

DSRP costs

Expenditures		DSRP	DSRP-b	DSRP-c	DSRP-100	DSRP-500	cost ref.
Electrical							
Pumps & Compressors							
KW RECYCOMP	59	227	5	7			37 ASPEN generated power requirements
KW PRESAIR	3282	10414	900	999			4889 ASPEN generated power requirements
KW Steam pumps	76	193	30	32			160 ASPEN steam simulations
Light & instruments							11/26/97
KW misc.	683	683	683	683			683 20% base case pump & compressor requirements
TOTAL	4100.4	11517.4	1618.4	1721			5769
unit cost \$/kWh	0.04	0.04	0.04	0.04			0.04 Self-gen. (Jan. 1990) Peters & Timmeraus
90 % op Cost \$/yr	\$1,293,988	\$3,634,615	\$510,728	\$543,234			\$1,820,690
Cooling Water							
lbs/hr	149,000	500,000	25,000	62,744			313,720 ASPEN Complete Steam Generation Scheme simulations
unit value \$/lb	2.6E-05	2.6E-05	2.6E-05	2.6E-05			2.6E-05 Tower (Jan. 1990) Peters & Timmeraus
90 % op Cost \$/yr	\$21,854	\$73,336	\$3,667	\$9,203			\$46,014
Oxygen							
lbs/hr	0	0	0	0			0
unit value \$/lb							
Cost \$/yr							
Additional Employees							
Engineers	2	2	2	2			2
unit cost	\$100,000	\$100,000	\$100,000	\$100,000			\$100,000
Maintenance	2	2	2	2			2
unit cost	\$70,000	\$70,000	\$70,000	\$70,000			\$70,000
Cost \$/yr	\$340,000	\$340,000	\$340,000	\$340,000			\$340,000
Consumed Coal Gas							
MW lost	7	23	2	3			15 Appendix J
unit cost \$/MWh	40	40	40	40			40 Self-gen. (Jan. 1990) Peters & Timmeraus
Cost \$/yr	\$2,287,295	\$7,259,195	\$652,927	\$963,138			\$4,714,074
totals (yearly)	\$3,943,137	\$11,307,146	\$1,507,322	\$1,855,574			\$6,920,778

DSRP costs

Benefits

	DSRP	DSRP-b	DSRP-c	DSRP-100	DSRP-500	Condition	value ref.	date of calc.
Sulfur Recovered lbs/hr	5,840	18,590	1,667	2,460	12,300			
90% op tons/year	23,037	73,332	6,576	9,704	48,520			11/4/97
unit value \$/ton	50	50	50	50	50	low purity	Chem. Eng. Progress 1996	
Revenue \$/yr	\$1,151,852	\$3,666,599	\$328,791	\$485,198	\$2,425,991			
Steam Generation lbs/hr	23,200	77,700	6,160	9,800	48,800	950 psia, 441 C		11/4/97
unit value \$/lb	0.0039	0.0039	0.0039	0.0039	0.0039	500 psig, (Jan. 1990)	Peters and Timmeraus	
90% op Revenue \$/yr.	\$713,833	\$2,390,725	\$189,535	\$301,533	\$1,501,511			
totals (yearly)	\$1,865,685	\$6,057,324	\$518,326	\$786,731	\$3,927,501			

	DSRP	DSRP-b	DSRP-c	DSRP-100	DSRP-500
YEARLY COST	\$2,077,452	\$5,249,823	\$988,996	\$1,068,843	\$2,993,277
EQUIPMENT COSTS	\$3,393,129	\$7,245,855	\$2,039,375	\$1,927,612	\$6,098,200

## AHGP Costs

### Equipment

Type	unit	AHGP Price	AHGP-b Price	AHGP-c Price	AHGP-100 Price	AHGP-500 Price	Mat. of Construction	Purchase date	price ref.	date of calculation
Heat Exchangers										
	HEATX	\$64,900	\$125,700	\$32,900	\$39,600	\$107,300	SS310 (SS 316)	June, 1996	aspen	12/3/97 AHGPcosts
	RCYHEATR	\$102,800	\$162,900	\$35,300	\$60,500	\$181,000	SS310 (SS 316)	June, 1996	aspen	1/22/98 steam
	N2-COOLR	\$42,000	\$72,200	\$16,800	\$26,500	\$66,400	SS304	June, 1996	aspen	1/22/98 steam
Condensers										
	COND	\$82,200	\$177,000	\$41,000	\$51,400	\$138,500	SS310-heat exchanger	June, 1996	aspen	1/22/98 steam
	LP-COND	\$8,200	\$11,100	\$6,200	\$7,000	\$10,000	SS310 tank (τ = 1min)	June, 1996	aspen	12/3/97 AHGPcosts
Demister										
	DEMISTR	\$53,100	\$109,000	\$30,600	\$35,000	\$83,700	SS310 1.5tank (τ = 1mir)	June, 1996	aspen	12/3/97 AHGPcosts
Compressor										
	CON-COMP	\$201,100	\$203,300	\$200,900	\$200,900	\$202,100	3 x (Carbon Steel)	June, 1996	aspen	12/3/97 AHGPcosts
	LIFTCOMP	\$485,000	\$820,000	\$161,600	\$161,600	\$820,000	3 x (Carbon Steel)	June, 1996	aspen mod.	12/3/97 AHGPcosts
	SO2-COMP	\$53,900	\$66,200	\$53,900	\$53,900	\$1,410,000	3 x (Carbon Steel)	June, 1996	aspen	12/3/97 AHGPcosts
Tanks										
	7 days storage	\$125,500	\$205,400	\$65,000	\$80,000	\$171,000	SS316	June, 1996	aspen	11/6/97
Reactors										
		\$2,939,588	\$12,297,497	\$1,562,672	\$2,177,791	\$8,869,074	SS310	June, 1996 (w install)	P&T calc	11/20/97
Pipes										
	pipe lines									
totals		\$4,158,288	\$14,250,297	\$2,206,872	\$2,894,191	\$12,059,074				

### Equipment -Steam side

Type	unit	AHGP Price	AHGP-b Price	AHGP-c Price	AHGP-100 Price	AHGP-500 Price	Mat. of Construction	date	price ref.	Purchase price ref.
pumps										
	PTOWR	\$3,400	\$5,000	\$2,800	\$2,800	\$4,300		June, 1996	aspen	11/26/97 steam
	PSTEAM	\$57,400	\$63,300	\$57,400	\$57,400	\$59,300		June, 1996	aspen	11/26/97 steam
Heat Exchangers										
	VCOOLR	\$7,000	\$8,000	\$6,700	\$6,800	\$7,600	shell CS / tube 304	June, 1996	aspen	11/26/97 steam
totals		\$67,800	\$76,300	\$66,900	\$67,000	\$71,200				

### Expenditures

	AHGP	AHGP-b	AHGP-c	AHGP-100	AHGP-500	cost ref.
Electrical						
Pumps & Compressors						
	8	26	2	3	17	ASPEN generated power requirements
CON-COMP						1/22/98
kW	13	28	3	5	27	ASPEN generated power requirements
LIFTCOMP						1/22/98
kW	38	114	11	16	80	ASPEN generated power requirements
SO2-COMP						1/22/98
kW	64	148	28	27	135	ASPEN generated power requirements
Steam pumps						
Light & instruments						
misc.	25	25	25	25	25	20% base case pump & compressor requirements
TOTAL	148	341	68	76	284	
unit cost \$/kWh	0.04	0.04	0.04	0.04	0.04	Self-gen. (Jan. 1990) Peters & Timmeraus
90 % op	\$46,579	\$107,485	\$21,491	\$24,109	\$89,490	
Cooling Water						
lbs/hr	79,200	4,530	434	33,351	166,756	
unit value \$/lb	2.6E-05	2.6E-05	2.6E-05	2.6E-05	2.6E-05	Tower (Jan. 1990) Peters & Timmeraus
90 % op	\$29,041	\$1,661	\$159	\$12,229	\$61,146	
Oxygen						
lbs/hr	4,129	12,536	1,195	1,739	8,694	
unit value \$/ton	\$20	\$20	\$20	\$20	\$20	Increased O2 plant production Dr. Roberts
90 % op	\$325,753	\$989,015	\$94,278	\$137,175	\$685,874	
Additional Employees						
Engineers	3	3	3	3	3	
unit cost	\$100,000	\$100,000	\$100,000	\$100,000	\$100,000	
Maintenance	2	2	2	2	2	
unit cost	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	
Cost \$/yr	\$440,000	\$440,000	\$440,000	\$440,000	\$440,000	
Consumed Coal Gas						
MW lost	1.506	4.580	0.436	0.634	3.172	Appendix J
unit cost \$/MWh	40	40	40	40	40	Self-gen. (Jan. 1990) Peters & Timmeraus
Cost \$/yr	\$475,257	\$1,445,338	\$137,591	\$200,075	\$1,001,007	
totals (yearly)		\$1,316,631	\$2,983,500	\$693,519	\$813,588	\$2,277,517

### Benefits

	AHGP	AHGP-b	AHGP-c	AHGP-100	AHGP-500	Condition	value ref.	date of calc.
Sulfur Recovered								
lbs/hr	5,731	17,440	1,593	2,413	12,067			
90 % op	22,607	68,796	6,284	9,520	47,599			11/4/97
tons/year	50	50	50	50	50	low purity	Chem. Eng. Progress 1996	
Revenue \$/yr	\$1,130,354	\$3,439,778	\$314,195	\$475,992	\$2,379,960			
Steam Generation								
lbs/hr	19,400	59,000	5,650	8,169	40,847	950 psia, 441 C		11/4/97
unit value \$/lb	0.0039	0.0039	0.0039	0.0039	0.0039	500 psig, (Jan. 1990) Peters and Timmeraus		
90 % op	\$96,912	\$1,815,351	\$173,843	\$251,360	\$1,256,798			
totals (yearly)		\$1,727,266	\$5,255,129	\$488,038	\$727,352	\$3,636,758		

	AHGP	AHGP-b	AHGP-c	AHGP-100	AHGP-500
YEARLY COST	-\$410,635	-\$2,271,630	\$205,481	\$86,236	-\$1,359,241
EQUIPMENT COSTS	\$4,226,088	\$14,326,597	\$2,273,772	\$2,961,191	\$12,130,274



# AHGP Costs

## Equipment - Steam side

Type	unit	AHGP Price	AHGP-b Price	AHGP-c Price	AHGP-100 Price	AHGP-500 Price Mat. of Construction	date	aspen	Purchase price ref.
pumps	PTOWR	\$3,400	\$5,000	\$2,800	\$2,800	\$4,300	June, 1996	aspen	11/26/97 steam
	PSTEAM	\$57,400	\$63,300	\$57,400	\$57,400	\$59,300	June, 1996	aspen	11/26/97 steam
Heat Exchangers	VCOOLR	\$7,000	\$8,000	\$6,700	\$6,800	\$7,600	June, 1996	aspen	11/26/97 steam
	totals	\$67,800	\$76,300	\$66,900	\$67,000	\$71,200			

# AHGP Costs

Expenditures		AHGP	AHGP-b	AHGP-c	AHGP-100	AHGP-500	cost.ref.
Electrical							
Pumps & Compressors							
kw	CON-COMP	8	26	2	3		1/22/98
kw	LIFT-COMP	13	28	3	5		1/22/98
kw	SO2-COMP	38	114	11	16		1/22/98
kw	Steam pumps	64	148	28	27		
kw	Light & instruments	25	25	25	25		
kw	misc.	148	341	68	76		
TOTAL	unit cost \$/kWh	0.04	0.04	0.04	0.04		
90 % op	Cost \$/yr	\$46,579	\$107,485	\$21,491	\$24,109	\$89,490	
Cooling Water							
lbs/hr		79,200	4,530	434	33,351	166,756	
unit value \$/lb		2.6E-05	2.6E-05	2.6E-05	2.6E-05	2.6E-05	
90 % op	Cost \$/yr	\$29,041	\$1,661	\$159	\$12,229	\$61,146	
Oxygen							
lbs/hr		4,129	12,536	1,195	1,739	8,694	
unit value \$/ton		\$20	\$20	\$20	\$20	\$20	
90 % op	Cost \$/yr	\$325,753	\$989,015	\$94,278	\$137,175	\$685,874	Dr. Roberts
Additional Employees							
Engineers	unit cost	3	3	3	3	3	
Maintenance	unit cost	2	2	2	2	2	
Consumed Coal Gas							
MW lost		1,506	4,580	0,436	0,634	3,172	Appendix J
unit cost \$/MWh		40	40	40	40	40	
90 % op	Cost \$/yr	\$475,257	\$1,445,338	\$137,591	\$200,075	\$1,001,007	Peters & Timmeraus
totals (yearly)		\$1,316,631	\$2,983,500	\$693,519	\$813,588	\$2,277,517	

# AHGP Costs

## Benefits

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Sulfur Recovered								
lbs/hr	5,731	17,440	1,593	2,413	12,067			
90% op tons/year	22,607	68,796	6,284	9,520	47,599			
unit value \$/ton	50	50	50	50	50	50 low purity	Chem. Eng. Progress 1996	11/4/97
Revenue \$/yr	\$1,130,354	\$3,439,778	\$314,195	\$475,992	\$2,379,960			
Steam Generation								
lbs/hr	19,400	59,000	5,650	8,169	40,847	950 psia, 441 C		
unit value \$/lb	0.0039	0.0039	0.0039	0.0039	0.0039	500 psig, (Jan. 1990)	Peters and Timmeraus	11/4/97
90% op Revenue \$/yr.	\$596,912	\$1,815,351	\$173,843	\$251,360	\$1,256,798			
<b>totals (Yearly)</b>	<b>\$1,727,266</b>	<b>\$5,255,129</b>	<b>\$488,038</b>	<b>\$727,352</b>	<b>\$3,636,758</b>			

	AHGP	AHGP-b	AHGP-c	AHGP-100	AHGP-500
YEARLY COST	-\$410,635	-\$2,271,630	\$205,481	\$86,236	-\$1,359,241
EQUIPMENT COSTS	\$4,226,088	\$14,326,597	\$2,273,772	\$2,961,191	\$12,130,274

**Appendix O**  
**Reaction Data Obtained from RTI**

The following data was obtained during correspondence with RTI.

DSRP reactions at 300 psi

Reaction	$\Delta H$ at 550°C (J/mol)	$\Delta H$ at 650°C (J/mol)	$\Delta H$ at 750°C (J/mol)
$0.5 \text{ SO}_2 + \text{H}_2 = (1/4)\text{S}_2 + \text{H}_2\text{O}$	-65128	-65795	-66436
$0.5 \text{ SO}_2 + \text{CO} = (1/4)\text{S}_2 + \text{CO}_2$	-101938	-101629	-101295

$\text{ZnO} + \text{H}_2\text{S}(\text{g}) = \text{ZnS} + \text{H}_2\text{O}(\text{g})$

Temp. °C	$\Delta H$ kcal	$\Delta S$ cal	$\Delta G$ kcal	K
400	-17.079	-0.071	-17.031	3.387E+5
500	-17.056	-0.040	-17.025	6.502E+4
600	-17.047	-0.029	-17.022	1.824E+4
700	-17.050	-0.032	-17.019	6.645E+3

$\text{ZnS} + 1.5 \text{ O}_2(\text{g}) = \text{ZnO} + \text{SO}_2(\text{g})$

Temp. °C	$\Delta H$ kcal	$\Delta S$ cal	$\Delta G$ kcal	K
500	-107.110	-18.940	-92.467	1.381E+26
550	-107.135	-18.971	-91.519	1.999E+24
600	-107.155	-18.995	-90.570	4.694E+22
650	-107.172	-19.013	-89.620	1.654E+21
700	-107.185	-19.027	-88.669	8.220E+19
750	-107.195	-19.038	-87.717	5.474E+18
800	-107.204	-19.046	-86.765	4.692E+17