Fugitives	Converter Offgas	Electric Furnace #1 Fugitives	Electric Furnace Offgas #1	Electric Furnace #2 Fugitives	Electric Furnace Offgas #2	Nickel Converter Fugitives
Percent of Sulfur In Concentrate (1)	100.0	0.63	0.90	0.10	62.4	0.90	0.10	29.295	0.04	0.36	0.02	0.185	0.03
Metric Tons Sulfur per Year	164,341	1,035	1,479	164	102,549	1,479	164	48,144	66	592	33	304	49
Gas Flow (SCFM)		60,000	1,000	100	47,042	10,000	1,000	49,184	200	2,000	200	2,000	100

(Continued)

	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Stream Name	Nickel Converter Offgas	Cu/Ni Matte	Discard Slag	Anode Furnace Fugitives	Anode Furnace Offgas	Acid Plant Tail Gas	H_2SO_4	Weak Acid Blowdown	Fugitive Emissions (Total)	Waste Gas	Scrubber Slurry	Clarifier Overflow	Sludge	Metallic Dust	Anode Copper
Percent of Sulfur In Concentrate (1)	0.27	3.00	2.30	0.01	0.088				0.3					0.09	0.0025
Metric Tons Sulfur per Year	444	4,930	3,780	16	145	542	146,841	3,310	492	498	4,481	779	7,012	148	4
Gas Flow (SCFM)	10,600			500	5,000	88,749			2,100	170,349				463.5	

NOTES AND LIST OF ASSUMPTIONS

FOR TABLE 1

Stream No.	
1	Basis for smelter model; 635,245 metric tons concentrate per year; 25.87% sulfur; 164,341 metric tons sulfur per year.
2	Assume spray drier uses streams 10 + 12 + 18 + products of combustion to dry concentrate from 15% moisture to 5% moisture; 200°F exit gas temperature; sulfur in gas from streams 10, 12, and 18.
3	Ventilation gases from slag and matte taps; estimated average flow of these intermittent gas streams; assume 1.0% of incoming sulfur is released in slag or matte taps and 0.9% is captured in these gas streams.
4	Fugitive emissions from slag and matte taps; 0.1% of incoming sulfur; estimated.
5	Sources: HA-373, SH-347; 55% matte; 14% dilution in furnace and waste heat boiler, 12% dilution in electrostatic precipitator, 24% dilution prior to acid plant; 10.82% SO_2 in gas to acid plant.
6	Ventilation gases from secondary converter hoods; estimated average flow; assume 1.0% of incoming sulfur escapes primary converter hoods and 0.9% is captured in this gas stream.
7	Fugitive emissions escaping secondary converter hoods; 0.1% of incoming sulfur; estimated.
8	Source: SH-347; 55% matte; 75% hood dilution, 12% dilution in flues and gas cleaning equipment; 4.85% SO_2 in gas to acid plant.

Stream No.	
⟨9⟩	Estimated; gas flow is assumed to be 10% of stream ⟨10⟩.
⟨10⟩	Estimated using other electric furnace data (MO-274).
⟨11⟩	Estimated; gas flow is assumed to be 10% of stream ⟨12⟩.
⟨12⟩	Same as stream ⟨10⟩.
⟨13⟩	Estimated; average gas flow assumed to be 10% of stream ⟨14⟩.
⟨14⟩	Estimated from data on copper converter (SH-347).
⟨15⟩	Estimated from data on copper converter (SH-347).
⟨16⟩	Estimated from data on copper converter (SH-347).
⟨17⟩	Estimated; gas flow is assumed to be 10% of stream ⟨18⟩.
⟨18⟩	Estimated average of this intermittent gas stream from private conversation with smelting company.
⟨19⟩	∿300 ppm SO_2 in acid plant tail gas; gas flow may vary with acid plant design.
⟨20⟩	97.44% sulfur recovery as acid.
⟨21⟩	Will vary; assume 2000 ppm $SO_4^{=}$, 2500 gpm.
⟨22⟩	Total of streams ⟨4⟩ ⟨7⟩ ⟨9⟩ ⟨11⟩ ⟨13⟩ and ⟨17⟩.
⟨23⟩	90% sulfur removal efficiency for scrubber.

Stream No.	
24	2 + 3 + 6 + 14 + 19 - 23.
25	10% of inlet to water treatment plant; 0.1 x (21 + 24).
26	21 + 24 - 25.
27	Source: SH-347; 0.09% of 1.
28	Basis: 0.005% S in anode copper.

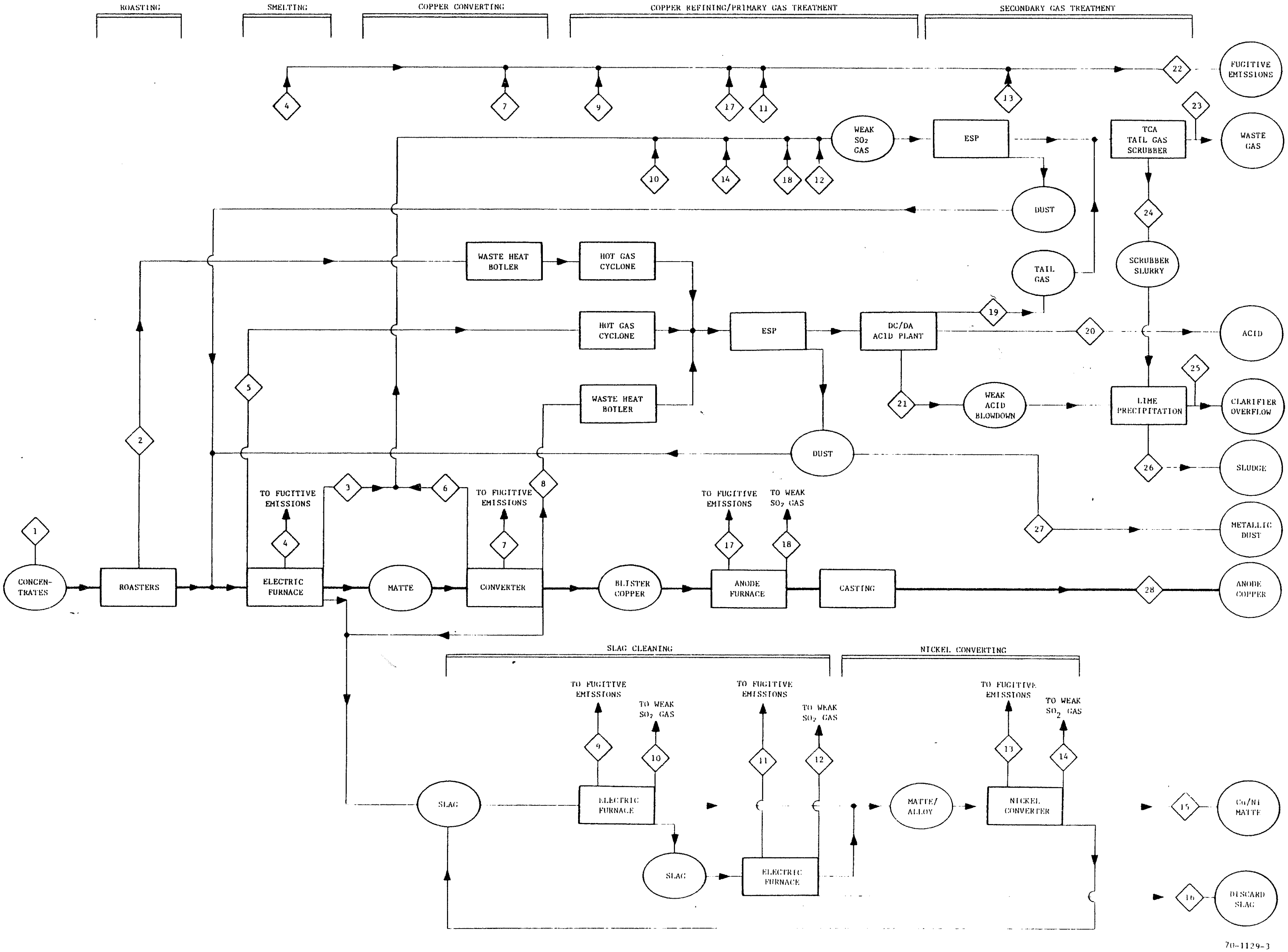

Figure 2. Flowscheme for a copper/nickel smelter using a fluosolids roaster/electric furnace combination.

TABLE 2. TOTAL SULFUR BALANCE - ELECTRIC SMELTING FURNACE CASE

	1	2	3	4	5	6	7	8	9	10	11	12	13
Stream Name	Concen-trate	Roaster Offgas	Electric Furnace Ventilation Gas (Slag/ Matte Taps)	Electric Furnace Fugitives	Electric Furnace Process Gas	Secondary Converter Hoods	Converter Fugitives	Converter Offgas	Electric Furnace #1 Fugitives	Electric Furnace #1 Offgas	Electric Furnace #2 Fugitives	Electric Furnace #2 Offgas	Nickel Converter Fugitives
Percent of Sulfur in Concen-trate (1)	100.0	50.0	0.9	0.1	12.8	0.9	0.1	28.9	0.04	0.36	0.02	0.18	0.03
Metric Tons Sulfur per Year	164,341	82,170	1,479	164	21,036	1,479	164	47,495	66	592	33	296	49
Gas Flow (SCFM)		25,155	1,000	100	12,250	10,000	1,000	49,184	200	2,000	200	2,000	100

(Continued)

	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Stream Name	Nickel Converter Offgas	Cu/Ni Matte	Discard Slag	Anode Furnace Fugitives	Anode Furnace Offgas	Acid Plant Tail Gas	H_2SO_4	Weak Acid Blowdown	Total Fugitive Emissions	Waste Gas	Scrubber Slurry	Clarifier Overflow	Sludge	Metallic Dust	Anode Copper
Percent of Sulfur in Concen-trate (1)	0.27	3.0	2.3	0.00975					0.30					0.09	0.0025
Metric Tons Sulfur per Year	444	4,930	3,780	16	144	484	146,758	3,310	493	492	4,426	774	6,962	148	4
Gas Flow (SCFM)	10,600			500	5,000	79,112			2,100	109,712					

NOTES AND LIST OF ASSUMPTIONS
FOR TABLE 2*

Stream No.	
◇2	Sources: MC-S-344, MO-274; gas stream temperature 1050°F; 16.2% SO_2 by volume.
◇5	Sources: MC-S-344, MO-274, DA-137; gas stream temperature 1150°F; 8.5% SO_2 by volume.

* Same as for Table 1 unless noted.

SECTION 3

LIMESTONE SCRUBBER COST ESTIMATE

The turbulent contact absorber (TCA) tail gas scrubber shown on Figures 1 and 2 was assumed to be the final gas cleaning device that would be used in any copper/nickel smelter built in Minnesota. A cost estimate was prepared listing the capital and operating costs for a TCA limestone scrubber with a venturi prescrubber. The basis for the limestone scrubber costs is a report prepared for TVA by McGlamery (MC-136). The basis for the limestone scrubber design is a Radian report prepared for EPA (BR-R-440). Costs were adjusted using the methods presented by Woods (WO-078) as described in BR-R-440.

The SO_2 scrubber design is shown in Figure 3. This is the same conceptual design used for the desulfurization of a steel mill sinter plant (BR-R-440). Tables 3 through 12 present the estimated capital and operating costs for the six cases considered. The first four cases assume that the acid plant tail gas will be scrubbed along with the other weak SO_2 smelter gases. Cases 5 and 6 list costs for scrubbing the gases without the acid plant tail gas. Cases 1 and 3 assume a 90% SO_2 removal efficiency. The other cases assume a scrubber exit gas concentration of 650 ppm SO_2. This corresponds to new source performance standards (NSPS). The report Appendix lists the process equipment items included in the cost estimate.

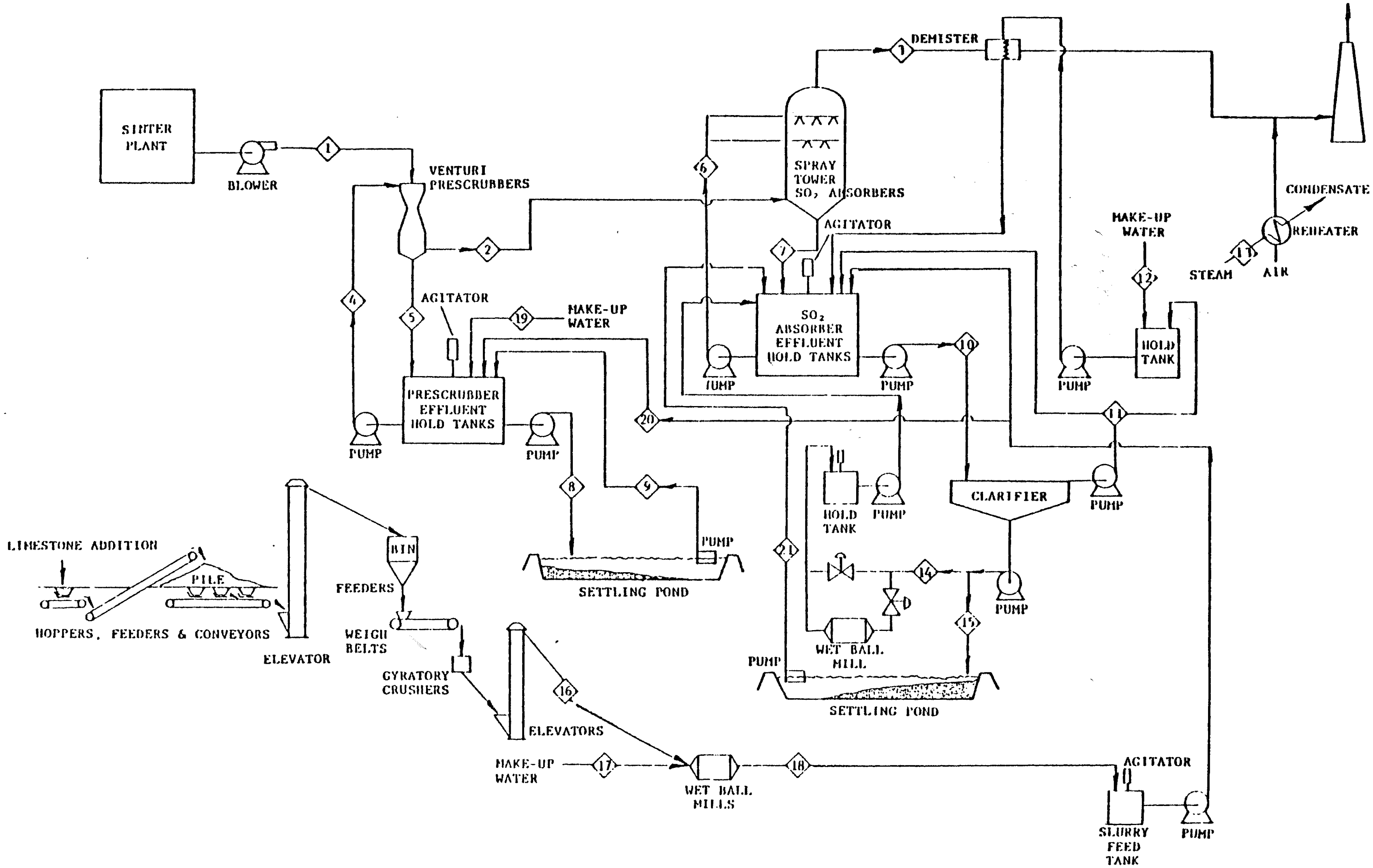

Figure 3. Process flow diagram - limestone scrubbing process for steel mill sinter plant application.

TABLE 3

ESTIMATED TOTAL CAPITAL INVESTMENT SUMMARY FOR FLUE GAS DESULFURIZATION USING LIMESTONE SLURRY SCRUBBING

CASE: ELECTRIC FURNACE

	Case 1 - 90% Scrubber Efficiency		Case 2 - NSPS	
Direct Costs:				
Process Equipment				
Materials Handling	$ 32,780		$ 30,600	
Feed Preparation	92,750		82,020	
Particulate Scrubbing	269,720		242,630	
SO_2 Scrubbing	389,550		347,540	
Gas Reheating	73,450		68,830	
Gas Handling	49,640		42,330	
Solids Disposal	184,050		166,620	
Services	134,730		134,730	
Particle Recirculation	30,720		27,800	
Subtotal		$1,257,390		$1,143,100
Equipment Installation		490,400		445,800
Piping		377,200		342,900
Structural Steel		62,900		57,200
Foundations		754,400		685,900
Insulation and painting		25,100		22,900
Electrical		88,000		80,000
Instruments		50,300		45,700
BL Building and Service*		62,900		57,200
Excavation and Fill Site Preparation		125,700		114,300
Auxiliaries		12,600		11,400
Sludge Ponds (installed)				
Particulate Disposal		46,000		37,000
Calcium Solids Disposal		142,000		112,000
Subtotal Direct Costs		$3,494,890		$3,155,400
Indirect Costs:				
Engineering Design and Supervision		454,300		410,200
Construction Field Expense		485,800		438,600
Contractor Fees		244,600		220,900
Contingency		513,700		463,800
Subtotal Indirect Costs		$1,698,400		1,533,500
TOTAL CAPITAL INVESTMENT		$5,193,290		$4,688,900

*Battery Limit

TABLE 4

ESTIMATED LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 1: Electric Furnace, 90% Scrubber Efficiency)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	20.7 M mtons	6.60/mton	136,600	6.58
Subtotal			136,600	6.58
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	6.50
Utilities				
Steam	39,600 M kg	3.31/M kg	131,100	6.31
Process water	196,200 M liters	0.029 liters	5,700	.27
Electricity	12,337,700 kWh	0.028/kWh	345,500	16.63
Maintenance				
Labor and material, .09 x 3,494,890			314,500	15.14
Analyses			29,400	1.42
Subtotal conversion costs			961,200	46.27
Subtotal direct costs			1,097,800	52.85
Indirect Costs				
Average capital charges at 14.9% of total capital investment			773,800	37.25
Overhead				
Plant, 20% of conversion costs			192,200	9.25
Administrative, 10% of operating labor			13,500	.65
Subtotal indirect costs			479,500	47.15
Total annual operating cost			2,077,300	100.00

Basis:

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/yr.

Midwest plant location, 1978 operating costs.

Total capital investment, $5,193,290; subtotal direct investment $3,494,890.

TABLE 5

ESTIMATED LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 2: Electric Furnace, NSPS)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	22.7 M mtons	6.60/mton	149,800	7.77
Subtotal			149,800	7.77
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	7.00
Utilities				
Steam	39,600 M kg	3.31/M kg	131,100	6.80
Process water	173,000 M liters	0.029 liters	5,000	.26
Electricity	10,876,000 kWh	0.028/kWh	304,500	15.79
Maintenance				
Labor and material, .09 x 3,155,400			284,000	14.72
Analyses			29,400	1.52
Subtotal conversion costs			889,000	46.09
Subtotal direct costs			1,038,800	53.86
Indirect Costs				
Average capital charges at 14.9% of total capital investment			698,600	36.22
Overhead				
Plant, 20% of conversion costs			177,800	9.22
Administrative, 10% of operating labor			13,500	.70
Subtotal indirect costs			889,900	46.14
Total annual operating cost			1,928,700	100.00

Basis.

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/yr.

Midwest plant location, 1978 operating costs.

Total capital investment, $4,688,900; subtotal direct investment $3,155,400.

TABLE 6

ESTIMATED TOTAL CAPITAL INVESTMENT SUMMARY FOR FLUE GAS DESULFURIZATION USING LIMESTONE SLURRY SCRUBBING

CASE: FLASH FURNACE

	Case 3 - 90% Scrubber Efficiency		Case 4 - NSPS	
Direct Costs:				
Process Equipment				
Materials Handling	$ 31,890		$ 27,380	
Feed Preparation	89,250		71,620	
Particulate Scrubbing	327,050		248,350	
SO_2 Scrubbing	496,540		375,780	
Gas Reheating	101,650		81,690	
Gas Handling	67,240		48,690	
Solids Disposal	169,930		135,430	
Services	134,730		134,730	
Particle Recirculation	30,720		24,660	
Subtotal		$1,449,000		$1,148,330
Equipment Installation		565,100		447,800
Piping		434,700		344,500
Structural Steel		72,500		57,400
Foundations		869,400		689,000
Insulation and painting		29,000		23,000
Electrical		101,400		80,400
Instruments		58,000		45,900
BL Building and Service*		72,500		57,400
Excavation and Fill Site Preparation		144,900		114,900
Auxiliaries		14,500		11,500
Sludge Ponds (installed)				
Particulate Disposal		54,000		32,000
Calcium Solids Disposal		144,000		85,000
Subtotal Direct Costs		4,009,000		$3,137,030
Indirect Costs:				
Engineering Design and Supervision		521,200		407,800
Construction Field Expense		557,300		436,000
Contractor Fees		280,600		219,600
Contingency		589,300		461,100
Subtotal Indirect Costs		1,948,400		1,524,500
TOTAL CAPITAL INVESTMENT		$5,957,400		$4,661,530

*Battery Limit

TABLE 7

LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 3: Flash Furnace, 90% Scrubber Efficiency)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	20.7 M mtons	6.60/mton	136,800	5.24
Subtotal			136,800	5.24
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	5.17
Utilities				
Steam	80,400 M kg	3.31/M kg	266,100	10.19
Process water	228,000 M liters	0.029/M liter	6,600	.25
Electricity	18,298,000 kWh	0.028/kWh	512,300	19.63
Maintenance				
Labor and material, .09 x 4,009,000			360,800	13.82
Analyses			29,400	1.13
Subtotal conversion costs			1,310,200	50.19
Subtotal direct costs			1,447,000	55.43
Indirect Costs				
Average capital charges at 14.9% of total capital investment			887,700	34.00
Overhead				
Plant, 20% of conversion costs			262,000	10.04
Administrative, 10% of operating labor			13,500	.52
Subtotal indirect costs			1,163,200	44.56
Total annual operating cost			2,610,200	100.00

Basis:

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/yr.

Midwest plant location, 1978 operating costs.

Total capital investment, $5,957,400 subtotal direct investment, $4,009,000.

TABLE 8

LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 4: Flash Furnace, NSPS)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	25.6 M mtons	6.60/mton	169,000	7.70
Subtotal			169,100	7.70
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	6.15
Utilities				
Steam	80,400 M kg	3.31/M kg	266,100	12.13
Process water	169,000 M liters	0.029/M liter	4,900	.22
Electricity	13,562,000 kWh	0.028/kWh	379,700	17.31
Maintenance				
Labor and material, .09 x 3,137,030			282,300	12.87
Analyses			29,400	1.34
Subtotal conversion costs			1,097,400	50.02
Subtotal direct costs			1,266,500	57.72
Indirect Costs				
Average capital charges at 14.9% of total capital investment			694,600	31.66
Overhead				
Plant, 20% of conversion costs			219,500	10.00
Administrative, 10% of operating labor			13,500	.62
Subtotal indirect costs			927,600	42.28
Total annual operating cost			2,194,100	100.00

Basis:

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/hr.

Midwest plant location, 1978 operating costs.

Total capital investment, $4,661,530 subtotal direct investment, $3,137,030.

TABLE 9

ESTIMATED TOTAL CAPITAL INVESTMENT SUMMARY FOR FLUE GAS DESULFURIZATION USING LIMESTONE SLURRY SCRUBBING

CASE 5: ELECTRIC FURNACE

		Case 5 - NSPS (no acid plant tail gas)
Direct Costs:		
Process Equipment		
Materials Handling	$ 30,690	
Feed Preparation	88,400	
Particulate Scrubbing	157,050	
SO_2 Scrubbing	264,240	
Gas Reheating	53,540	
Gas Handling	113,590	
Solids Disposal	175,040	
Services	134,800	
Particle Recirculation	29,420	
Subtotal		$1,017,350
Equipment Installation		396,800
Piping		305,200
Structural Steel		50,900
Foundations		610,400
Insulation and painting		20,300
Electrical		71,200
Instruments		40,700
BL Building and Service*		50,900
Excavation and Fill Site Preparation		101,700
Auxiliaries		10,200
Sludge Ponds (Installed)		
Particulate Disposal		6,000
Calcium Solids Disposal		60,700
Subtotal Direct Costs		$2,742,350
Indirect Costs:		
Engineering Design and Supervision		$ 356,500
Construction Field Expense		381,200
Contractor Fees		192,000
Contingency		403,100
Subtotal Indirect Costs		$1,332,800
TOTAL CAPITAL INVESTMENT		$4,075,150

*Battery Limit

TABLE 10

ESTIMATED LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 5: Electric Furnace, NSPS, no acid plant tail gas)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	31.0 M mtons	6.60/mton	204,400	10.93
Subtotal			204,400	10.93
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	7.22
Utilities				
Steam	18,700 M kg	3.31/M kg	61,900	3.31
Process water	222,200 M liters	0.029/M liters	6,400	.34
Electricity	13,970,000 kWh	0.028/kWh	391,200	20.92
Maintenance				
Labor and material, .09 x 2,742,350			246,800	13.20
Analyses			29,400	1.57
Subtotal conversion costs			870,700	46.57
Subtotal direct costs			1,075,100	57.50
Indirect Costs				
Average capital charges at 14.9% of total capital investment			607,200	32.47
Overhead				
Plant, 20% of conversion costs			174,100	9.31
Administrative, 10% of operating labor			13,500	.72
Subtotal indirect costs			794,800	42.50
Total annual operating cost			1,869,900	100.00

Basis:

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/yr.

Midwest plant location, 1978 operating costs.

Total capital investment, $4,075,150 subtotal direct investment $2,742,350

TABLE 11

ESTIMATED TOTAL CAPITAL INVESTMENT SUMMARY FOR FLUE GAS DESULFURIZATION USING LIMESTONE SLURRY SCRUBBING

CASE 6: FLASH FURNACE

		Case 6 - NSPS (no acid plant tail gas)
Direct Costs:		
Process Equipment		
Materials Handling	$ 28,850	
Feed Preparation	77,410	
Particulate Scrubbing	284,420	
SO_2 Scrubbing	396,980	
Gas Reheating	66,800	
Gas Handling	46,130	
Solids Disposal	116,630	
Services	134,800	
Particle Recirculation	27,090	
Subtotal		$1,152,020
Equipment Installation		449,300
Piping		345,600
Structural Steel		57,600
Foundations		691,200
Insulation and painting		23,000
Electrical		80,600
Instruments		46,100
BL Building and Service*		57,600
Excavation and Fill Site Preparation		115,200
Auxiliaries		11,500
Sludge Ponds (Installed)		
Particulate Disposal		16,900
Calcium Solids Disposal		65,600
Subtotal Direct Costs		$3,112,220
Indirect Costs:		
Engineering Design and Supervision		404,600
Construction Field Expense		432,600
Contractor Fees		217,800
Contingency		457,500
Subtotal Indirect Costs		1,512,500
TOTAL CAPITAL INVESTMENT		$4,624,720

*Battery Limit

TABLE 12

ESTIMATED LIMESTONE SLURRY PROCESS

TOTAL ANNUAL OPERATING COSTS

(Case 6: Flash Furnace, NSPS, no acid plant tail gas)

	Annual Quantity	Unit Cost, $	Total Annual Cost, $	Percent of Total Annual Operating Cost
Direct Costs				
Delivered raw material				
Limestone	25.7 M mtons	6.60/mton	169,400	8.30
Subtotal			169,400	8.30
Conversion costs				
Operating labor and supervision	13,500 man-hr	10.00/man-hr	135,000	6.61
Utilities				
Steam	43,700 M kg	3.31/M kg	144,600	7.08
Process water	169,300 M liters	0.029/M liter	4,900	.24
Electricity	13,586,700 kWh	0.028/kWh	380,400	18.64
Maintenance				
Labor and material, .09 x 3,112,200			280,100	13.72
Analyses			29,400	1.44
Subtotal conversion costs			974,400	47.73
Subtotal direct costs			1,143,800	56.03
Indirect Costs				
Average capital charges at 14.9% of total capital investment			689,100	33.76
Overhead				
Plant, 20% of conversion costs			194,900	9.55
Administrative, 10% of operating labor			13,500	.66
Subtotal indirect costs			897,500	43.97
Total annual operating cost			2,041,300	100.00

Basis:

Life of scrubber, 30 yr.

Stack gas reheat to 79.4°C.

On-stream time, 7,000 hr/yr.

Midwest plant location, 1978 operating costs.

Total capital investment, $4,624,720; subtotal direct investment, $3,112,220

SECTION 4
LIMESTONE SCRUBBER WATER CONSUMPTION ESTIMATE

The limestone scrubber design used for the cost estimates in Section 3 (see Figure 3) is a closed-loop system. Water consumption is estimated to range between 40 and 50 gallons per minute. The actual consumption will vary depending on the quantity of particulates in the gas stream and the desired prescrubber particulate removal efficiency. This assumes a constant gas volume and SO_2 concentration.

Approximately 95% of the water consumed is expected to be vaporized as the gas cools and exits in the stack gases. The remaining 5% will remain in the settled sludge or evaporate from the settling pond.

SECTION 5
ELECTROSTATIC PRECIPITATOR CAPITAL COST ESTIMATES

Electrostatic precipitator costs versus efficiency were estimated using an article by Caplan in Chemical Engineering, p. 153, April 10, 1978 and cost figures provided in a private conversation with Leslie E. Sparks of IERL in North Carolina. Table 13 lists the efficiency, the corresponding ft^2 of collecting surface required per 1000 scfm of gas, and the ft^2 required at each efficiency relative to 97% removal. Table 14 translates these figures into installed capital costs for the various smelter offgases considered in 1977 dollars. These cost figures should be regarded as rough estimates to be used only for economic modelling in the Regional Copper-Nickel Study.

TABLE 13. COLLECTING SURFACE VERSUS EFFICIENCY FOR METALLURGICAL HOT ELECTROSTATIC PRECIPITATORS†

Efficiency	Ft^2 collecting surface / 1000 SCFM	Ft^2 required / Ft^2 @ 97% eff
90	152	0.655
95	200	0.862
97	232	1.000
98	259	1.116
99	301	1.297
99.5	350	1.509
99.7	381	1.642
99.9	460	1.983
99.95	502	2.164

† Source: Caplan, F., Chemical Engineering, p. 153, April 10, 1978.

TABLE 14. ESTIMATED CAPITAL COST INSTALLED FOR REMOVING PARTICULATES FROM VARIOUS SMELTER GAS STREAMS

		Flash Furnace Case				Electric Furnace Case				
		Capital Cost (M$)* % Efficiency					Capital Cost (M$)* % Efficiency			
Gas Stream	Gas Flow (1000 SCFM)	97	99	99.5	99.9	Gas Flow (1000 SCFM)	97	99	99.5	99.9
Dryer	60.0	417.6	541.8	630.0	828.0	---	---	---	---	---
Roaster	---	---	---	---	---	25.2	175.4	227.6	264.6	347.8
Smelting Furnace	47.0	327.1	424.4	493.5	648.6	12.3	85.6	111.1	129.2	169.7
Copper Converters	49.2	342.4	444.3	516.6	679.0	49.2	342.4	444.3	516.6	679.0
Nickel Converter	10.6	73.8	95.7	111.3	146.3	10.6	73.8	95.7	111.3	146.3
Weak SO_2 Gas†	178.3	1241.0	1610.0	1872.2	2460.5	109.7	763.5	990.6	1152.0	1513.9

†If particulate removal is not performed in SO_2 scrubber.

*@ \$30/Ft^2 of collecting surface (installed); M$ = thousands of dollars.

SECTION 6
NO_x EMISSIONS EVALUATION

No literature data was found containing data on NO_x emissions from either copper or nickel smelters. Data provided by a smelting company indicated that a Japanese copper smelter measured 4 ppm NO_x at the outlet of their TCA SO_2 scrubber (∿200,000 scfm). The value of 4 ppm seems reasonable because of the following:

- No fuel nitrogen of the form R-N is present in the concentrate.
- All NO_x present in smelting furnace off gases comes from thermal fixation of molecular nitrogen (N_2) in the combustion air.
- The smelting reactions occur at temperatures lower than those needed for significant NO_x generation i.e., below 3000°F (BA-002).
- Local temperatures on the concentrate particles should be lower than the temperature on coal particles. First, because of the lower heat of reaction and second, because the copper and iron present act as a significant heat sink.
- The expected residence time, approximately 20 seconds (KE-162), and average temperature, approximately 2800°F, are not sufficient to generate significant NO_x concentrations based on reported reaction rate calculations (BA-002) for the following reaction:

$$N_2 + O_2 \rightleftarrows 2NO$$

These qualitative statements can be supported by using the following equation (BA-002):

$$\frac{d[NO]}{dt} = A_f\, e^{-E_f/RT} [N_2][O_2]^{\frac{1}{2}} - A_r\, e^{-E_r/RT} [NO]^2 [O_2]^{-\frac{1}{2}} \text{ g·moles/cc/sec}$$

where: $\frac{d[NO]}{dt}$ = net formation rate for NO_x (assumed constant for this calculation),

A_i = Frequency factor,

T = 2500°F for the case with no oxygen enrichment; 2800°F with 300 Nm^3 O_2/metric ton Cu, and

E_f, E_r = Forward and reverse reaction activation energies.

assume: a) N_2:O_2 mole ratio is 0.54:0.46 for oxygen enriched case,

b) Furnace residence time is 20 seconds (KE-162), and

c) Flash furnace shaft is a homogeneous reactor.

These approximations allow the NO_x formation rate (moles/sec) and the NO_x concentration (ppm) to be calculated. For the no O_2 enrichment case, an NO_x concentration of 3 ppm NO_x was calculated. For the case of 300 Nm^3 O_2/metric ton Cu, a concentration of 15 ppm NO_x was calculated.

These numbers are certainly on the same order of magnitude as the 4 ppm NO_x figure reported by the Japanese smelting company. Of course, the 4 ppm NO_x value includes approximately two 2 volumes of dilution air for every one of process gas. The 3 ppm and 15 ppm NO_x calculated above do not.

Table 15 presents some information on power plant NO_x emisssions which will place potential smelter NO_x emissions in perspective. The power plant data in Table 15 (FA-154) are for different types of firing mechanisms, i.e., different flame temperatures. A typical gas flow from a 500 MW coal-fired power plant should range from 1.0 to 1.25 million scfm depending on the coal heating value and moisture content. Obviously, the NO_x emissions from a smelter ($\sim$200,000 scfm, 4 ppm NO_x) would be insignificant compared to only one 500 MW power plant.

TABLE 15. CONCENTRATION RANGES OF NO_x FROM COAL-FIRED POWER PLANTS

Type of Firing	Typical NO_x concentration, ppm
Vertical	225 - 310
Horizontally opposed	340 - 375
Spreader (stoker)	400 - 470
Tangential (corner)	420 - 500
Front wall	390 - 600
Cyclone	800 - 1200

SECTION 7

ESTIMATE OF PARTICULATE EMISSIONS

There is no existing data which would enable an exact calculation to be made of the total particulates generated by a smelter. As a result, it was estimated that ten percent of the incoming concentrate would be released as particulate in the smelter gas streams. This is a conservative estimate, the actual number is believed to be smaller. The gas streams are then assumed to be cleaned by the various particulate control devices, each assigned a particulate removal efficiency consistent with those reported for similar control applications. This is shown schematically in Figure 4 for the flash and electric furnace cases. The total particulate emissions estimated were 285 and 0.3 metric tons per year for the flash and electric furnace cases respectively.

The removal efficiencies shown assume normal operating conditions within the design limitations of the control technology. Particulate emissions during upset conditions could be significantly higher than those indicated for normal conditions.

The emission sources listed in Figure 4 are subject to both federal and state air pollution control regulations. Two types of federal regulations apply to the smelting schemes considered in this report. These are:

- Standards of Performance for New Stationary Sources (NSPS)†, and
- Prevention of Significant Air Quality Deterioration (PSD)††.

These standards are subject to a certain amount of interpretation with respect to their applicability to primary copper/nickel smelting. It is presumed here that NSPS would apply to the dryer or roaster, smelting furnace, and converters as stated in EPA 40 CFR 60.160. The entire smelter would be subject to PSD requirements as stated in Part 51, Requirements for Preparation, Adoption, and Submission of Implementation Plans††. In addition, any surface mine or concentrating facility would also be required to meet PSD regulations.

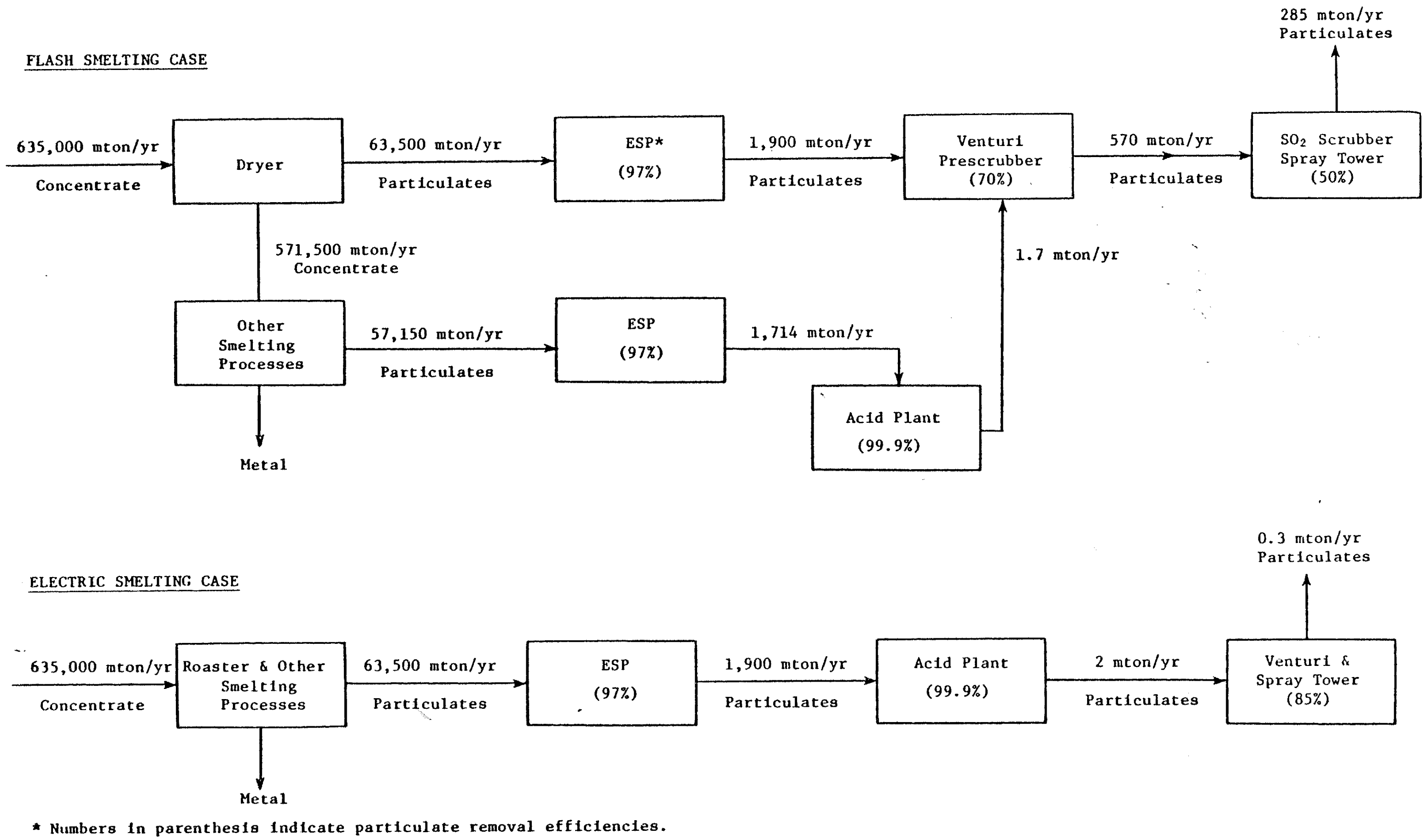

Figure 4. Particulate emissions from flash and electric smelting schemes.

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† Environmental Protection Agency, "Standards of Performance for Primary Copper Smelters," 40 CFR 60.160, Env. Rept., 121:1527.

†† Environmental Protection Agency, "1977 Clean Air Act; Prevention of Significant Air Quality Deterioration," Fed. Reg. 43 (118), 26379-26410 (1978).

APPENDIX

TABLE A-1

CASE 1, ELECTRIC FURNACE, 90% SCRUBBER EFFICIENCY

WORK SHEETS FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Unloading hopper No. 1	1	Capacity .30 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	580	580
2.	Limestone feeder No. 1 (vibrating)	1	5.5 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	1,120	1,120
3.	Conveyor (belt) No. 1	1	5.5 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	580	580
4.	Conveyor (belt) No. 2	1	5.5 kg/s	0.81 0.65	Fund of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	2,760	2,760
5.	Hoppers under pile	3	Capacity .20 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	470	1,410
6.	Limestone feeder No. 2 (vibrating)	3	2.6 kg/s	0.58	Chem. Engr. 3-24-69	580	1,740
7.	Conveyor (belt) No. 3	1	2.6 kg/s	0.65 0.81	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	4,290	4,290
8.	Tunnel sump pump	2	2.8×10^{-4} m^3/s, carbon steel, neoprene lining, 163.6 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		690	1,380
9.	Elevator No. 1	1	2.6 kg/s	0.83	Chem. Engr. 3-24-69	2,450	2,450
10.	Bin	1	Capacity 14.9 m^2, carbon steel	0.68	Chem. Engr. 3-24-69	5,240	5,240
11.	Car shaker	1	Railroad trackside vibrator	----	----	6,920	6,920
12.	Dust collecting system No. 1	1	.11 m^3/s, inertial separators, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	580	580
13.	Dust collecting system No. 2	1	.31 m^3/s, inertial separators, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69	1,100	1,100
14.	Bag filter system	1	0.83 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,630	2,630
	SUBTOTAL						32,780

TABLE A-1 (Continued)

AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge feeder	1	0.7 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	310	310
2.	Weigh feeder	1	0.7 kg/s, carbon steel	0.65	Chem. Engr. 3-24-69 Guthrie	3,750	3,750
3.	Gyratory crusher	1	0.7 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	2,190	2,190
4.	Elevator No. 2	1	0.7 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	1,100	1,100
5.	Wet ball mill	1	6.9 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	50,740	50,740
		1	75,230 MW motor	1.07	Fund. of Cost Engr. 1964	3,610	3,610
6.	Slurry feed tank	1	Capacity 18.3 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	5,330	5,330
	Lining	1	5.57×10^{-3} m neoprene	----	----	4,710	4,710
7.	Agitator, slurry feed tank	1	1308 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	2,960	2,960
				0.64	Fund. of Cost Engr. 1964		
8.	Pumps, slurry feed tank	2	6.6×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,890	3,780
9.	Dust collecting system	1	.41 m^3/s, inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	1,370	1,370
10.	Hoist	1	1579 kg electric	0.81	Popper, H.	10,270	10,270
11.	Bag filter system	1	0.83 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,630	2,630
	SUBTOTAL						92,750

TABLE A-1 (Continued)
AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Tank particulate scrubber, effluent hold	1	Capacity 174.8 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	30,640	30,640
	Lining	1	5.57×10^{-3} m neoprene	----	----	22,500	22,500
2.	Agitator, effluent hold tank	1	6542 W, neoprene coated	0.26 0.50	Fund of Cost Engr. Guthrie Chem. Engr. 3-24-69 Guthrie	5,850	5,850
3.	Pumps, recycle slurry	2	.23 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		16,780	33,560
4.	Venturi scrubber	1	52.1 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	118,090	118,090
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	30,010	30,010
6.	Soot blowers	5		1.00	TVA	5,050	25,250
7.	Bleed pump	2	1.4×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,910	3,820
	SUBTOTAL						269,720

TABLE A-1 (Continued)

AREA 4 - SO_2 SCRUBBING

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Spray tower scrubber	1	Gas Flow 52.1 m^3/s, carbon steel, neoprene		Western Precipitator Div., Joy Mfg. Co.[a]	140,040	140,040
2. Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	30,010	30,010
3. Tank, absorber effluent hold	1	Capacity 620.8 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	43,920	43,920
Lining	1	5.57×10^{-3} m neoprene	----	----	37,500	37,500
4. Agitator, SO_2 absorber hold tank	1	26,167 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	12,410	12,410
5. Pumps, SO_2 absorber recycle	3	.40 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		25,660	76,980
6. Pumps, makeup water	1	1.1×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,430	1,430
7. Soot blowers	5		1.00	TVA	5,050	25,250
8. Demister	1	Carbon steel, neoprene lined	----	----	13,980	13,980
9. Pump, bleed	2	5.9×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,920	3,340
10. Tank, demister wash	1	Capacity 1.66 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,340	1,340
11. Pump, demister wash	2	1.1×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,400	2,800
SUBTOTAL						389,550

[a]Indicates source of spray tower cost

TABLE A-1 (Continued)

AREA 5 - REHEAT

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Steam reheater	1	1.7×10^5 W rating, 64.4 m^2 surface area	0.80	Chem. Engr. 3-24-69	48,200	48,200
2. Soot	5		1.00	TVA	5,050	25,250
SUBTOTAL						73,450

AREA 6 - GAS HANDLING

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Fan	1	1.01×10^6 W drive	0.68	Chem. Engr. 3-24-69	49,640	49,640

AREA 7 - SOLIDS DISPOSAL

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Clarifier	1	5.1×10^3 m^3/s	0.68	PEDCo (PE-146)	164,770	164,770
2. Pumps, pond feed	2	1.3×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,490	2,980
3. Pump, clarifier water recycle	2	3.8×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		3,310	6,620
4. Pumps, particulate pond water recycle	2	3.2×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		3,790	7,580
5. Pumps, SO_2 pond water recycle	2	5.1×10^{-4} m^3/s, carbon steel, neoprene lined			1,050	2,100
SUBTOTAL						184,050

TABLE A-1 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Payloader			----	----	31,280	31,280
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,300	33,300
4. Service building-equipment			----	----	44,150	44,150
5. Stores-equipment			----	----	13,370	13,370
SUBTOTAL						134,730

AREA 10 - PARTICLE RECIRCULATION

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Wet ball mill	1	2.8×10^{-4} m^3/s	0.65	McGlamery	28,780	28,780
2. Pump, particle recirculation	2	2.8×10^{-4} m^3/s, molded polypropylene	Depends on gpm and head requirements resulting in changes of motor and impeller size		480	960
3. Tank, particle recirculation surge	1	Capacity 1.0 m^3, carbon steel, neoprene lined	0.68	McGlamery	980	980
SUBTOTAL						30,720

TABLE A-2

CASE 2, ELECTRIC FURNACE, NSPS*

WORK SHEET FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197- Cost
1.	Unloading hopper No. 1	1	Capacity .26 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	520	520
2.	Limestone feeder No. 1 (vibrating)	1	4.8 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	1,040	1,040
3.	Conveyor (belt) No. 1	1	4.8 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	520	520
4.	Conveyor (belt) No. 2	1	4.8 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	2,470	2,470
5.	Hoppers under pile	3	Capacity .18 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	430	1,290
6.	Limestone feeder No. 2 (vibrating)	3	2.3 kg/s	0.58	Chem. Engr. 3-24-69	540	1,620
7.	Conveyor (belt) No. 3	1	2.3 kg/s	0.65 0.31	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	3,960	3,960
8.	Tunnel sump pump	2	2.4×10^{-4} m^3/s, carbon steel, neoprene lining, 141.7 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		620	1,240
9.	Elevator No. 1	1	2.3 kg/s	0.33	Chem. Engr. 3-24-69	2,320	2,320
10.	Bin	1	Capacity 12.9 m^2, carbon steel	0.68	Chem. Engr. 3-24-69	4,760	4,760
11.	Car shaker	1	Railroad trackside vibrator	----	----	6,920	6,920
12.	Dust collecting system No. 1	1	.09 m^3/s, inertial separators, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	490	490
13.	Dust collecting system No. 1	1	.26 m^3/s, inertial separators, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69	960	960
14.	Bag filter system	1	0.77 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,490	2,490
	SUBTOTAL						30,600

*New Source Performance Standards, 650 ppm SO_2 in scrubber effluent

TABLE A-2 (Continued)
AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge feeder	1	.6 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	280	280
2.	Weigh feeder	1	.6 kg/s, carbon steel	0.65	Chem. Engr. 3-24-69 Guthrie	3,390	3,390
3.	Gyratory crusher	1	.6 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	1,820	1,820
4.	Elevator No. 2	1	.6 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	990	990
5.	Wet ball mill	1	6.0 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	46,330	46,330
		1	65,120 W motor	1.07	Fund. of Cost Engr. 1964	3,100	3,100
6.	Slurry feed tank	1	Capacity 15.8 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	4,830	4,830
	Lining	1	4.82×10^{-3} m neoprene	----	----	4,060	4,060
7.	Agitator, slurry feed tank	1	1132 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	2,760	2,760
				0.46	Fund. of Cost Engr. 1964		
8.	Pumps, slurry feed tank	2	5.8×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,730	1,730
9.	Dust collecting system	1	.36 m^3/s, inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	1,240	1,240
10.	Hoist	1	1367 kg electric	0.81	Popper, H.	9,130	9,130
11.	Bag filter system	1	0.71 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,360	2,360
	SUBTOTAL						82,020

TABLE A-2 (Continued)
AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197- Cost
1.	Tank particulate scrubber, effluent hold	1	Capacity 152.1 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	27,870	27,870
	Lining	1	4.82 x 10^{-3} m neoprene	----	----	20,340	20,340
2.	Agitator effluent, hold tank	1	5662 W, neoprene coated	0.26 0.50	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	5,630	5,630
3.	Pumps, recycle slurry	2	.20 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		15,220	30,440
4.	Venturi scrubber	1	41.1 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	102,430	102,430
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	27,230	27,230
6.	Soot blowers	5		1.00	TVA	5,050	25,250
7.	Bleed pump	2	1.2 x 10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,720	3,440
	SUBTOTAL						242,530

TABLE A-2 (Continued)

AREA 4 - SO_2 SCRUBBING

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Spray tower scrubber	1	Gas Flow 41.1 m^3/s, carbon steel, neoprene		Western Precipitator Div., Joy Mfg. Co.[a]	118,620	118,620
2. Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	27,230	27,230
3. Tank, absorber effluent hold	1	Capacity 537.4 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	39,810	39,810
Lining	1	4.82×10^{-3} m neoprene	----	----	34,000	34,000
4. Agitator, SO_2 absorber hold tank	1	22,650 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	12,100	12,100
5. Pumps, SO_2 absorber recycle	3	.35 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		23,370	70,110
6. Pumps, makeup water	1	9.2×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,300	1,300
7. Soot blowers	5		1.00	TVA	5,050	25,250
8. Demister	1	Carbon steel, neoprene lined	----	----	11,840	11,840
9. Pump, bleed	2	5.1×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,730	3,460
10. Tank, demister wash	1	Capacity 1.43 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,220	1,220
11. Pump, demister wash	2	9.9×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,300	2,600
SUBTOTAL						347,540

[a]Indicates source of spray tower cost

TABLE A-2 (Continued)

AREA 5 - REHEAT

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Steam reheater	1	1.5×10^5 W rating 55.7 m surface area	0.80	Chem. Engr. 3-24-69	43,580	43,580
2.	Soot	5		1.00	TVA	5,050	25,250
	SUBTOTAL						68,830

AREA 6 - GAS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Fan	1	7.99×10^5 W drive	0.68	Chem. Engr. 3-24-69 Guthrie	42,330	42,330

AREA 7 - SOLIDS DISPOSAL

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Clarifier	1	4.4×10^3 m^3/s	0.68	PEDCo (PE-146)	149,040	149,040
2.	Pumps, pond feed	2	1.1×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,330	2,660
3.	Pump, clarifier water recycle	2	3.4×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		3,060	6,120
4.	Pumps, particulate pond water recycle	2	2.8×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		3,450	6,900
5.	Pumps, SO_2 pond water recycle	2	4.4×10^{-4} m^3/s, carbon steel, neoprene lined			950	1,900
	SUBTOTAL						166,620

TABLE A-2 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Payloader			----	----	31,280	31,280
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,300	33,300
4. Service building-equipment			----	----	44,150	44,150
5. Stores-equipment			----	----	13,370	13,370
SUBTOTAL						134,730

AREA 10 - PARTICLE RECIRCULATION

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Wet ball mill	1	2.4×10^{-4} m^3/s	0.65	McGlamery	26,030	26,030
2. Pump, particle recirculation	2	2.4×10^{-4} m^3/s, molded polypropylene	Depends on gpm and head requirements resulting in changes of motor and impeller size		430	860
3. Tank, particle recirculation surge	1	Capacity 0.9 m^3, carbon steel, neoprene lined	0.68	McGlamery	910	910
SUBTOTAL						27,800

TABLE A-3

CASE 3, FLASH FURNACE, 90% SCRUBBER EFFICIENCY

WORK SHEET FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Unloading hopper No. 1	1	Capacity .27 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	540	540
2.	Limestone feeder No. 1 (vibrating)	1	5.0 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	1,060	1,060
3.	Conveyor (belt) No. 1	1	5.0 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	540	540
4.	Conveyor (belt) No. 2	1	5.0 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	2,550	2,550
5.	Hoppers under pile	3	Capacity .18 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	450	1,350
6.	Limestone feeder No. 2 (vibrating)	3	2.4 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	540	1,620
7.	Conveyor (belt) No. 3	1	2.4 kg/s	0.65 0.81	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	4,020	4,020
8.	Tunnel sump pump	2	2.8 x 10^{-4} m^3/s, carbon steel, neoprene lining, 267.4 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller size		690	1,380
9.	Elevator No. 1	1	2.4 kg/s	0.83	Chem. Engr. 3-24-69	2,360	2,360
10.	Bin	1	Capacity 13.6 m^3, carbon steel	0.68	Chem. Engr. 3-24-69	4,090	4,090
11.	Car shaker	1	Railroad trackside vibrator	----	----	3,330	3,330
12.	Dust collecting system No. 1	1	.10 m^3/s inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	540	540
13.	Dust collecting system No. 2	1	.29 m^3/s inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69	1,040	1,040
14.	Bag filter system	1	.76 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,470	2,470
	SUBTOTAL						31,39[illegible]

TABLE A-3 (Continued)

AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge feeder	1	.7 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	310	310
2.	Weigh feeder	1	.7 kg/s, carbon steel	0.65	Chem. Engr. 3-24-69 Guthrie	3,750	3,750
3.	Gyratory crusher	1	.7 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	2,190	2,190
4.	Elevator No. 2	1	.7 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	1,100	1,100
5.	Wet ball mill	1	6.4 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	48,200	48,200
		1	68,260 W motor	1.07	Fund. of Cost Engr. 1964	3,260	3,260
6.	Slurry feed tank	1	Capacity 18.1 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	5,200	5,200
	Lining	1	5.53×10^{-3} m neoprene	----	----	4,590	4,590
7.	Agitator, slurry feed tank	1	1300 W, neoprene coated	0.50 0.46	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	2,960	2,960
8.	Pumps, slurry feed tank	2	6.0×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,890	3,780
9.	Dust collecting system	1	.36 m^3/s, inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	1,240	1,240
10.	Hoist	1	1,568 kg electric	0.81	Popper, H.	10,200	10,200
11.	Bag filter system	1	.76 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,470	2,470
	SUBTOTAL						89,250

TABLE A-3 (Continued)

AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Tank, particulate scrubber, effluent hold	1	Capacity 151.7 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	27,800	27,800
	Lining	1	5.53 x 10^{-3} m neoprene	----	----	20,500	20,500
2.	Agitator, effluent hold tank	1	6,500 W, neoprene coated	0.26 0.50	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	5,830	5,830
3.	Pumps, recycle slurry	2	.4 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		21,950	43,900
4.	Venturi scrubber	1	84.1 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	157,400	157,400
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	42,650	42,650
6.	Soot blowers	5	----	1.00	TVA	5,050	25,250
7.	Bleed pump	2	1.6 x 10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,860	3,720
	SUBTOTAL						327,050

TABLE A-3 (Continued)

AREA 4 - SO_2 SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197- Cost
1.	Spray tower scrubber	1	Gas flow 84.1 m^3/s, carbon steel, neoprene	----	Western Precipitation Div. Joy Mfr. Co.[a]	225,400	225,400
2.	Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	41,970	41,970
3.	Tank absorber effluent hold	1	Capacity 462.6 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	35,960	35,960
	Lining	1	5.53×10^{-3} m neoprene	----	----	30,680	30,680
4.	Agitator, SO_2 absorber hold tank	1	19501 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	12,090	12,090
5.	Pumps, SO_2 absorber recycle slurry	3	.54 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		31,030	93,090
6.	Pumps, makeup water	1	9.7×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,440	1,440
7.	Soot blowers	5		1.00	TVA	5,050	25,250
8.	Demister	1	Carbon steel, neoprene lined	----	----	22,540	22,540
9.	Pump, bleed	2	5.8×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,900	3,800
10.	Tank, demister wash	1	Capacity 1.65 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,340	1,340
11.	Pump, demister wash	2	1.2×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,490	2,980
	SUBTOTAL						496,540

[a]Indicates source of spray tower cost

TABLE A-3 (Continued)

AREA 5 - REHEAT

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Steam reheater	1	3.5×10^{6} W rating $127.5\ m^{2}$ surface area	0.80	Chem. Engr. 3-24-69 Guthrie	76,400	76,400
2.	Soot blowers	5	---	1.00	TVA	5,050	25,250
	SUBTOTAL						101,650

AREA 6 - GAS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Fan	1	1.37×10^{6} W motor drive	0.68	Chem. Engr. 3-24-69	67,240	67,240

AREA 7 - SOLIDS DISPOSAL

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Clarifier	1	$4.8 \times 10^{-3}\ m^{3}/s$	----	PEDCO (PE-146	153,390	153,390
2.	Pumps, pond feed	2	$1.2 \times 10^{-3}\ m^{3}/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,490	2,980
3.	Pump, clarifier water recycle	2	$3.6 \times 10^{-3}\ m^{3}/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		3,350	6,700
4.	Pumps, particulate pond water recycle	2	$2.8 \times 10^{-3}\ m^{3}/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,390	4,780
5.	Pumps, SO_2 pond water recycle	2	$5.0 \times 10^{-4}\ m^{3}/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,040	2,080
	SUBTOTAL						169,930

TABLE A-3 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Payloader			----	----	31,280	31,280
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,300	33,300
4. Service building-equipment			----	----	44,150	44,150
5. Stores-equipment			----	----	13,370	13,370
SUBTOTAL						134,730

AREA 10 - PARTICLE RECIRCULATION

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Wet ball mill	1	2.8×10^{-4} m^3/s	0.65	McGlamery	28,780	28,780
2. Pump, particle recirculation	2	2.8×10^{-4} m^3/s molded polypropylane	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		480	960
3. Tank, particle recirculation surge	1	Capacity 1.0 m^3, carbon steel, neoprene lined	0.68	McGlamery	980	980
SUBTOTAL						30,720

TABLE A-4

CASE 4, FLASH FURNACE, NSPS*

WORK SHEET FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Unloading hopper No. 1	1	Capacity .20 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	440	440
2.	Limestone feeder No. 1 (vibrating)	1	3.7 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	890	890
3.	Conveyor (belt) No. 1	1	3.7 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	420	420
4.	Conveyor (belt) No. 2	1	3.7 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	2,000	2,000
5.	Hoppers under pile	3	Capacity 0.14 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	370	1,110
6.	Limestone feeder No. 2 (vibrating)	3	1.3 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	470	1,410
7.	Conveyor (belt) No. 3	1	1.3 kg/s	0.65 0.81	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	3,330	3,330
8.	Tunnel sump pump	2	2.0×10^{-4} m^3/s carbon steel, neoprene lining, 118.4 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller size		540	1,080
9.	Elevator	1	1.3 kg/s	0.83	Chem. Engr. 3-24-69	1,360	1,360
10.	Bin	1	Capacity 9.9 m^3, carbon steel	0.68	Chem. Engr. 3-24-69	3,290	3,290
11.	Car shaker	1	Railroad trackside vibrator	----	----	8,330	8,330
12.	Dust collecting system No. 1	1	0.08 m^3/s inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	440	440
13.	Dust collecting system No. 2	1	0.21 m^3/s inertial separator, cyclone hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69	800	800
14.	Bag filter system	1	0.55 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	1,980	1,980
	SUBTOTAL						27,330

*New Source Performance Standards, 650 ppm SO_2 in scrubber effluent.

TABLE A-4 (Continued)

AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge	1	0.5 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	260	260
2.	Weigh feeder	1	0.5 kg/s, carbon steel	0.65	Chem. Engr. 3-24-69 Guthrie	3,010	3,010
3.	Gyratory crusher	1	0.5 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	1,460	1,460
4.	Elevator No. 2	1	0.5 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	880	880
5.	Wet ball mill	1	4.7 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	39,440	39,440
		1	49703 W motor	1.07	Fund. of Cost Engr. 1964	2,320	2,320
6.	Slurry feed tank	1	Capacity 13.2m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	4,190	4,190
	Lining	1	4.03 x 10^{-3}m neoprene	----	----	3,680	3,680
7.	Agitator, slurry feed tank	1	947 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	2,520	2,520
				0.46	Fund. of Cost Engr. 1964		
8.	Pumps, slurry feed tank	2	4.4 x 10^{-4}m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,520	3,040
9.	Dust collecting system	1	0.26 m^3/s, inertial separator, cyclone hoppers, fan and drive	0.80	Chem. Engr. 3-24-69 Guthrie	950	950
10.	Hoist	1	1142 kg electric	0.81	Popper, H.	7,890	7,890
11.	Bag filter system	1	0.55 m^3/s, automatic fabric dust collectors bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	1,980	1,980
	SUBTOTAL						71,620

TABLE A-4 (Continued)

AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197 Cost
1.	Tank particulate scrubber, affluent hold	1	Capacity 110.5 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	22,430	22,430
	Lining	1	4.03×10^{-3} m neoprene	----	----	16,360	16,360
2.	Agitator, effluent hold tank	1	4734 W, neoprene coated	0.26 0.50	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	5,380	5,380
3.	Pumps, recycle slurry	2	.2 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		13,510	27,020
4.	Venturi scrubber	1	49.5 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	114,520	114,520
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	34,350	34,350
6.	Soot blowers	5	----	1.00	TVA	5,050	25,250
7.	Bleed pump	2	1.2×10^{-3} m^3/s carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,520	3,040
	SUBTOTAL						248,350

TABLE A-4 (Continued)

AREA 4 - SO_2 SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Spray tower scrubber	1	Gas flow 49.5 m^3/s, carbon steel, neoprene	----	Western Precipitation Div. Joy Mfr. Co.[a]	155,550	155,500
2.	Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	33,310	33,310
3.	Tank absorber effluent hold	1	Capacity 336.9 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	28,990	28,990
	Lining	1	4.03×10^{-3} m neoprene	----	----	24,590	24,590
4.	Agitator, SO_2 absorber hold tank	1	14201 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	10,320	10,320
5.	Pumps, SO_2 absorber recycle slurry	3	.39 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		24,720	74,160
6.	Pumps, makeup water	1	7.0×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,150	1,150
7.	Soot blowers	5		1.00	TVA	5,050	25,250
8.	Demister	1	Carbon steel, neoprene lined	----	----	15,550	15,550
9.	Pump, bleed	2	4.3×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,540	3,080
10.	Tank, demister wash	1	Capacity 1.20 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,080	1,080
11.	Pump, demister wash Wash	2	8.3×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,150	2,300
	SUBTOTAL						375,730

[a]Indicates source of spray tower cost

TABLE A-4 (Continued)

AREA 5 - REHEAT

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197 Cost
1.	Steam reheater	1	2.6×10^5 W rating $92.8\ m^2$ surface area	0.80	Chem. Engr. 3-24-69 Guthrie	60,240	60,24
2.	Soot blowers	5	---	1.00	TVA	4,290	21,45
	SUBTOTAL						81,69

AREA 6 - GAS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197 Cost
1.	Fan	1	8.09×10^5 W motor drive	0.68	Chem. Engr. 3-24-69 Guthrie	48,690	48,690

AREA 7 - SOLIDS DISPOSAL

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197 Cost
1.	Clarifier	1	$3.5 \times 10^{-3}\ m^3/s$	---	PEDCO (PE-146)	122,970	122,97
2.	Pumps, pond feed	2	$8.3 \times 10^{-4}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,150	2,30
3.	Pump, clarifier water recycle	2	$2.3 \times 10^{-3}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,440	4,88
4.	Pumps, particulate pond water recycle	2	$2.0 \times 10^{-3}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,800	3,60
5.	Pumps, SO_2 pond water recycle	2	$3.7 \times 10^{-4}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		840	1,68
	SUBTOTAL						135,-3

TABLE A-4 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-197[illegible] Cost
1. Payloader			----	----	31,280	31,280
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,300	33,300
4. Service building-equipment			----	----	44,150	44,150
5. Stores-equipment			----	----	13,370	13,370
SUBTOTAL						134,73[illegible]

AREA 10 - PARTICLE RECIRCULATION

	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-19[illegible] Cost
1. Wet ball mill	1	2.0×10^{-4} m^3/s	0.65	McGlamery	23,130	23,13[illegible]
2. Pump, particle recirculation	2	2.0×10^{-4} m^3/s, molded polypropylane	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		380	76[illegible]
3. Tank, particle recirculation surge	1	Capacity .70 m^3, carbon steel, neoprene lined	0.68	McGlamery	770	77[illegible]
SUBTOTAL						24,6[illegible]

TABLE A-5

CASE 5, ELECTRIC FURNACE, NSPS*

WORK SHEET FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Unloading hopper No. 1	1	Capacity 0.28 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	260	260
2.	Limestone feeder No. 1 (vibrating)	1	5.2 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	1,090	1,090
3.	Conveyor (belt) No. 1	1	5.2 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	560	560
4.	Conveyor (belt) No. 2	1	5.2 kg/s	0.81 0.65	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	2,650	2,650
5.	Hoppers under pile	3	Capacity 0.19 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	450	1,350
6.	Limestone feeder No. 2 (vibrating)	3	2.5 kg/s	0.58	Chem. Engr. 3-24-69	570	1,710
7.	Conveyor (belt) No. 3	1	2.5 kg/s	0.65 0.81	Chem. Engr. 3-24-69 Guthrie Fund. of Cost Engr. 1964	4,180	4,180
8.	Tunnel sump pump	2	2.7 x 10^{-4} m^3/s, carbon steel, neoprene lining, 241.0 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		450	900
9.	Elevator	1	2.5 kg/s	0.83	Chem. Engr. 3-24-69	2,490	2,490
10.	Bin	1	Capacity 14 m^2, carbon steel	0.68	Chem. Engr. 3-24-69	5,070	5,070
11.	Car shaker	1	Railroad trackside vibrator	----	----	6,920	6,920
12.	Dust collecting system No. 1	1	0.10 m^3/s, inertial separators, cyclone, hoppers, fan and drive	0.80	Chem. Engr. 3-24-69	540	540
13.	Dust collecting system No. 2	1	0.29 m^3/s, inertial separators, cyclone, hoppers, fan and drive	0.80	Chem. Engr. 3-24-69	440	440
14.	Bag filter system	1	0.78 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,530	2,530
	SUBTOTAL						$30,690

*New Source Performance Standards, 650 ppm SO_2 in scrubber effluent, acid plant tail gas not treated.

TABLE A-5 (Continued)

AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge feeder	1	0.7 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	300	300
2.	Weigh feeder	1	0.7 kg/s, carbon steel	0.65	Chem. Engr. 3-24-69 Guthrie	3,630	3,630
3.	Gyratory crusher	1	0.7 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	2,070	2,070
4.	Elevator No. 2	1	0.7 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	1,060	1,060
5.	Wet ball mill	1	0.62 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	49,130	49,130
		1	71,333 W motor	1.07	Fund. of Cost Engr. 1964	3,420	3,420
6.	Slurry feed tank	1	Capacity 17.4 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	5,150	5,150
	Lining	1	0.53×10^{-2} m neoprene	----	----	4,540	4,540
7.	Agitator, slurry feed tank	1	1240 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	2,890	2,890
				0.46	Fund. of Cost Engr. 1964		
8.	Pumps, slurry	2	0.6×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,260	2,520
9.	Dust collecting system	1	0.39 m^3/s, inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	1,330	1,330
10.	Hoist	1	1496 kg electric	0.81	Popper, H.	9,830	9,830
11.	Bag filter system	1	0.78 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,530	2,530
	SUBTOTAL						88,400

TABLE A-5 (Continued)

AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Tank particulate scrubber, effluent hold	1	Capacity 165.8 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	29,560	29,560
	Lining	1	0.53×10^{-2} m neoprene	----	----	21,700	21,700
2.	Agitator, effluent hold tank	1	6,203 W, neoprene coated	0.26 0.50	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	5,760	5,760
3.	Pumps, recycle slurry	2	.22 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		10,970	21,940
4.	Venturi scrubber	1	6.8 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	75,130	75,130
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	69,370	69,370
6.	Soot blowers	5		1.00	TVA	1,240	6,200
7.	Bleed pump	2	1.3×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,260	2,520
	SUBTOTAL						157,050

TABLE A-5 (Continued)

AREA 4 - SO_2 SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Spray tower scrubber	1	Gas flow 24.5 m^3/s, carbon steel, neoprene		Western Precipitator Div., Joy Mfg. Co.[a]	82,620	82,620
2.	Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	69,370	69,370
3.	Tank, absorber effluent hold	1	Capacity 588.6 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	42,380	42,380
	Lining	1	0.53×10^{-2} m neoprene	----	----	21,690	21,690
4.	Agitator, SO_2 absorber hold tank	1	24811 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	12,670	12,670
5.	Pumps, SO_2 absorber recycle	3	0.38 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		16,980	16,980
6.	Pumps, makeup water	1	1.0×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		940	940
7.	Soot blowers	5		1.00	TVA	1,240	6,200
8.	Demister	1	Carbon steel, neoprene lined	----	----	5,700	5,700
9.	Pump, bleed	2	0.6×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,250	2,500
10.	Tank, demister wash	1	Capacity 1.57 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,290	1,290
11.	Pump, demister wash	2	1.1×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		950	1,900
	SUBTOTAL						264,240

[a]Indicates source of spray tower cost

TABLE A-5 (Continued)

AREA 5 - REHEAT

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Steam reheater	1	1.66×10^5 W rating $61.0\ m^2$ surface area	0.80	Chem. Engr. 3-24-69	47,340	47,340
2. Soot	5		1.00	TVA	1,240	6,200
SUBTOTAL						53,540

AREA 6 - GAS HANDLING

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Fan	1	3.41×10^5 W drive	0.68	Chem. Engr. 3-24-69 Guthrie	113,590	113,590

AREA 7 - SOLIDS DISPOSAL

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Clarifier	1	4.8×10^3 m /s	0.68	PEDCO (PE-146)	158,400	158,400
2. Pumps, pond feed	2	$6.0 \times 10^{-3}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,960	5,920
3. Pump, clarifier water recycle	2	$0.4 \times 10^{-2}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,180	4,360
4. Pumps, particulate pond water recycle	2	$0.3 \times 10^{-2}\ m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,500	5,000
5. Pumps, SO_2 pond water recycle	2	$0.5 \times 10^{-3}\ m^3/s$, carbon steel, neoprene lined			680	1,360
SUBTOTAL						175,040

TABLE A-5 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Payloader			----	----	31,300	31,300
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,320	33,320
4. Service building-equipment			----	----	44,170	44,170
5. Stores-equipment			----	----	13,380	13,380
SUBTOTAL						134,800

AREA 10 - PARTICLE RECIRCULATION

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Wet ball mill	1	2.7×10^{-4} m^3/s	0.65	McGlamery	27,900	27,900
2. Pump, particle recirculation	2	2.7×10^{-4} m^3/s, molded polypropylene	Depends on gpm and head requirements resulting in changes of motor and impeller size		300	600
3. Tank, particle recirculation surge	1	Capacity 0.9 m^3, carbon steel, neoprene lined	0.68	McGlamery	920	920
SUBTOTAL						29,420

TABLE A-6

CASE 6, FLASH FURNACE, NSPS*

WORK SHEET FOR PROCESS EQUIPMENT COSTS

AREA 1 - MATERIALS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Unloading hopper No. 1	1	Capacity .22 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	470	470
2.	Limestone feeder No. 1 (vibrating)	1	4.2 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	960	960
3.	Conveyor (belt) No. 1	1	4.2 kg/s	0.81	Fund. of Cost Engr. 1964	470	470
				0.65	Chem. Engr. 3-24-69 Guthrie		
4.	Conveyor (belt) No. 2	1	4.2 kg/s	0.81	Fund. of Cost Engr. 1964	2,230	2,230
				0.65	Chem. Engr. 3-24-69 Guthrie		
5.	Hoppers under pile	3	Capacity 0.15 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	400	1,200
6.	Limestone feeder No. 2 (vibrating)	3	2.0 kg/s	0.58	Chem. Engr. 3-24-69 Guthrie	500	1,500
7.	Conveyor (belt) No. e	1	2.0 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	3,600	3,600
				0.81	Fund. of Cost Engr. 1964		
8.	Tunnel sump pump	2	2.3×10^{-4} m^3/s, carbon steel, neoprene lining, 311.0 watt motor	Depends on gpm and head requirements resulting in changes of motor and impeller size		460	920
9	Elevator No. 1	1	2.0 kg/s	0.83	Chem. Engr. 3-24-69	2,060	2,060
10.	Bin	1	Capacity 11.2 m^3, carbon steel	0.68	Chem. Engr. 3-24-69	3,590	3,590
11.	Car shaker	1	Railroad trackside vibrator	----	----	8,330	8,330
12.	Dust collecting system No. 1	1	0.09 m /s inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69 Guthrie	480	480
13.	Dust collecting system No. 2	1	0.24 m^3/s inertial separator, cyclone, hoppers, fan, and drive	0.80	Chem. Engr. 3-24-69	880	880
14.	Bag filter system	1	.626 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,160	2,160
	SUBTOTAL						28,850

*New Source Performance Standards, 650 ppm SO_2 in scrubber effluent, acid plant tail gas not treated.

TABLE A-6 (Continued)

AREA 2 - FEED PREPARATION

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Bin discharge feeder	1	0.6 kg/s, carbon steel	0.58	Chem. Engr. 3-24-69 Guthrie	270	270
2	Weigh feeder	1	0.6 kg/s, carbon steel	0.64	Chem. Engr. 3-24-69 Guthrie	3,280	3,280
3.	Gyratory crusher	1	0.6 kg/s	1.20	Chem. Engr. 3-24-69 Guthrie	1,680	1,680
4.	Elevator No. 2	1	0.6 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	950	950
5.	Wet ball mill	1	5.3 kg/s	0.65	Chem. Engr. 3-24-69 Guthrie	42,730	42,730
		1	56,400 W motor	1.07	Fund. of Cost Engr. 1964	2,660	2,660
6.	Slurry feed tank	1	Capacity 15.0 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	4,580	4,580
	Lining	1	0.45×10^{-2}m neoprene	----	----	4,000	4,000
7.	Agitator, slurry feed tank	1	1075 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	2,690	2,690
				0.46	Fund. of Cost Engr. 1964		
8.	Pumps, slurry feed tank	2	$0.50 \times 10^{-3} m^3/s$, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,290	2,580
9.	Dust collecting system	1	0.30 m^3/s, inertial separator, cyclone, hoppers, fan and drive	0.80	Chem. Engr. 3-24-69 Guthrie	1,080	1,080
10.	Hoist	1	1296 kg electric	0.81	Popper, H.	8,750	8,750
11.	Bag filter system	1	0.63 m^3/s, automatic fabric dust collectors, bag support, shaker system, isolation damper, motor, drive, dust hopper, fan and motor	0.68	Chem. Engr. 3-24-69	2,160	2,160
	SUBTOTAL						77,410

TABLE A-6 (Continued)

AREA 3 - PARTICULATE SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Tank, particulate scrubber, effluent hold	1	Capacity 125.4 m^3, carbon steel	0.68	Chem. Engr. 3-24-69 Guthrie	24,450	24,450
	Lining	1	0.45×10^{-2} m neoprene	----	----	17,780	17,780
2.	Agitator, effluent hold tank	1	5373 W, neoprene coated	0.26 0.50	Fund. of Cost Engr. 1964 Chem. Engr. 3-24-69 Guthrie	5,560	5,560
3.	Pumps, recycle slurry	2	0.3 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		14,040	28,080
4.	Venturi scrubber	1	45.8 m^3/s, carbon steel, neoprene lined	0.60	Universal Oil Products	109,350	109,350
5.	Venturi sump	1	Carbon steel, neoprene lining	0.68	Chem. Engr. 3-24-69 Guthrie	85,200	85,200
6.	Soot blowers	5	----	1.00	TVA	2,280	11,400
7.	Bleed pump	2	1.4×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,300	2,600
	SUBTOTAL						284,420

TABLE A-6 (Continued)

AREA 4 - SO_2 SCRUBBING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Spray tower scrubber	1	Gas flow 45.8 m^3/s, carbon steel, neoprene	----	Western Precipitation Div. Joy Mfr. Co.[a]	147,400	147,400
2.	Spray tower sump	1	Carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	83,850	83,850
3.	Tank absorber effluent hold	1	Capacity 382.4 m^3, carbon steel, field erected	0.68	Chem. Engr. 3-24-69 Guthrie	31,610	31,610
	Lining	1	1.05×10^{-2} m neoprene	----	----	26,720	26,720
4.	Agitator, SO_2 absorber hold tank	1	37314 W, neoprene coated	0.50	Chem. Engr. 3-24-69 Guthrie	11,000	11,000
5.	Pumps, SO_2 absorber recycle slurry	3	0.45 m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		21,080	63,240
6.	Pumps, makeup water	1	0.8×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,000	1,000
7.	Soot blowers	5		1.00	TVA	2,280	11,400
8.	Demister	1	Carbon steel, neoprene lined	----	----	13,900	13,900
9.	Pump, bleed	2	0.5×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,280	2,560
10.	Tank Demister Wash	1	Capacity 1.36 m^3, carbon steel, neoprene lined	0.68	Chem. Engr. 3-24-69 Guthrie	1,180	2,360
11.	Pump, Demister Wash	2	1.0×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		930	1,960
	SUBTOTAL						396,960

[a]Indicates source of spray tower cost

TABLE A-6 (Continued)

AREA 5 - REHEAT

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Steam reheater	1	2.9×10^6 W rating 105.4 m^2 surface area	0.80	Chem. Engr. 3-24-69 Guthrie	65,660	65,660
2.	Soot blowers	5	----	1.00	TVA	2,280	11,400
	SUBTOTAL						66,800

AREA 6 - GAS HANDLING

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Fan	1	7.47×10^5 W motor drive	0.68	Chem. Engr. 3-24-69 Guthrie	46,130	46,130

AREA 7 - SOLIDS DISPOSAL

	Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1.	Clarifier	1	4.0×10^{-3} m^3/s	----	PEDCO (PE-146)	104,530	104,530
2.	Pumps, pond feed	2	1.0×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		980	1,960
3.	Pump, clarifier water recycle	2	3.9×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		2,750	5,500
4.	Pumps, particulate pond water recycle	2	2.3×10^{-3} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		1,610	3,220
5.	Pumps, SO_2 pond water recycle	2	4.2×10^{-4} m^3/s, carbon steel, neoprene lined	Depends on gpm and head requirements resulting in changes of motor and impeller size		710	1,420
	SUBTOTAL						116,630

TABLE A-6 (Continued)

AREA 8 - UTILITIES

Note: There is no process equipment in this area.

AREA 9 - SERVICES

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Payloader			----	----	31,300	31,300
2. Plant vehicles			----	----	----	12,630
3. Maint. & instrument shop-equipment			----	----	33,320	33,320
4. Service building-equipment			----	----	44,170	44,170
5. Stores-equipment			----	----	13,380	13,380
SUBTOTAL						134,300

AREA 10 - PARTICLE RECIRCULATION

Item	No.	Description	Size-Cost Scale Factor	Factor Source	Base Cost Each (1977)	Total Mid-1977 Cost
1. Wet ball mill	1	2.3×10^{-4} m^3/s	0.65	McGlamery	25,260	25,260
2. Pump, particle recirculation	2	2.3×10^{-4} m^3/s, molded polypropylane	Depends on gpm and head requirements resulting in changes of motor and impeller sizes		500	1,000
3. Tank, particle recirculation surge	1	Capacity 0.8 m^3, carbon steel, neoprene lined	0.68	McGlamery	830	830
SUBTOTAL						27,090