Desulf and Regen transport reactor price calculation

DSRP

Regenerator Reactor			air volume	215,340	cfh	HP-O2-N2
v (ft/sec) =	20	72000 ft/hr	ROG volume	299,541	cfh	ROG
V (cfh) =	277,458		regen sorbent flow	1,201,050	lb/hr	ZNS2RGEN
Area =	3.854 ft^2		regen sorbent vol.	20,018	cfh	
I.D.	27.137 in					
			sorbent vol%	7.21%		
thickness=	0.494					
shell wt.=	14,298 lbs		Corrosion depth	0.125	in	
heads wt.=	323 lbs		reactor height	100	ft	

total wt. 16,814 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

size vs. regen size 1

total wt. 16,814 lbs

Desulfurization Reactor			coal gas in volume	1,409,220	cfh	RAW-CG
v (ft/sec) =	20	72000 ft/hr	cg out volume	1,877,650	cfh	CG-CALC
V (cfh) =	1,687,918		regen sorbent flow	2,669,000	lb/hr	ZNS
Area =	23.443 ft^2		regen sorbent vol.	44,483	cfh	
I.D.	66.933 in					
			sorbent vol%	2.64%		
thickness=	1.035					
shell wt.=	73,889 lbs		Corrosion depth	0.125	in	
heads wt.=	4,121 lbs		reactor height	100	ft	

total wt. 89,711 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

size vs. desulf size 1

total wt. 89,711 lbs

total wt. 213,051 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.415 $/lb	1990 $	1.4152335	1.234	
	1.512 $/lb	1996 $		<100,000 lb calc	

Cost of installation $644,349

Total reactor cost **$1,771,959** includes cost of installation

DSRP-b reactor

DSRP-b Reactor Cost

DSRP

DSRP Reactor

v (ft/sec) gas =	3	10800	ft/hr	slipstream	153,708	cfh	SLIPSTREAM
V (cfh) =	393,089			ROG volume	237,184	cfh	ROG-COOL
space time -gas	33.33	seconds		reactor effluent	361,900	cfh	RXNPRD
v (ft/sec) cat =	2.3	8280	ft/hr	DSRP reactor Q	-51,320,000	BTU/hr	
				catalyst flow	1,001,581	lb/hr	
				catalyst vol.	16,693	cfh	
Area =	36.868	ft^2					
I.D.	83.936	in		catalyst vol%	5.47%		
thickness=	1.266	in					
shell wt.=	113,355	lbs		Corrosion depth	0.125	in	
heads wt.=	7,929	lbs		reactor height	100	ft	

total wt. 139,477 lbs (includes additional 15% for nozzles, manholes, etc.)

DSRP Standpipe

Cyclone (20% of reactor size)		27,895	Area =	36.87	ft^2
			I.D.	83.94	in
standpipe height	40	ft	thickness=	1.27	in
			shell wt.=	45,342	lbs
residense time	11.05	minutes	heads wt.=	7,929	lbs

total wt. 89,157 lbs (includes additional 15% on standpipe weight + Cyclone weight)

Heat Exchanger

Heat Exchanger Area (ft^2) 3556 heat exchanger pipe thickness 0.25 in

volume of steel 74

total weight 36,229 lbs

total wt. 264,863 lbs weight for DSRP reactor system

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.371	$/lb	1990 $	1.371208108	1.146
	1.465	$/lb	1996 $		<100,000 lb calc

Cost of installation $776,129

Total reactor cost **$2,134,355** includes cost of installation

Desulf and Regen transport reactor price calculation

DSRP

Regenerator Reactor			air volume	19,366	cfh	HP-O2-N2
v (ft/sec) =	20	72000 ft/hr	ROG volume	26,009	cfh	ROG
V (cfh) =	23,882		regen sorbent flow	71,663	lb/hr	ZNS2RGEN
Area =	0.332 ft^2		regen sorbent vol.	1,194	cfh	
I.D.	7.962 in					
			sorbent vol%	5.00%		
thickness=	0.233					
shell wt.=	1,981 lbs		Corrosion depth	0.125	in	
heads wt.=	13 lbs		reactor height	100	ft	
total wt.	2,293 lbs	(includes additional 15% for nozzles, manholes, etc.)				
Regenerator Standpipe						
			size vs. regen size	1		
total wt.	2,293 lbs					
Desulfurization Reactor			coal gas in volume	1,139,050	cfh	RAW-CG
v (ft/sec) =	20	72000 ft/hr	cg out volume	1,186,750	cfh	CG-CALC
V (cfh) =	1,164,094		regen sorbent flow	71,663	lb/hr	ZNS
Area =	16.168 ft^2		regen sorbent vol.	1,194	cfh	
I.D.	55.585 in					
			sorbent vol%	0.10%		
thickness=	0.880					
shell wt.=	52,215 lbs		Corrosion depth	0.125	in	
heads wt.=	2,419 lbs		reactor height	100	ft	
total wt.	62,829 lbs	(includes additional 15% for nozzles, manholes, etc.)				
Desulfurization Standpipe						
			size vs. desulf size	1		
total wt.	62,829 lbs					

total wt. **130,244 lbs** weight for desulfurization and regeneration transport reactors

COST

			>100,000 lb calc	
C.S. unit price for quantiy needed	1.528 $/lb	1990 $	1.5276336	1.459
	1.632 $/lb	1996 $		<100,000 lb calc

Cost of installation $425,193

Total reactor cost **$1,169,282** includes cost of installation

DSRP-c reactor

DSRP-c Reactor Cost

DSRP

DSRP Reactor

v (ft/sec) gas =	3	10800 ft/hr	slipstream	9,443	cfh	SLIPSTREAM
V (cfh) =	31,212		ROG volume	20,364	cfh	ROG-COOL
space time -gas	33.33 seconds		reactor effluent	29,995	cfh	RXNPRD
v (ft/sec) cat =	2.3	8280 ft/hr	DSRP reactor Q	-4,029,000	BTU/hr	
			catalyst flow	78,632	lb/hr	
			catalyst vol.	1,311	cfh	
Area =	2.93 ft^2					
I.D.	23.650 in		catalyst vol%	5.41%		
thickness=	0.446 in					
shell wt.=	11,265 lbs		Corrosion depth	0.125	in	
heads wt.=	222 lbs		reactor height	100	ft	

total wt. 13,210 lbs (includes additional 15% for nozzles, manholes, etc.)

DSRP Standpipe

Cyclone (20% of reactor size)	2,642	Area =	2.93	ft^2
		I.D.	23.65	in
standpipe height	40 ft	thickness=	0.45	in
		shell wt.=	4,506	lbs
residense time	11.17 minutes	heads wt.=	222	lbs

total wt. 8,079 lbs (includes additional 15% on standpipe weight + Cyclone weight)

Heat Exchanger

Heat Exchanger Area (ft^2) 279 heat exchanger pipe thickness 0.25 in

volume of steel 6

total weight 2,844 lbs

total wt. 24,133 lbs weight for DSRP reactor system

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	2.588 $/lb	1990 $	2.092218539	2.588	
	2.766 $/lb	1996 $		<100,000 lb calc	

Cost of installation $133,482

Total reactor cost **$367,075** includes cost of installation

Desulf and Regen transport reactor price calculation

DSRP

Regenerator Reactor

v (ft/sec) =	20	72000 ft/hr	air volume	28,592	cfh	HP-O2-N2
V (cfh) =	36,020		ROG volume	39,921	cfh	ROG
Area =	0.500 ft^2		regen sorbent flow	105,797	lb/hr	ZNS2RGEN
I.D.	9.778 in		regen sorbent vol.	1,763	cfh	
			sorbent vol%	4.90%		
thickness=	0.258					
shell wt.=	2,690 lbs		Corrosion depth	0.125	in	
heads wt.=	22 lbs		reactor height	100	ft	

total wt. 3,119 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

size vs. regen size 1

total wt. 3,119 lbs

Desulfurization Reactor

v (ft/sec) =	20	72000 ft/hr	coal gas in volume	506,745	cfh	RAW-CG
V (cfh) =	545,644		cg out volume	575,144	cfh	CG-CALC
Area =	7.58 ft^2		regen sorbent flow	281,971	lb/hr	ZNS
I.D.	38.06 in		regen sorbent vol.	4,700	cfh	
			sorbent vol%	0.86%		
thickness=	0.642					
shell wt.=	26,075 lbs		Corrosion depth	0.125	in	
heads wt.=	827 lbs		reactor height	100	ft	

total wt. 30,938 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

size vs. desulf size 1

total wt. 30,938 lbs

total wt. 68,113 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.819 $/lb	1990 $	1.7075181	1.819	
	1.943 $/lb	1996 $		<100,000 lb calc	

Cost of installation $264,748

Total reactor cost **$728,057** includes cost of installation

DSRP-100 reactor

DSRP-100 Reactor Cost

DSRP

DSRP Reactor

v (ft/sec) gas =	3	10800 ft/hr		slipstream	15,723	cfh	SLIPSTREAM
V (cfh) =	48,391			ROG volume	31,647	cfh	ROG-COOL
space time -gas	33.33 seconds			reactor effluent	45,210	cfh	RXNPRD
v (ft/sec) cat =	2.3	8280 ft/hr		DSRP reactor Q	-6,459,000	BTU/hr	
				catalyst flow	126,056	lb/hr	
				catalyst vol.	2,101	cfh	
Area =	4.540 ft^2						
I.D.	29.454 in			catalyst vol%	5.59%		
thickness=	0.525 in						
shell wt.=	16,508 lbs			Corrosion depth	0.125	in	
heads wt.=	405 lbs			reactor height	100	ft	

total wt. 19,451 lbs (includes additional 15% for nozzles, manholes, etc.)

DSRP Standpipe

Cyclone (20% of reactor size)	3,890		Area =	4.54	ft^2
			I.D.	29.45	in
standpipe heigh	40 ft		thickness=	0.53	in
			shell wt.=	6,603	lbs
residense time	10.81 minutes		heads wt.=	405	lbs

total wt. 11,950 lbs (includes additional 15% on standpipe weight + Cyclone weight)

Heat Exchanger

Heat Exchanger Area (ft^2) 448 heat exchanger pipe thickness 0.25 in

volume of steel 9

total weight 4,560 lbs

total wt. 35,960 lbs weight for DSRP reactor system

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	2.260 $/lb	1990 $		1.928109822	2.26
	2.415 $/lb	1996 $			<100,000 lb calc

Cost of installation $173,677

Total reactor cost **$477,612** includes cost of installation

Desulf and Regen transport reactor price calculation

DSRP

Regenerator Reactor			air volume	139,951	cfh	HP-O2-N2
v (ft/sec) =	20	72000 ft/hr	ROG volume	194,430	cfh	ROG
V (cfh) =	176,007		regen sorbent flow	528,985	lb/hr	ZNS2RGEN
Area =	2.445 ft^2		regen sorbent vol.	8,816	cfh	
I.D.	21.614 in					
			sorbent vol%	5.01%		
thickness=	0.419					
shell wt.=	9,656 lbs		Corrosion depth	0.125	in	
heads wt.=	174 lbs		reactor height	100	ft	

total wt. 11,305 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

size vs. regen size 1

total wt. 11,305 lbs

Desulfurization Reactor			coal gas in volume	2,531,530	cfh	RAW-CG
v (ft/sec) =	20	72000 ft/hr	cg out volume	2,867,390	cfh	CG-CALC
V (cfh) =	2,722,971		regen sorbent flow	1,410,630	lb/hr	ZNS
Area =	37.82 ft^2		regen sorbent vol.	23,511	cfh	
I.D.	85.01 in					
			sorbent vol%	0.86%		
thickness=	1.280348					
shell wt.=	116,135 lbs		Corrosion depth	0.125	in	
heads wt.=	8,227 lbs		reactor height	100	ft	

total wt. 143,017 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

size vs. desulf size 1

total wt. 143,017 lbs

total wt. 308,644 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.342 $/lb	1990 $	1.3421617	1.088	
	1.434 $/lb	1996 $		<100,000 lb calc	

Cost of installation $885,263

Total reactor cost **$2,434,474** includes cost of installation

DSRP-500 reactor

DSRP-500 Reactor Cost

DSRP

DSRP Reactor

v (ft/sec) gas =	3	10800 ft/hr		slipstream	76,726	cfh	SLIPSTREAM
V (cfh) =	236,095			ROG volume	153,894	cfh	ROG-COOL
space time -gas	33.33 seconds			reactor effluent	221,163	cfh	RXNPRD
v (ft/sec) cat =	2.3	8280 ft/hr		DSRP reactor Q	-31,370,000	BTU/hr	
				catalyst flow	612,229	lb/hr	
				catalyst vol.	10,204	cfh	
Area =	22.148 ft^2						
I.D.	65.058 in			catalyst vol%	5.56%		
thickness=	1.009 in						
shell wt.=	70,050 lbs			Corrosion depth	0.125	in	
heads wt.=	3,798 lbs			reactor height	100	ft	

total wt. 84,925 lbs (includes additional 15% for nozzles, manholes, etc.)

DSRP Standpipe

Cyclone (20% of reactor size)		16,985	Area =	22.15	ft^2
			I.D.	65.06	in
standpipe height	40 ft		thickness=	1.01	in
			shell wt.=	28,020	lbs
residense time	10.86 minutes		heads wt.=	3,798	lbs

total wt. 53,575 lbs (includes additional 15% on standpipe weight + Cyclone weight)

Heat Exchanger

Heat Exchanger Area (ft^2) 2174 heat exchanger pipe thickness 0.25 in

volume of steel 45

total weight 22,146 lbs

total wt. **160,646 lbs** weight for DSRP reactor system

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.477 $/lb	1990 $		1.477409568	1.359
	1.579 $/lb	1996 $			<100,000 lb calc

Cost of installation $507,200

Total reactor cost **$1,394,800** includes cost of installation

Appendix I
Sizing Reactors for the AHGP

Copies of the reactor system sizing calculations follow. They include estimates of the reactor system costs. The equations describe in *Appendix G - Calculation of Reactor Size* where used in the spreadsheet.

Desulf and Regen transport reactor price calculation

AHGP

N2 lift

v (ft/sec) =	50	180000 ft/hr	N2 in volume	42,761	cfh	N2SOURCE
V (cfh) =	64,033		N2 out volume	79,826	cfh	N2EXIT
Area =	0.356 ft^2		regen sorbent flow	164,358	lb/hr	FEO-ZNO
I.D.	8.245 in		regen sorbent vol.	2,739	cfh	
			sorbent vol%	4.28%		
thickness=	0.237					
shell wt.=	2,085 lbs		Corrosion depth	0.125	in	
heads wt.=	14 lbs		reactor height	100	ft	

key
caculated or constant values
inputed variables

total wt. 2,415 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

			residence time	10	min	
volume -sorbent	457 ft^3					
			heat removal	14,850,494	BTU/hr	RGENSTND
Heat Exchanger Area	1,029 ft^2		heat exchanger pipe thickness	0.25	in	
length of pipe	2,620 ft		heat exchanger pipe I.D.	1	in	
volume -heat exchanger	32 ft^3					
necessary standpipe volum	489 ft^3		standpipe height	60	ft	
Area =	8 ft^2					
I.D. =	39 in					
			Corrosion depth	0.125	in	
thickness=	0.650 in					
shell wt. =	16,085 lbs					
heads wt. =	863 lbs					

total wt. 19,491 lbs (includes additional 15% for nozzles, manholes,etc.

Desulfurization Reactor

v (ft/sec) =	20	72000 ft/hr	coal gas in volume	1,130,000	cfh	H2S-CG
V (cfh) =	1,135,506		cg out volume	1,130,000	cfh	CLEAN-CG
Area =	15.77 ft^2			164,358	lb/hr	COLDSORB
I.D.	54.90 in			166,009	lb/hr	STNDPIPE
			regen sorbent flow	330,367	lb/hr	
			regen sorbent vol.	5,506	cfh	
thickness=	0.871 in		sorbent vol%	0.48%		
shell wt.=	51,023 lbs		Corrosion depth	0.125	in	
heads wt.=	2,334 lbs		reactor height	100	ft	

total wt. 61,361 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

			residence time	1	min	
volume -sorbent	2,767 ft^3					
Area =	28 ft^2		standpipe height	100	ft	
I.D. =	71 in					
			Corrosion depth	0.125	in	
thickness=	1.093 in					
shell wt. =	83,058 lbs					
heads wt. =	4,930 lbs					

total wt. 101,186 lbs (includes additional 15% for nozzles, manholes,etc.

Three Stage Regenerator

			number of reactors	2		
I.D. =	13.01 ft		standpipe height	45	ft	
I.D. =	156 in					
thickness=	2.247 in					
shell wt. =	168,516 lbs		Corrosion depth	0.125	in	
heads wt. =	48,735 lbs					

total wt. 260,701 lbs (includes additional 20% for cyclones, nozzles, manholes,etc.

total wt. 383,793 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.303 $/lb	1990 $	1.30330926	1.01	
	1.393 $/lb	1996 $		<100,000 lb calc	

Cost of installation $1,068,941

Total reactor cost **$2,939,588** includes cost of installation

SO2 Regenerator Sizing - Commercial Embodiment

Givens:	Revised (SO2 Regen) Case E-2
Sorbent circulation rate, lb/h	166010
Sorbent bulk density, lb/ft3	62.4
Req'd rxtr residence time, h	1
Regen Gas v_{super}, cm/sec	2.5
Desired H/D	2
Adjusted values:	
Assumed Bed Depth, ft	10
SO2 needed ft3/hr	79812.5

Calculated values:	
Hold-up volume, ft3	2660.41667
Diameter, ft	18.4047564
X-section area, ft2	266.041667
Calculated H/D	0.54333781
RG Vol. flow rate, acf/sec	21.8210028
RG flow rate, lb/hr	86366.3549
Ratio of RG flow/sorbent, lb/lb	0.52024791
Calculated Bed Depth, ft	

Operating conditions/Gas Density Calc'ns:	
Pressure, psig	275
Pressure, psia	289.7
MW of gas	64
Bed Temp., C	600
Bed Temp., R	1571.67
R, gas constant,	10.73
Gas density, lb/ft3	1.099429

Desulf and Regen transport reactor price calculation

AHGP

N2 lift

v (ft/sec) =	50	180000 ft/hr	N2 in volume	91,631	cfh	N2SOURCE
V (cfh) =	141,578		N2 out volume	175,069	cfh	N2EXIT
Area =	0.787 ft^2		regen sorbent flow	493,650	lb/hr	FEO-ZNO
I.D.	12.260 in		regen sorbent vol.	8,228	cfh	
			sorbent vol%	5.81%		
thickness=	0.292					
shell wt.=	3,815 lbs		Corrosion depth	0.125	in	
heads wt.=	39 lbs		reactor height	100	ft	

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caculated or constant values
inputed variables

total wt. 4,432 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

			residence time	10	min	
volume -sorbent		1371 ft^3				
			heat removal	49,966,040	BTU/hr	RGENSTND
Heat Exchanger Area		3,462 ft^2	heat exchanger pipe thickness	0.25	in	
length of pipe		8,817 ft	heat exchanger pipe I.D.	1	in	
volume -heat exchanger		108 ft^3				
necessary standpipe volum		1,479 ft^3	standpipe height	60	ft	
Area =	24.7 ft^2					
I.D. =	67.2 in					
			Corrosion depth	0.125	in	
thickness=	1.039 in					
shell wt. =	44,713 lbs					
heads wt. =	4,176 lbs					

total wt. 56,222 lbs (includes additional 15% for nozzles, manholes,etc.

Desulfurization Reactor

v (ft/sec) =	20	72000 ft/hr	coal gas in volume	1,160,000	cfh	H2S-CG
V (cfh) =	1,176,539		cg out volume	1,160,000	cfh	CLEAN-CG
Area =	16.341 ft^2			493,650	lb/hr	COLDSORB
I.D.	55.881 in			498,670	lb/hr	STANDPIP
			regen sorbent flow	992,320	lb/hr	
			regen sorbent vol.	16,539	cfh	
thickness=	0.884 in		sorbent vol%	1.41%		
shell wt.=	52,734 lbs		Corrosion depth	0.125	in	
heads wt.=	2,456 lbs		reactor height	100	ft	

total wt. 63,468 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

			residence time	1	min	
volume -sorbent		8,311 ft^3				
Area =	83 ft^2		standpipe height	100	ft	
I.D. =	123 in					
			Corrosion depth	0.125	in	
thickness=	1.803 in					
shell wt. =	237,425 lbs					
heads wt. =	24,424 lbs					

total wt. 301,127 lbs (includes additional 15% for nozzles, manholes,etc.

Three Stage Regenerators

		number of reactors	6		
I.D. =	12.99 ft	standpipe height	45	ft	
I.D. =	156 in				
thickness=	2.243 in				
shell wt. =	167,848 lbs	Corrosion depth	0.125	in	
heads wt. =	48,443 lbs				

total wt. 1,557,295 lbs (includes additional 20% for cyclones, nozzles, manholes,etc.

total wt. 1,919,076 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.090 $/lb	1990 $	1.09039137	0.585	
	1.165 $/lb	1996 $		<100,000 lb calc	

Cost of installation $4,471,817

Total reactor cost **$12,297,497** includes cost of installation

SO2 Regenerator Sizing - Commercial Embodiment

AHGP-b
(SO2 Regen)

Givens:	**Case E-2**
Sorbent circulation rate, lb/l	496000
Sorbent bulk density, lb/ft3	62.4
Req'd rxtr residence time, h	1
Regen Gas v_{super}, cm/sec	2.5
Desired H/D	2
Adjusted values:	
Assumed Bed Depth, ft	10
SO2 needed ft3/hr	238461.5385

Calculated values:	
Hold-up volume, ft3	7948.71795
Diameter, ft	31.8129385
X-section area, ft2	794.871795
Calculated H/D	0.31433751
RG Vol. flow rate, acf/sec	65.1961774
RG flow rate, lb/hr	258042.961
Ratio of RG flow/sorbent, lb/lb	0.52024791
Calculated Bed Depth, ft	

Operating conditions/Gas Density Calc'ns:	
Pressure, psig	275
Pressure, psia	289.7
MW of gas	64
Bed Temp., C	600
Bed Temp., R	1571.67
R, gas constant,	10.73
Gas density, lb/ft3	1.099429

AHGP-c
Desulf and Regen transport reactor price calculation

AHGP

N2 lift

v (ft/sec) =	50	180000 ft/hr	N2 in volume	8,552	cfh	N2SOURCE
V (cfh) =	13,240		N2 out volume	16,326	cfh	N2EXIT
Area =	0.074 ft^2		regen sorbent flow	48,050	lb/hr	FEO-ZNO
I.D. =	3.749 in		regen sorbent vol.	801	cfh	
			sorbent vol%	6.05%		
thickness=	0.176					
shell wt.=	704 lbs		Corrosion depth	0.125	in	
heads wt.=	2 lbs		reactor height	100	ft	

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caculated or constant values
inputed variables

total wt. 812 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

			residence time	10	min	
volume -sorbent	133 ft^3					
			heat removal	48,050	BTU/hr	RGENSTND
Heat Exchanger Area	3.25 ft^2		heat exchanger pipe thickness	0.25	in	
length of pipe	8.27 ft		heat exchanger pipe I.D.	1	in	
volume -heat exchanger	0.10 ft^3					
necessary standpipe volume	134 ft^3		standpipe height	60	ft	
Area =	2.2 ft^2					
I.D. =	20.2 in					
			Corrosion depth	0.125	in	
thickness=	0.400 in					
shell wt. =	5,168 lbs					
heads wt. =	145 lbs					

total wt. 6,110 lbs (includes additional 15% for nozzles, manholes,etc.

Desulfurization Reactor

v (ft/sec) =	20	72000 ft/hr	coal gas in volume	1,120,000	cfh	H2S-CG
V (cfh) =	1,121,611		cg out volume	1,120,000	cfh	CLEAN-CG
Area =	15.58 ft^2			48,050	lb/hr	COLDSORB
I.D. =	54.56 in			48,626	lb/hr	STANDPIP
			regen sorbent flow	96,676	lb/hr	
			regen sorbent vol.	1,611	cfh	
thickness=	0.867 in		sorbent vol%	0.14%		
shell wt.=	50,444 lbs		Corrosion depth	0.125	in	
heads wt.=	2,294 lbs		reactor height	100	ft	

total wt. 60,648 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

		residence time	1	min	
volume -sorbent	810 ft^3				
Area =	8.10 ft^2	standpipe height	100	ft	
I.D. =	38.55 in				
		Corrosion depth	0.125	in	
thickness=	0.649 in				
shell wt. =	26,687 lbs				
heads wt. =	857 lbs				

total wt. 31,676 lbs (includes additional 15% for nozzles, manholes,etc.

Three Stage Regenerator

		number of reactors	1		
I.D. =	9.90 ft	standpipe height	45	ft	
I.D. =	119 in				
thickness=	1.739 in				
shell wt. =	99,156 lbs	Corrosion depth	0.125	in	
heads wt. =	21,807 lbs				

total wt. 145,156 lbs (includes additional 20% for cyclones, nozzles, manholes,etc.

total wt. 183,754 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.447 $/lb	1990 $	1.44706713	1.298	
	1.546 $/lb	1996 $		<100,000 lb calc	

Cost of installation $568,244

Total reactor cost **$1,562,672** includes cost of installation

SO2 Regenerator Sizing - Commercial Embodiment

	AHGP-c (SO2 Regen)
Givens:	**Case E-2**
Sorbent circulation rate, lb/h	48000
Sorbent bulk density, lb/ft3	62.4
Req'd rxtr residence time, hr	1
Regen Gas v_{super}, cm/sec	2.5
Desired H/D	2
Adjusted values:	
Assumed Bed Depth, ft	10
SO2 needed ft3/hr	23077

Calculated values:	
Hold-up volume, ft3	769.23
Diameter, ft	9.90
X-section area, ft2	76.92
Calculated H/D	1.01
RG Vol. flow rate, acf/sec	6.31
RG flow rate, lb/hr	24971.90
Ratio of RG flow/sorbent, lb/lb	0.52
Calculated Bed Depth, ft	

Operating conditions/Gas Density Calc'ns:	
Pressure, psig	275
Pressure, psia	289.7
MW of gas	64
Bed Temp., C	600
Bed Temp., R	1571.67
R, gas constant,	10.73
Gas density, lb/ft3	1.10

AHGP-100

Desulf and Regen transport reactor price calculation (0.4211 the size of the AHGP case)

AHGP

N2 lift

v (ft/sec) =	50	180000 ft/hr	N2 in volume	18,007	cfh	N2SOURCE
V (cfh) =	26,964		N2 out volume	33,615	cfh	N2EXIT
Area =	0.150 ft^2		regen sorbent flow	69,211	lb/hr	FEO-ZNO
I.D.	5.350 in		regen sorbent vol.	1,154	cfh	
			sorbent vol%	4.28%		
thickness=	0.198					
shell wt.=	1,129 lbs		Corrosion depth	0.125	in	
heads wt.=	5 lbs		reactor height	100	ft	

key
caculated or constant values
inputed variables

total wt. 1,304 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

			residence time	10	min	
volume -sorbent		192 ft^3				
			heat removal	6,253,543	BTU/hr	RGENSTND
Heat Exchanger Area		433 ft^2	heat exchanger pipe thickness	0.25	in	
length of pipe		1,103 ft	heat exchanger pipe I.D.	1	in	
volume -heat exchanger		14 ft^3				
necessary standpipe volume		206 ft^3	standpipe height	60	ft	
Area =	3.43 ft^2					
I.D. =	25.08 in					
			Corrosion depth	0.125	in	
thickness=	0.466 in					
shell wt. =	7,478 lbs					
heads wt. =	260 lbs					

total wt. 8,899 lbs (includes additional 15% for nozzles, manholes,etc.

Desulfurization Reactor

			coal gas in volume	475,843	cfh	H2S-CG
v (ft/sec) =	20	72000 ft/hr	cg out volume	475,843	cfh	CLEAN-CG
V (cfh) =	478,162			69,211	lb/hr	COLDSORB
Area =	6.64 ft^2			69,906	lb/hr	STNDPIPE
I.D.	35.62 in		regen sorbent flow	139,118	lb/hr	
			regen sorbent vol.	2,319	cfh	
thickness=	0.609 in		sorbent vol%	0.48%		
shell wt.=	23,154 lbs		Corrosion depth	0.125	in	
heads wt.=	687 lbs		reactor height	100	ft	

total wt. 27,418 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

		residence time	1	min	
volume -sorbent	1,165 ft^3				
Area =	11.7 ft^2	standpipe height	100	ft	
I.D. =	46.2 in				
		Corrosion depth	0.125	in	
thickness=	0.753 in				
shell wt. =	37,140 lbs				
heads wt. =	1,430 lbs				

total wt. 44,356 lbs (includes additional 15% for nozzles, manholes,etc.

Three Stage Regenerators

		number of reactors	1		
I.D. =	11.94 ft	standpipe height	45	ft	
I.D. =	143 in				
thickness=	2.073 in				
shell wt. =	142,638 lbs	Corrosion depth	0.125	in	
heads wt. =	37,858 lbs				

total wt. 216,595 lbs (includes additional 20% for cyclones, nozzles, manholes,etc.

total wt. 271,154 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.367 $/lb	1990 $	1.36665221	1.137	
	1.460 $/lb	1996 $		<100,000 lb calc	

Cost of installation $791,924

Total reactor cost **$2,177,791** includes cost of installation

SO2 Regenerator Sizing - Commercial Embodiment

AHGP-100
(SO2 Regen)

Givens:	**Case E-2**
Sorbent circulation rate, lb/h	69910
Sorbent bulk density, lb/ft3	62.4
Req'd rxtr residence time, hr	1
Regen Gas v_{super}, cm/sec	2.5
Desired H/D	2

Adjusted values:

Assumed Bed Depth, ft	10.00
SO2 needed ft3/hr	33611

Calculated values:	
Hold-up volume, ft3	1,120.35
Diameter, ft	11.94
X-section area, ft2	112.04
Calculated H/D	0.84
RG Vol. flow rate, acf/sec	9.19
RG flow rate, lb/hr	36,370.53
Ratio of RG flow/sorbent, lb/lb	0.520
Calculated Bed Depth, ft	

Operating conditions/Gas Density Calc'ns:	
Pressure, psig	275
Pressure, psia	289.7
MW of gas	64
Bed Temp., C	600
Bed Temp., R	1571.67
R, gas constant,	10.73
Gas density, lb/ft3	1.099429

AHGP-500

Desulf and Regen transport reactor price calculation (2.1055 the size of the AHGP case)

AHGP

N2 lift

v (ft/sec) =	50	180000 ft/hr	N2 in volume	90,033	cfh	N2SOURCE
V (cfh) =	134,821		N2 out volume	168,074	cfh	N2EXIT
Area =	0.75 ft^2		regen sorbent flow	346,056	lb/hr	FEO-ZNO
I.D.	11.96 in		regen sorbent vol.	5,768	cfh	
			sorbent vol%	4.28%		
thickness=	0.287592409					
shell wt.=	3,671 lbs		Corrosion depth	0.125	in	
heads wt.=	37 lbs		reactor height	100	ft	

key
caculated or constant values
inputed variables

total wt. 4,264 lbs (includes additional 15% for nozzles, manholes, etc.)

Regenerator Standpipe

		residence time	10	min	
volume -sorbent	961 ft^3				
		heat removal	31,267,715	BTU/hr	RGENSTND
Heat Exchanger Area	2,167 ft^2	heat exchanger pipe thickness	0.25	in	
length of pipe	5,517 ft	heat exchanger pipe I.D.	1	in	
volume -heat exchanger	68 ft^3				
necessary standpipe volume	1,029 ft^3	standpipe height	60	ft	
Area =	17 ft^2				
I.D. =	56 in				
		Corrosion depth	0.125	in	
thickness=	0.887 in				
shell wt. =	31,844 lbs				
heads wt. =	2,480 lbs				

total wt. 39,472 lbs (includes additional 15% for nozzles, manholes,etc.

Desulfurization Reactor

			coal gas in volume	2,379,215	cfh	H2S-CG
v (ft/sec) =	20	72000 ft/hr	cg out volume	2,379,215	cfh	CLEAN-CG
V (cfh) =	2,390,808			346,056	lb/hr	COLDSORB
Area =	33.21 ft^2			349,532	lb/hr	STNDPIPE
I.D.	79.66 in		regen sorbent flow	695,588	lb/hr	
			regen sorbent vol.	11,593	cfh	
thickness=	1.208 in		sorbent vol%	0.48%		
shell wt.=	102,638 lbs		Corrosion depth	0.125	in	
heads wt.=	6,813 lbs		reactor height	100	ft	

total wt. 125,868 lbs (includes additional 15% for nozzles, manholes, etc.)

Desulfurization Standpipe

		residence time	1	min	
volume -sorbent	5,826 ft^3				
Area =	58 ft^2	standpipe height	100	ft	
I.D. =	103 in				
		Corrosion depth	0.125	in	
thickness=	1.530 in				
shell wt. =	168,662 lbs				
heads wt. =	14,526 lbs				

total wt. 210,666 lbs (includes additional 15% for nozzles, manholes,etc.

Three Stage Regenerators

		number of reactors	5		
I.D. =	11.94 ft	standpipe height	45	ft	
I.D. =	143 in				
thickness=	2.073 in				
shell wt. =	142,618 lbs	Corrosion depth	0.125	in	
heads wt. =	37,850 lbs				

total wt. 1,082,809 lbs (includes additional 20% for cyclones, nozzles, manholes,etc.

total wt. 1,337,211 lbs weight for desulfurization and regeneration transport reactors

COST

				>100,000 lb calc	
C.S. unit price for quantiy needed	1.129 $/lb	1990 $	1.12859015	0.661	
	1.206 $/lb	1996 $		<100,000 lb calc	

Cost of installation $3,225,118

Total reactor cost **$8,869,074** includes cost of installation

SO2 Regenerator Sizing - Commercial Embodiment

	AHGP-500 (SO2 Regen) Case E-2	Calculated values:		Operating conditions/Gas Density Calc'ns:	
Givens:		Hold-up volume, ft3	5,600.96	Pressure, psig	275
		Diameter, ft	26.70	Pressure, psia	289.7
Sorbent circulation rate, lb/h	349500	X-section area, ft2	560.10	MW of gas	64
Sorbent bulk density, lb/ft3	62.4	Calculated H/D	0.37	Bed Temp., C	600
Req'd rxtr residence time, hr	1	RG Vol. flow rate, acf/sec	45.94	Bed Temp., R	1571.67
Regen Gas v_{super}, cm/sec	2.5	RG flow rate, lb/hr	181,826.64	R, gas constant,	10.73
Desired H/D	2	Ratio of RG flow/sorbent, lb/lb	0.520	Gas density, lb/ft3	1.099429
		Calculated Bed Depth, ft			
Adjusted values:					
Assumed Bed Depth, ft	10.00				
SO2 needed ft3/hr	168,029				

Appendix J
Power Generation Achievable from Clean Coal Gas

Two sources where used in determining the power generated by the clean coal gas. The Sierra power generating facility was used as the basis for determining the power generating capacity coal gas.

Sierra Clean Coal Gas Feed		
H_2 (lbmole/hr)	CO (lbmole/hr)	Power Generation (MW)
5760	7570	260

The individual contribution of the H_2 and CO where determined assuming there relative contribution was consistent with their standard heats of combustion.

Standard heat of combustion (Felled & Rousseau):
ΔH°_{comb} (H_2) = -3.605E-2 MW hr/ lbmole ΔH°_{comb} (CO) = -3.569E-2 MW hr/ lbmole

Power generation can be expressed:

$$E\,[5760\,\Delta H_C\,(H_2) + 7570\,\Delta H_C\,(CO)] = 260\ MW$$

where:

E = Efficiency of power generation

assuming:

ΔH_C (CO) = 0.99 ΔH_C (H_2)

and substituting gives:

$$13{,}254\ E\ \Delta H_C(H_2) = 260\ MW$$

$$E\ \Delta H_C(H_2) = 0.0196\ MW\ hr\ /\ lbmole$$

therefore

$$E\ \Delta H_C(CO) = 0.0194\ MW\ hr\ /\ lbmole$$

The values calculated above can be used to write a power generation expression.

Power Generation {MW} = 0.0196 (H_2 {lbmoles/hr}) + 0.0194 (CO {lbmoles/hr})

The plants power generation is determined by inserting the clean coal gas flows for H_2 and CO into the above equation. HGD coal gas consumption is assessed as a debit equivalent to the cost of the lost power generation. The power generation lost is determined by inserting the difference in the dirty coal gas and clean coal gas molar flow rates into the above equation. The cost of the electricity is taken as $0.04 per kWh. The plant has been assumed to be in operation 90% of the year.

Summary of Power Generation Calculations

simulation	H_2 clean	H_2 in	CO clean	CO in	MW made	MW lost
DSRP	11,444.58	11,765.37	212,200.52	218,162.00	258.25	7.248
DSRP-b	11,450.19	12,468.32	212,276.67	231,196.50	258.35	23.003
DSRP-c	11,443.82	11,535.37	212,195.77	213,897.17	258.24	2.069
DSRP-100	4,819.31	4,954.40	89,357.59	91,868.05	108.75	3.052
DSRP-500	24,110.94	24,772.09	447,055.34	459,341.97	544.06	14.938
AHGP	11,355.75	11,510.68	213,439.25	213,439.25	258.24	1.506
AHGP-b	11,175.21	11,646.28	215,953.67	215,953.67	258.23	4.580
AHGP-c	11,419.66	11,464.48	212,582.61	212,582.61	258.27	0.436
AHGP-100	4,781.91	4,847.15	89,879.27	89,879.27	108.74	0.634
AHGP-500	23,909.53	24,235.73	449,396.34	449,396.34	543.72	3.172

Appendix K
Calculation of Reactor Pressure Drops

Pressure drops for transport reactors have been calculated assuming the pressure drops are related to the energy required to lift the sorbent / catalyst to the top of the reactor.

Energy balance for lifting solid to top of reactor:

$$\Delta E_{PART} = \Delta E_{GAS}$$

$$m_{PART} (g / g_C) h = \Delta P \, m_{GAS} / \rho_{GAS}$$

$$\Delta P = m_{PART} (g / g_C) h \, \rho_{GAS} / m_{GAS}$$

$$\Delta P_{REACTOR} = 1.5 \text{ (Energy to lift particle)}$$

DSRP Regeneration Reactor

$$\Delta P = 1.5 \, m_{PART} (g / g_C) h \, \rho_{GAS} / m_{GAS}$$

m_{PART} = sorbent mass flow, ZNS2RGEN & ZNO average

$(g / g_C) = 1$ lb_f/lb_m

h = reactor height, defined in Appendix H

ρ_{GAS} = gas density, HP-O2-N2 & ROG average

m_{GAS} = gas mass flow, HP-O2-N2 & ROG average

DSRP Regeneration Reactor (DSRP)

$$\Delta P = 1.5 \, (250{,}000 \text{ } lb_m/hr) \, (1 \text{ } lb_f/lb_m) \, (100 \text{ ft}) \, (0.5 \text{ } lb_m/ft^3) / (40{,}000 \text{ } lb_m/hr) \, (1 \text{ } ft^3 / 144 \text{ } in^2)$$

$$\Delta P = 3.32 \text{ psi}$$

DSRP Regeneration Reactor (DSRP-b)

$$\Delta P = 1.5 \, (1{,}200{,}000 \text{ } lb_m/hr) \, (1 \text{ } lb_f/lb_m) \, (100 \text{ ft}) \, (0.5 \text{ } lb_m/ft^3) / (130{,}000 \text{ } lb_m/hr) (1 \text{ } ft^3 / 144 \text{ } in^2)$$

$$\Delta P = 4.8 \text{ psi}$$

DSRP Regeneration Reactor (DSRP-c)

$$\Delta P = 1.5 \, (71{,}000 \text{ } lb_m/hr) \, (1 \text{ } lb_f/lb_m) \, (100 \text{ ft}) \, (0.5 \text{ } lb_m/ft^3) / (12{,}000 \text{ } lb_m/hr) (1 \text{ } ft^3 / 144 \text{ } in^2)$$

$$\Delta P = 3.2 \text{ psi}$$

DSRP Regeneration Reactor (DSRP-100) (DSRP-500)

same as base case $\Delta P = 3.3$ psi

DSRP Reactor

$$\Delta P = 1.5\ m_{PART}\ (g / g_C)\ h\ \rho_{GAS} / m_{GAS}$$

m_{PART} = catalyst mass flow, Appendix H

$(g / g_C) = 1\ lb_f/lb_m$

h = reactor height, defined in Appendix H

ρ_{GAS} = gas density, ROG-COOL & RXNPRD average

m_{GAS} = gas mass flow, RXNPRD

DSRP Reactor (DSRP)

$\Delta P = 1.5\ (300{,}000\ lb_m/hr)\ (1\ lb_f/lb_m)\ (100\ ft)\ (0.53\ lb_m/ft^3) / (55{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 3.0$ psi

DSRP Reactor (DSRP-b)

$\Delta P = 1.5\ (1{,}000{,}000\ lb_m/hr)(1\ lb_f/lb_m)\ (100\ ft)\ (0.53\ lb_m/ft^3) / (185{,}000\ lb_m/hr)(1\ ft^3/ 144\ in^2)$

$\Delta P = 3.0$ psi

DSRP Reactor (DSRP-c)

$\Delta P = 1.5\ (79{,}000\ lb_m/hr)(1\ lb_f/lb_m)\ (100\ ft)\ (0.55\ lb_m/ft^3) / (15{,}000\ lb_m/hr)(1\ ft^3/ 144\ in^2)$

$\Delta P = 3.0$ psi

DSRP Reactor (DSRP-100) (DSRP-500)

same as base case $\Delta P = 3.0$ psi

DSRP Desulfurization Reactor

$$\Delta P = 1.5\ m_{PART}\ (g / g_C)\ h\ \rho_{GAS} / m_{GAS}$$

m_{PART} = sorbent mass flow, ZNS

$(g / g_C) = 1\ lb_f/lb_m$

h = reactor height, defined in Appendix H

ρ_{GAS} = gas density, RAW-CG & CG-CALC average

m_{GAS} = gas mass flow, CG-CALC

DSRP Desulfurization Reactor (DSRP)

$\Delta P = 1.5\ (670{,}000\ lb_m/hr)\ (1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (510{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 0.6$ psi

DSRP Desulfurization Reactor (DSRP-b)

$\Delta P = 1.5\ (2{,}700{,}000\ lb_m/hr)(1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (660{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 1.6$ psi

DSRP Desulfurization Reactor (DSRP-c)

$\Delta P = 1.5\ (72{,}000\ lb_m/hr)(1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (460{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 0.06$ psi

DSRP Desulfurization Reactor (DSRP-100) (DSRP-500)

same as base case $\Delta P = 0.6$ psi

AHGP Desulfurization Reactor

$\Delta P = 1.5\ m_{PART}\ (g / g_C)\ h\ \rho_{GAS} / m_{GAS}$

m_{PART} = sorbent mass flow, STNDPIPE + COLDSORB

$(g / g_C) = 1\ lb_f/lb_m$

h = reactor height, defined in Appendix I

ρ_{GAS} = gas density, H2S-CG & CLEAN-CG average

m_{GAS} = gas mass flow, CLEAN-CG

AHGP Desulfurization Reactor (AHGP-100 and AHGP-500 results will be consistent)

$\Delta P = 1.5\ (330{,}000\ lb_m/hr)\ (1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (450{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 0.3$ psi

AHGP-b Desulfurization Reactor

$\Delta P = 1.5\ (990{,}000\ lb_m/hr)\ (1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (460{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 0.9$ psi

AHGP-c Desulfurization Reactor

$\Delta P = 1.5\ (97{,}000\ lb_m/hr)\ (1\ lb_f/lb_m)\ (100\ ft)\ (0.4\ lb_m/ft^3) / (440{,}000\ lb_m/hr)\ (1\ ft^3 / 144\ in^2)$

$\Delta P = 0.09$ psi

The pressure drop through the bubble bed regenerator is calculated as the sum of the static head in each stage times 1.3.

AHGP 3-Stage Regenerator Reactor

$$\Delta P = 1.3\ g/g_C\ (\rho\ h_{top\text{-}stage} + \rho\ h_{stage2} + \rho\ h_{bottom\text{-}stage})\ (1/144)$$

m_{PART} = sorbent mass flow, FES-ZNS

$(g / g_C) = 1\ lb_f/lb_m$

h = reactor stage height,

ρ_{GAS} = average of density of streams entering and exiting the reactor stage

AHGP 3-Stage Regenerator Reactors

$$\Delta P = 1.3\ (1\ lb_f/lb_m)\ [\ (3.66\ lb_m/ft^3)\ (5.0\ ft) + (3.20\ lb_m/ft^3)\ (10\ ft) + (3.40\ lb_m/ft^3)\ (2.5\ ft)]\ (\ 1\ ft^3 / 144\ in^2)$$

$$\Delta P = 0.5\ psi$$

Appendix L
Summary of the Process Pressure Drops

This appendix contains lists of the calculated pressure drops for the DSRP and AHGP at the various feed conditions.

DSRP pressure drops are used to determine the pressure rise needed from the RECYCOMP (sends tailgas to the Desulfurization reactor) and PRESAIR (pressurizes the air fed to the regenerator) Reactor pressure drops are calculated in Appendix H. Pressure drops in other equipment has been assigned without calculations.

Having streams enter the DSRP Reactor at the same pressure (bold pressures) was the starting point for the calculations.

DSRP (base case) & DSRP-100 & DSRP-500

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
PRESAIR	13.7 psia inlet P	278.9
pipe [P-02-N2]	0	278.9
AIR-HX (shell)	2.0	276.9
pipe [HP-O2-N2]	0	276.9
REGENERATOR	3.3	273.6
pipe [ROG]	0	273.6
AIR-HX (tube)	2.0	271.6
pipe [ROG-COOL]	0	**271.6**
DSRP	2.0	268.6
pipe [RXNPRD]	0	268.6
PD-COOLR	2.0	266.6
pipe [COOLPRD]	0	266.6
High Press. Cond.	2.0	264.6
pipe [TAILGAS]	0	264.6
VALVE	2.6	262.0
pipe [TAILGAS2]	0	262.0
RECYCOMP		275

Coal Gas Slipstream Pressure

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
Desulfurization Reactor	0.6	274.4
pipe [SLIPSTRM]	0	274.4
VALVE2	2.8	271.6
pipe [SLPSTRM]	0	**271.6**

DSRP-b

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
PRESAIR	13.7 psia inlet P	279.4
pipe [P-O2-N2]	0	279.4
AIR-HX (shell)	2.0	277.4
pipe [HP-O2-N2]	0	277.4
REGENERATOR	4.8	272.6
pipe [ROG]	0	272.6
AIR-HX (tube)	2.0	270.6
pipe [ROG-COOL]	0	**270.6**
DSRP	3.0	267.6
pipe [RXNPRD]	0	267.6
PD-COOLR	2.0	265.6
pipe [COOLPRD]	0	265.6
High Press. Cond.	2.0	263.6
pipe [TAILGAS]	0	263.6
VALVE	2.6	261.0
pipe [TAILGAS2]	0	261.0
RECYCOMP		275

Coal Gas Slipstream Pressure

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
Desulfurization Reactor	1.6	273.4
pipe [SLIPSTRM]	0	273.4
VALVE2	2.8	270.6
pipe [SLPSTRM]	0	**270.6**

DSRP-c

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
PRESAIR	13.7 psia inlet P	279.3
pipe [P-O2-N2]	0	279.3
AIR-HX (shell)	2.0	277.3
pipe [HP-O2-N2]	0	277.3
REGENERATOR	3.2	274.1
pipe [ROG]	0	274.1
AIR-HX (tube)	2.0	272.1
pipe [ROG-COOL]	0	**272.1**
DSRP	3.0	269.1
pipe [RXNPRD]	0	269.1
PD-COOLR	2.0	267.1
pipe [COOLPRD]	0	267.1
High Press. Cond.	2.0	265.1
pipe [TAILGAS]	0	265.1
VALVE	2.6	262.5
pipe [TAILGAS2]	0	262.5
RECYCOMP		275

DSRP-c

Coal Gas Slipstream Pressure

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
Desulfurization Reactor	0.06	274.9
pipe [SLIPSTRM]	0	274.9
VALVE2	2.8	272.1
pipe [SLPSTRM]	0	**272.1**

AHGP pressure drop calculations determine the required ΔP for the SO2-COMP, compressor. The pressure drop balance is done to insure the SO_2 loop with maintain desired pressure. The set pressure (bold) in the SO_2 loop is the pressure at the 3-Stage Regenerator exit. This pressure is set to equal the calculated exit pressure of the AHGP Desulfurization reactor (Appendix K).

AHGP (base case), & AHGP-100 & AHGP-500

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
3-Stage Regenerator	0.5 (Append. K)	**274.7**
pipe [COOLS2]	0	274.7
HEATX (tube)	2.0	272.7
pipe [S2V+L]	0	272.7
COND-EQ	2.0	270.7
pipe [IN-COND]	0	270.7
DEMISTR	5	265.7
pipe [UNP-RSO2]	0	265.7
SO2-COMP		279.2
pipe [RCYHEATR]	0	279.2
RCYHEATR	2.0	277.2
pipe [WARMRCY]	0	277.2
HEATX (shell)	2.0	275.2
pipe [FEEDRG1]	0	275.2 to 3-Stage Regenerator

AHGP-b

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
3-Stage Regenerator	0.5 (Append. K)	**274.1**
pipe [COOLS2]	0	274.1
HEATX (tube)	2.0	272.1
pipe [S2V+L]	0	272.1
COND-EQ	2.0	270.1
pipe [IN-COND]	0	270.1
DEMISTR	5	265.1
pipe [UNP-RSO2]	0	265.1
SO2-COMP		278.6
pipe [RCYHEATR]	0	278.6
RCYHEATR	2.0	276.6
pipe [WARMRCY]	0	276.6
HEATX (shell)	2.0	274.6
pipe [FEEDRG1]	0	274.6 to 3-Stage Regenerator

AHGP-c

Equipment	ΔP drop (psi)	P_{EXIT} (psia)
3-Stage Regenerator	0.5 (Append. K)	**274.9**
pipe [COOLS2]	0	274.9
HEATX (tube)	2.0	272.9
pipe [S2V+L]	0	272.9
COND-EQ	2.0	270.9
pipe [IN-COND]	0	270.9
DEMISTR	5	265.9
pipe [UNP-RSO2]	0	265.9
SO2-COMP		279.4
pipe [RCYHEATR]	0	279.4
RCYHEATR	2.0	277.4
pipe [WARMRCY]	0	277.4
HEATX (shell)	2.0	275.4
pipe [FEEDRG1]	0	275.4 to 3-Stage Regenerator

Appendix M
Summary of Major HGD Equipment

The following tables list equipment required for both HGD processes under various feed conditions. Equipment specifications are also listed in the tables.

DSRP - base Process Equipment Specifications

		DSRP	DSRP-b	DSRP-c	DSRP-100	DSRP-500
REACTORS						
Desulfurization reactor						
	height (ft)	100	100	100	100	100
	diameter (ft)	4.9	5.6	4.6	3.2	7.1
	weight (lbs)	70,000	90,000	63,000	31,000	140,000
Desulf. standpipe						
	height (ft)	100	100	100	100	100
	diameter (ft)	4.9	5.6	4.6	3.2	7.1
	weight (lbs)	70,000	90,000	63,000	31,000	140,000
Regeneration reactor						
	height (ft)	100	100	100	100	100
	diameter (ft)	1.3	2.3	0.66	0.82	1.8
	weight (lbs)	6,000	17,000	2,000	3,000	11,000
Regen. standpipe						
	height (ft)	100	100	100	100	100
	diameter (ft)	1.3	2.3	0.66	0.82	1.8
	weight (lbs)	6,000	17,000	2,000	3,000	11,000
DSRP Reactor						
	height (ft)	100	100	100	100	100
	diameter (ft)	3.8	7.0	2.0	2.5	5.4
	weight (lbs)	43,000	140,000	13,000	19,000	85,000
DSRP standpipe						
	height (ft)	40	40	40	40	40
	diameter (ft)	3.8	7.0	2.0	2.5	5.4
	weight (lbs)	27,000	89,000	8,000	12,000	540,000
COMPRESSORS						
PRESAIR						
	acfh	570,000	1,800,000	160,000	240,000	1,200,000
	Pin (psia)	13.7	13.7	13.7	13.7	13.7
	Pout (psia)	278.9	279.4	279.3	278.9	278.9
	power (hp)	3,300	10,000	900	1,400	6,900
	stages	6	6	6	6	6
RECOMP						
	acfh	49,000	170,000	14,000	21,000	100,000
	Pin (psia)	264.4	261	262.5	264.4	264.4
	Pout (psia)	275	275	275	275	275
	power (hp)	59	227	17	25	124
	stages	1	1	1	1	1
HEAT EXCHANGERS						
AIRHX						
	Duty (BTU/hr)	4,300,000	14,000,000	1,200,000	1,900,000	9,600,000
	Area (ft^2)	700	2,200	200	300	1,400
	tube mat.	SS 310	SS 310	SS 310	SS 310	SS 310
	shell mat.	SS 304	SS 304	SS 304	SS 304	SS 304
DSRP						
	Duty (BTU/hr)	15,000,000	51,000,000	4,000,000	6,500,000	31,000,000
	Area (ft^2)	1,000	3,600	280	450	2,200
	tube mat.	SS 310	SS 310	SS 310	SS 310	SS 310
PDCOOLR						
	Duty (BTU/hr)	5,200,000	17,000,000	1,400,000	2,200,000	11,000,000
	Area (ft^2)	1,000	3,200	300	300	2,000
	tube mat.	SS 310	SS 310	SS 310	SS 310	SS 310
	shell mat.	SS 310	SS 310	SS 310	SS 310	SS 310
MISC.						
High Pressure Condenser						
	Duty (BTU/hr)	10,500,000	35,100,000	2,940,000	4,320,000	21,600,000
	Material	SS 310	SS 310	SS 310	SS 310	SS 310
VAPORIZR						
	Duty (BTU/hr)	550,000	1,900,000	150,000	230,000	1,100,000
	Material	SS 310	SS 310	SS 310	SS 310	SS 310
Storage Tank						
	vol. (ft^3)	5,600	18,000	1,600	2,400	11,000
	Material	SS 310	SS 310	SS 310	SS 310	SS 310

EQPTSPEC.XLS

AHGP Process Equipment Specifications

	AHGP	AHGP - b	AHGP - c	AHGP - 100	AHGP -500
REACTORS					
Desulfurization reactor					
height (ft)	100	100	100	100	100
diameter (ft)	4.58	4.66	4.55	2.97	6.64
weight (lbs)	61,361	63,000	61,000	27,000	130,000
Desulf. standpipe					
height (ft)	100	100	100	100	100
diameter (ft)	5.92	10.25	3.21	3.85	8.58
weight (lbs)	100,000	300,000	32,000	44,000	210,000
Regeneration reactor					
# of reactors	2	6	1	1	5
height (ft)	45	45	45	45	45
diameter (ft)	13.0	13.0	0.8	11.9	11.9
weight (lbs)	260,000	1,600,000	150,000	270,000	1,000,000
Regen. standpipe & RGENSTAND					
height (ft)	60	60	60	60	60
diameter (ft)	3.25	5.6	1.68	2.1	4.7
weight (lbs)	19,000	56,000	6,100	8,900	39,000
Duty (BTU/hr)	15,000,000	50,000,000	48,000	6,300,000	31,000,000
N2 Lift					
height (ft)	100	100	100	100	100
diameter (ft)	0.69	1.02	0.31	0.45	1.00
weight (lbs)	2,400	4,400	800	1,300	4,300
COMPRESSORS					
CON-COMP					
acfh	1,500	4,400	400	600	3,200
Pin (psia)	15	15	15	15	15
Pout (psia)	279	279	279	279	279
power (hp)	8	26	2	3	17
stages	1	1	1	1	1
LIFTCOMP					
acfh	43,000	92,000	8,600	18,000	91,000
Pin (psia)	272	272	272	272	272
Pout (psia)	275	275	275	275	275
power (hp)	13	28	3	5	27
stages	1	1	1	1	1
SO2-COMP					
acfh	29,000	85,000	8,400	12,000	61,000
Pin (psia)	266	265	266	266	266
Pout (psia)	279	279	279	279	279
power (hp)	38	114	11	16	80
stages	1	1	1	1	1
HEAT EXCHANGERS					
N2-COOLR					
Duty (BTU/hr)	7,020,000	15,800,000	1,480,000	3,130,000	15,700,000
Area (ft^2)	1,100	2,600	210	470	2,300
tube mat.	SS 304	SS 304	SS 304	SS 304	SS 304
shell mat.	SS 304	SS 304	SS 304	SS 304	SS 304
HEATX					
Duty (BTU/hr)	5,100,000	15,000,000	1,500,000	2,100,000	11,000,000
Area (ft^2)	1,600	3,600	500	700	3,500
tube mat.	SS 310	SS 310	SS 310	SS 310	SS 310
shell mat.	SS 310	SS 310	SS 310	SS 310	SS 310
RCYHEATR					
Duty (BTU/hr)	2,530,000	6,070,000	697,000	1,070,000	5,330,000
Area (ft^2)	3,200	7,800	570	1,300	6,700
tube mat.	SS 310	SS 310	SS 310	SS 310	SS 310
shell mat.	SS 310	SS 310	SS 310	SS 310	SS 310
MISC.					
COND-EQ					
Duty (BTU/hr)	5,380,000	16,000,000	1,560,000	2,400,000	12,000,000
Material	SS 310	SS 310	SS 310	SS 310	SS 310
DEMISTR					
Duty (BTU/hr)	0	0	0	0	0
Material	SS 310	SS 310	SS 310	SS 310	SS 310
LP-COND					
vol. (ft^3)	30	100	10	10	70
Material	SS 310	SS 310	SS 310	SS 310	SS 310
Storage Tank					
vol. (ft^3)	5,600	18,000	1,600	2,400	11,000
Material	SS 310	SS 310	SS 310	SS 310	SS 310

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Appendix N
Summary of HGD Costs

The following pages are taken from an Excel spreadsheet containing the culmination of all costs and benefits for all simulated Hot Gas Desulfurization processes.

DSRP costs

Equipment -Sulfur side

Type	unit	DSRP Price	DSRP-b Price	DSRP-c Price	DSRP-100 Price	DSRP-500 Price	Mat. of Construction	Purchase date	Purchase price ref.	date of calculation
Heat Exchangers										
	AIRHX	$33,500	$71,500	$17,900	$19,400	$55,300	SS304 / SS310 tubes	June, 1996	aspen DAIRHX	1/22/98
	PDCOOLR	$63,400	$126,600	$25,200	$42,000	$90,400	SS310 (calc w SS316)	June, 1996	aspen	1/22/98
Tanks										
7 days	Sulfur Storage	$125,500	$205,400	$65,000	$80,000	$171,000	SS310 (calc w SS316)	June, 1996	aspen	11/6/97
Condenser										
	High Pressure	$40,400	$82,200	$18,500	$21,900	$59,600	SS310 (calc w SS316)	June, 1996	aspen	
Vaporiser										
	VAPORIZR	$16,100	$17,800	$15,900	$15,200	$16,700	SS310 (calc w SS316)	June, 1996	aspen	
Compressor										
	RECOMP	$52,900	$52,900	$52,900	$52,900	$52,900	Carbon Steel	June, 1996	aspen	
	PRESAIR	$844,000	$2,680,000	$241,000	$416,000	$1,740,000		1997 Ingesoll-Rand Centac Pricing		10/20/97
Reactors										
	Desulf & Regen	$1,328,000	$1,772,000	$1,169,000	$728,000	$2,434,000	SS310 (calc w SS316)	June, 1996 (w install)	P&T calc	10/7/97
	DSRP reactor	$812,129	$2,134,355	$367,075	$477,612	$1,394,800	SS310 (calc w SS316)	June, 1996 (w install)	P&T calc	10/16/97
Pipes										
	pipe lines									
	totals	$3,315,929	$7,142,755	$1,972,475	$1,853,012	$6,014,700				

Equipment -Steam side

Type	unit	DSRP Price	DSRP-b Price	DSRP-c Price	DSRP-100 Price	DSRP-500 Price	Mat. of Construction	date		Purchase price ref.
Heat Exchangers										
	LCOOLR	$7,600	$8,100	$0	$6,800	$7,600		June, 1996	aspen	11/26/97
	VCOOLR	$7,000	$8,400	$6,700	$6,800	$7,600		June, 1996	aspen	11/26/97
Pumps										
	PTOWR	$4,200	$8,000	$2,800	$3,200	$5,500		June, 1996	aspen	11/26/97
	PHOTH2O	$1,000	$3,500	$0	$400	$3,500		price quote from General Pumps		
	PSTEAM	$57,400	$75,100	$57,400	$57,400	$59,300		June, 1996	aspen	11/26/97
	totals	$77,200	$103,100	$66,900	$74,600	$83,500				

Expendatures

		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		11/26/97
Light & instruments									
kW	misc.	683	683	683	683	683	20% base case pump & compressor requirements		
TOTAL	kW	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								
Addtional 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			

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

DSRP costs

Equipment -Sulfur side

Type	unit	DSRP Price	DSRP-b Price	DSRP-c Price	DSRP-100 Price	DSRP-500 Price	Mat. of Construction	Purchase date	Purchase price ref.	date of calculation
Heat Exchangers										
	AIRHX	$33,500	$71,500	$17,900	$19,400	$55,300	SS304 / SS310 tubes	June, 1996	aspen DAIRHX	1/22/98
	PDCOOLR	$63,400	$126,600	$25,200	$42,000	$90,400	SS310 (calc w SS316)	June, 1996	aspen	1/22/98
Tanks										
7 days	Sulfur Storage	$125,500	$205,400	$65,000	$80,000	$171,000	SS310 (calc w SS316)	June, 1996	aspen	11/6/97
Condenser										
	High Pressure	$40,400	$82,200	$18,500	$21,900	$59,600	SS310 (calc w SS316)	June, 1996	aspen	
Vaporiser										
	VAPORIZR	$16,100	$17,800	$15,900	$15,200	$16,700	SS310 (calc w SS316)	June, 1996	aspen	
Compressor										
	RECOMP	$52,900	$52,900	$52,900	$52,900	$52,900	Carbon Steel	June, 1996	aspen	
	PRESAIR	$844,000	$2,680,000	$241,000	$416,000	$1,740,000		1997 Ingesoll-Rand	Centac Pricing	10/20/97
Reactors										
	Desulf & Regen	$1,328,000	$1,772,000	$1,169,000	$728,000	$2,434,000	SS310 (calc w SS316)	June, 1996 (w install)	P&T calc	10/7/97
	DSRP reactor	$812,129	$2,134,355	$367,075	$477,612	$1,394,800	SS310 (calc w SS316)	June, 1996 (w install)	P&T calc	10/16/97
Pipes										
	pipe lines									
	totals	$3,315,929	$7,142,755	$1,972,475	$1,853,012	$6,014,700				

DSRP costs

Equipment -Steam side

Type	unit	DSRP Price	DSRP-b Price	DSRP-c Price	DSRP-100 Price	DSRP-500 Price	Mat. of Construction	date		Purchase price ref.
Heat Exchangers										
	LCOOLR	$7,600	$8,100	$0	$6,800	$7,600		June, 1996	aspen	11/26/97
	VCOOLR	$7,000	$8,400	$6,700	$6,800	$7,600		June, 1996	aspen	11/26/97
Pumps										
	PTOWR	$4,200	$8,000	$2,800	$3,200	$5,500		June, 1996	aspen	11/26/97
	PHOTH2O	$1,000	$3,500	$0	$400	$3,500		price quote from General Pumps		
	PSTEAM	$57,400	$75,100	$57,400	$57,400	$59,300		June, 1996	aspen	11/26/97
	totals	$77,200	$103,100	$66,900	$74,600	$83,500				