Intermountain Power Agency

DRAFT - Mass Balance Assumptions for Design Rate
17.5 wt% Pet Coke (4% S), 96.9% SO2 rem, 4 Absorbers

Red values are input variables, black are calculation results, & blue are copied from another cell.

Parameter		Generating Unit 1	Generating Unit 2	Notes & Reference
Generating unit				
Net Load	MW	830	830	
Annual Capacity Factor	%	94.0	94.0	
Net Heat Rate	Btu/kWh	9,515	9,515	
Fuel Burn Rate	lb/hr	645,899	645,899	
% Pet Coke Based on Wt Basis	%	17.5	17.5	
% Pet Coke Based on Btu Basis	%	20.0	20.0	
Coal/coke blend analysis				
Higher Heating Value	Btu/lb	12,227	12,227	
Ash Content	%	8.25	8.25	
Sulfur Content	%	1.15	1.15	
	lb SO_2/MBtu	1.87	1.87	
Chlorine	%	0.03	0.03	
Baghouse				
Fly Ash	% of total	80	80	
Baghouse Efficiency	%	99.95	99.95	
Fly Ash Removed in Baghouse	lb/hr	42,623	42,623	
HCl Collection Efficiency	%	50.0	50.0	
SO_2 Collection Efficiency	%	15.5	15.5	
FGD Inlet Gas				
Temperature	F	285	285	
Pressure	inwg	4.5	4.5	
Flow	acfm	2,729,849	2,729,849	
	lb/hr	7,595,060	7,595,060	
H_2O	lb/hr	350,818	350,818	
SO_2	lb/hr	12,504	12,504	764 ppm SO2
HCl	lb/hr	96	96	10 ppm HCl
Fly Ash	lb/hr	21	21	
FGD Outlet Gas				
Temperature	F	120	120	
Pressure	inwg	1.0	1.0	
Flow	acfm	2,295,092	2,295,092	
	lb/hr	7,926,313	7,926,313	
H_2O	lb/hr	649,753	649,753	
SO_2	lb/hr	392	392	392 lbSO2/hr is design basis
HCl	lb/hr	0	0	
Fly Ash	lb/hr	11	11	
FGD Makeup (Circ. Water Makeup)				
Inlet Quench Flow Rate	gal/min	0	0	
pH	units	7.00		
sp gr	-	1.00		
chlorides	mg/L	300		
DBA	mg/L	0		
NH_4OH reagent				
NH_4OH (aq)	wt %	28.0		
Balance (H_2O)	wt %	72.0		Circ Water Makeup
pH	units	9.96		
sp gr	-	0.90		
DBA				
DBA conc	% DBA	50		
solids	%wt	0		
pH	units	2.00		
sp gr	-	1.04		
chlorides	mg/L	0		
DBA	mg/L	520,000		
consumption	lb/ton SO_2 r	10.0		

	Coal	Pet coke	Blend
Wt%	82.5	17.5	100
S	0.54	4.00	1.15
Cl	0.033	0.01	0.03
Ash	9.94	0.30	8.25
Btu/lb	11,851	14,000	12,227

Note, when changing coke %S, also adjust FGD outlet lb SO2/Mbt

Coke %S	FF collection of SO2
0	32.0
3	18.3
3.5	16.9
4	15.5
4.5	14.5
5	13.5
5.5	12.7
6	12.0

Source: CT makeup

Ca	45 mg/L	SO4	200 mg/L
Mg	35 mg/L	CO3	30 mg/L
Na	200 mg/L	SiO2	6 mg/L
K	2 mg/L	F	1 mg/L

A	B	C	D	E	F	G	H	I	J	K	L	M
FGD System Design Parameters												
	Outlet SO_2	lb SO_2/MBtu	0.059	0.059			Adjust lb/MBtu to reach desired outlet lb SO2/hr in D40					
	SO_2 Removed	%	96.9	96.9	Total							
		lb/hr	12,112	12,112	24,223							
	Reagent Utilization	SO_2 r/NH_4	100.0%					DBA NSL	60.6 lb/hr			
	Sulfite Oxidation	%	100.0					DBA SL	58.1 lb/hr			
	$(NH_4)_2SO_4$ Concentration	%	30.0					total DBA	118.7 lb/hr			
		pH	5.00									
		spgr	1.16									
	HCl Removal	%	100	100								
		lb/hr	96	96	192							
	Fly Ash Removal	%	50	50								
		lb/hr	11	11	21							
	Chlorides	mg/L	1,559	1,559								
	DBA	mg/L	1,000									
	Oxidation Air	O/SO_2 r	3.00					9,084 lb O2/hr/unit at these conditions				
	Operating Modules	per unit	4	4				7,440 lb O2/hr/unit at 3%S, 3 O/SO2				
	Operating Spray Pumps	per module	3	3				2.46 O/SO2 (act) at 3%S, 3 O/SO2 design				
	Module Length/Width	ft	37									
	Module Area	sq ft	1,369									
	Absorber Pump Seal Water	gpm/pump	13.75		Circ Water							
Mist Eliminators (circ water)												
	ME Wash Total	gpm/module	144		Current usage							
	ME Wash Total	gpm/module	21		Proposed usage, using							
	1st stage ME bottom wash	gpm/sq ft	1.5		these wash parameters							
		min.cycl	1.00									
		cycle/hr	0.50									
	1st stage ME top wash	gpm/sq ft	0.5									
		min.cycl	1.00									
		cycle/hr	0.13									
	2nd stage ME bottom wash	gpm/sq ft	0.50									
		min.cycl	1.00									
		cycle/hr	0.13									
	2nd stage ME top wash	gpm/sq ft	0.50									
		min.cycl	1.00									
		cycle/hr	0.13									
Oxidation Air												
	Oxidation Air Quench	lb H_2O/lb air	0.050									
	Pressure	psia	28.7									
	Temperature	F	220									
	Humidity	lb/lb	0.0045		(60F, 40%RH)							
Evaporation/Crystallization												
Feed Stream (Units 1 & 2 combined)												
	$(NH_4)_2SO_4$ in Feed	wt %	30									
		lb/hr	49,969									
	NH_4Cl Impurity in Feed	wt %	0.169									
		lb/hr	282									
Crystallizer Underflow												
	Solids	wt%	75									
	pH	units	5.50									
	$(NH_4)_2SO_4$ spgr	-	1.77									
Crystallizer Overheads												
	Liquid carryover	ppm	100									
	pH	units	7.00									
	spgr	-	1.00									
	Liquid Carryover	ppm	100									
Centrifuge												
	Cake Solids	wt %	98									
	$(NH_4)_2SO_4$ spgr	-	1.77									
	Centrate Solids	wt %	1.0									
	Centrate purged	%	50									
Fluidized Bed Dryer												
	Product Moisture Content	wt %	0.1									
	Product spgr	--	1.77									

Intermountain Power Agency
DRAFT - Mass Balance
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	Flow No.	101	102	105	201	202	205	315
	Description	Unit 1 Inlet Flue Gas	Unit 1 Outlet Flue Gas	Unit 1 Oxidation Air	Unit 2 Inlet Flue Gas	Unit 2 Outlet Flue Gas	Unit 2 Oxidation Air	Total Oxidation Air
	Parameter							
8	Flow, acfm	2,729,849	2,295,092	6,328	2,729,849	2,295,092	6,328	12,655
9	Flow, lb/hr	7,595,060	7,926,313	39,415	7,595,060	7,926,313	39,415	78,830
10	H_2O, lb/hr	350,818	649,753	177	350,818	649,753	177	353
11	SO_2, lb/hr	12,504	392	0	12,504	392	0	0
12	HCl, lb/hr	96	0	0	96	0	0	0
13	Fly ash lb/hr	21	11	0	21	11	0	0
14	Oxygen, lb/hr	--	--	9,084	--	--	9,084	18,167
15	Temp, F	285	120	220	285	120	220	220
16	Pressure, inwg	4.5	1.0	388	4.5	1.0	388	388

gpm evap/unit
598

Unit 1 Data

	Flow No.	114	115	120	121	122	124	125	126	130
	Description	Unit 1 Ammonium Reagent	Unit 1 DBA Reagent	ME Wash (Return)	Oxid Air Quench (Circ H2O)	Pump Seals (Return)	Inlet Duct Quench (Circ H2O)	Absorber Makeup (Return)	Return Water to Unit 1	Unit 1 Absorber Bleed
	Parameter									
23	Flow, gpm	106	0.5	86	3.9	165	0	376	627	144
24	Flow, lb/hr	47,668	237	42,815	1,972	82,566	0	188,320	313,734	83,281
25	NH_4OH Conc., wt %	28	0	0	0	0	0	0	0	0
26	$(NH_4)_2SO_4$ Conc., wt %	0	0	0	0	0	0	0	0	30
27	pH	9.96	2.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00
28	Specific gravity	0.90	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.16
29	H_2O, lb/hr	34,301	119	42,815	1,972	82,566	0	188,270	313,652	58,145
30	NH_4OH, lb/hr	13,339	0	0	0	0	0	0	0	0
31	$(NH_4)_2SO_4$, lb/hr	0	0	0	0	1	0	3	4	24,984
32	NH_4Cl, lb/hr	0	0	0	0	0	0	0	0	141
33	Fly ash, lb/hr	0	0	0	0	0	0	0	0	11
34	Cl, lb/hr	12	0	11	1	20	0	47	78	91
35	Cl, ppm	360	0	248	300	248	300	248	248	1,559
36	DBA, lb/hr	0	119	0	0	0	0	0	0	58
37	DBA, ppm	0	520,000	0	0	0	0	0	0	1,000

Unit 2 Data

	Flow No.	214	215	220	221	222	224	225	226	230
	Description	Unit 2 Ammonium Reagent	Unit 2 DBA	ME Wash (Return)	Oxid Air Quench (Circ H2O)	Pump Seals (Return)	Inlet Duct Quench (Circ H2O)	Return Water Make-up	Return Water to Unit 2	Unit 2 Absorber Bleed
	Parameter									
44	Flow, gpm	106	0.5	86	3.9	165	0	376	627	144
45	Flow, lb/hr	47,668	237	42,815	1,972	82,566	0	188,320	313,734	83,281
46	NH_4OH Conc., wt %	28	0	0	0	0	0	0	0	0
47	$(NH_4)_2SO_4$ Conc., wt %	0	0	0	0	0	0	0	0	30
48	pH	9.96	2.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00
49	Specific gravity	0.90	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.16
50	H_2O, lb/hr	34,301	119	42,815	1,972	82,566	0	188,270	313,652	58,145
51	NH_4OH, lb/hr	13,339	0	0	0	0	0	0	0	0
52	$(NH_4)_2SO_4$, lb/hr	0	0	1	0	1	0	3	4	24,984
53	NH_4Cl, lb/hr	0	0	0	0	0	0	0	0	141
54	Fly ash, lb/hr	0	0	0	0	0	0	0	0	11
55	Cl, lb/hr	12	0	11	1	20	0	47	78	91
56	Cl, ppm	360	0	248	300	248	300	248	248	1,559
57	DBA, lb/hr	0	119	0	0	0	0	0	0	58
58	DBA, ppm	0	520,000	0	0	0	0	0	0	1,000

Common Support Equipment

	Parameter	Flow No. / Description	301 Total Ammonia	302 Circ Water to Ammonia Hydrolyzer	306 Total Ammonium Reagent	310 Total DBA	311 Total Circ Water to Absorbers	312 Circ Water to Thick. Oflow Tank	313 Total Return Water
65	Flow, gpm		40	165	212	0.9	8	1,035	1,254
66	Flow, lb/hr		12,958	82,322	95,280	475	3,945	518,094	627,468
67	NH_4OH Conc., wt %		100	0	28	0	0	0	0
68	$(NH_4)_2SO_4$ Conc., wt %		0	0	0	0	0	0	0
69	pH		NA	7.00	9.96	2.00	7.00	7.00	7.00
70	Specific gravity		0.64	1.00	0.90	1.04	1.00	1.00	1.00
71	H_2O, lb/hr		0	82,322	68,602	237	3,943	517,939	627,303
72	NH_4OH, lb/hr (NH_3)		(12,958)	0	26,678	0	0.0	0	0
73	$(NH_4)_2SO_4$, lb/hr		0	0	0	0	0.0	0	9
74	NH_4Cl, lb/hr		0	0	0	0	0.0	0	0
75	Fly ash, lb/hr		0	0	0	0	0.0	0	0
76	Cl, lb/hr		0	25	25	0	1	155	155
77	Cl, ppm		0	300	360	0	300	300	248
78	DBA, lb/hr		0	0	0	237	0.0	0	0
79	DBA, ppm		0	0	0	520,000	0	0	0

Crystallizer and Dryer System (NOTE, THIS SPREADSHEET HAS NOT BEEN COMPLETED)

	Parameter	Flow No. / Description	401 Crystallizer Feed	402 Crystallizer Overheads (vapor)	403 Crystallizer Overhead Condensate	404 Centrifuge Feed	410 Centrifuge Liquid Recycle	411 Centrifuge Liquid Purge	412 Centrifuge Solids Product	413 Dryer Solids Product	414 Dryer Exhaust Gas
86	Flow, gpm		288	NA	219	85	13	13	NA	NA	NA
87	Flow, lb/hr		166,860	109,374	109,374	64,131	6,461	6,461	51,208	50,234	974
88	NH_4OH Conc., wt %		0	0	0	0	0	0	0	0	0
89	$(NH_4)_2SO_4$ Conc., wt %		30	0.0	0	78	0.4	0.4	97.5	99.4	0.0
90	Solids Conc., wt %		0	0	0	75	1.0	1.0	98.0	99.9	0.1
91	pH		5.00	7.00	7.00	5.50	7.00	7.00	NA	NA	NA
92	Specific gravity		1.16	1.00	1.00	1.51	1.00	1.00	1.77	1.77	NA
93	H_2O, lb/hr		116,290	109,365	109,365	12,826	5,901	5,901	1,024	50.2	974
94	NH_4OH, lb/hr		0	0	0	0	0	0	0	0	0
95	$(NH_4)_2SO_4$, lb/hr		49,969	8.5	8.5	49,985	24.6	24.6	49,935	49,935	0
96	NH_4Cl, lb/hr		282	0.10	0.10	564	282	282	0	0	0
97	Fly ash, lb/hr		21	0.004	0.004	21	0.01	0.01	21	21	0
98	non-NH_4 Salts, lb/hr		--	0.03	0.03	184	0.1	0.1	183	183	0
99	Cl, lb/hr		181	0.1	0.1	336	154	154	27	27	0
100	Cl, ppm		1,559	0.5	0.5	26,165	26,165	26,165	26,165	26,165	0
101	DBA, lb/hr		116	0.04	0.04	215	99	99	17	17	0
102	DBA, ppm		1,000	0.3	0.3	16,787	16,787	16,787	16,787	16,787	16,787

Crystallizer and Dryer System Utilities

	Parameter	Flow No. / Description	501	502	503	504	505	506	507	508
109	Flow, gpm									
110	Flow, lb/hr									
111										
112										
113										
114										
115										
116										
117										
118										
119										
120										
121										
122										
123										
124										
125										

ACAPP

INPUT
H2O
NH4
SO4
Cl
Ca
Mg
Na
K
SiO2
CO3
F
Adipic
Succinic
Glutaric

OUTPUT
H2O
NH4
SO4
Cl
Ca
Mg
Na
K
SiO2
CO3
F
Adipic
(NH4)2SO4(s)
CaSO4-.5H2O(s)
CaSO4-2H2O(s)
NaCl(s)
MgSO4-H2O(s)
Na2SO4(s)
SiO2(s)
Adipic(s)
Total Solids
AS
non-AS Salts

AS Purity
wt% solids

acapp filename ipp8a

MW	Absorber Bleed (lb-mols)	Absorber Bleed (lb-mols) Adjusted for pH & pCO2	Absorber Bleed (mg/L)	Crys. Feed + Recycle (lb-mols)	Centrifuge Feed (lb-mols)	Dryer Solids (lb-mols)	Adjusted (to get ACAPP to run) Dryer Solids (lb-mols) 300 moles AS	ppm		Absorber Bleed lb/hr
18	6460.5510			6788.3842	712.5646	2.7865	13.0875		H2O	116,290
18	757.0999	765.59	118,502	757.4727	757.3435	756.5979	156.5979		NH4	13,781
96	379.8087		313,541	379.9951	379.9305	392.1453	92.1453		SO4	36,462
35.5	10.3794		3,169	20.0005	19.9971	0.7549	0.7549		Cl	368
40	0.6797		234	1.2588	0.6797	5.3623	5.3623		Ca	27
24.3	0.8703		182	1.6116	0.8703	7.0863	7.0863		Mg	21
23	5.2540		1,039	9.7295	5.2540	43.6866	52.9000		Na	121
39.1	0.0309		10	0.0572	0.0309				K	1.2
60.1	0.0603		31	0.1117	0.0603				SiO2	3.6
60	0.3021	0.185	95	0.5594	0.3021				CO3	11
19	0.0318		5	0.0589	0.0318				F	0.6
146	0.1593		200	0.2950					Adipic	23
118	0.2267		230	0.4198					Succinic	27
132	0.5022		570	0.9299					Glutaric	66

18	5146.1111		712.5646				
18	757.0999		207.7528	757.3435		756.5979	
96	379.8087		103.9131	379.9305		392.1453	
35.5	10.3794		20.0005	19.9971		0.7549	
40	0.6797		0.0366	0.6797		5.3623	
24.3	0.8703		1.6116	0.8703		7.0863	
23	5.2540		9.7295	5.2540		52.9000	
39.1	0.0309		0.0572				
60.1	0.0603		0.0064				
60	0.3021		0.5594				
19	0.0318		0.0589				
146	0.1593		0.2950				
132	0		274.8599				
145.1	0		1.2221				
172.1	0		0				
58.5	0		0				
138.4	0		0				
142	0		0				
60.1	0		0.1053				
146	0.0000		0				
lb/hr	0.00		36,465.16	0.00		0.00	
lb/hr	0.00		36,281.51	0.00		0.00	
lb/hr	0.00		183.65	0.00		0.00	

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
	0.0%			99.5%	0.0%		0.0%					
	0.00%			73.98%	0.00%		0.00%					

Overall FGD Water Balance
830 MW per unit, 2 units, 17.5 wt% Pet Coke (4% S), 96.9% SO2 rem, 4 Absorbers

Flue Gas Inlet Water =	1,402 gpm		Flue Gas Outlet Water =	2,597 gpm
Oxidation Air Humidity =	0.7 gpm		Dryer Exhaust Moisture =	2 gpm
Ammonia Aqua Converter =	165 gpm		Solids Product Moisture =	0.1 gpm
Total Circ Water =	1,043 gpm	D Syst	Crystallizer Purge =	12 gpm
DBA =	0.5 gpm	Both U		
Total Water In =	2,611 gpm		Total Water Out =	2,611 gpm
Difference =	0			

Overall FGD Water and Chloride Balance
830 MW per unit, 2 units, 17.5 wt% Pet Coke (4% S), 96.9% SO2 rem, 4 Absorbers

Flue Gas Inlet Water =	1,402 gpm		Flue Gas Outlet Water =	2,597 gpm
Cl =	187 lb/hr		Cl =	0 lb/hr
Oxidation Air Humidity =	0.7 gpm		Dryer Exhaust Moisture =	1.9 gpm
Cl =	0 lb/hr		Cl =	0 lb/hr
Ammonia Hydrolyzer Water =	165 gpm	D Syst	Solids Product Moisture =	0.1 gpm
Cl =	25 lb/hr		Cl =	27 lb/hr
Total Circ Water Makeup =	1,043 gpm	Both U		
Cl =	157 lb/hr			
DBA Water =	0.5 gpm			
Cl =	0 lb/hr			
Total Water In =	2,611 gpm		Total Water Out =	2,599 gpm
			Water Evaporated =	1195 gpm
Total Cl In =	368 lb/hr		Total Cl Out =	27 lb/hr

Absorber Module Water Balance
Proposed Ammonium Sulfate FGD Process
17.5 wt% Pet Coke (4% S), 96.9% SO2 rem, 4 Absorbers

Pump seals =	41 gpm	One Absorber Module	Evaporation =	149 gpm
Ammonia Feed =	21 gpm		Absorber Bleed =	29 gpm
M.E. wash =	21 gpm			
DBA =	0.1 gpm			
Ox air quench =	1 gpm			
Return water =	94 gpm			
Total Water In =	178 gpm		Total Water Out =	178 gpm

Water Mass Balance Around Unit 1 Absorber

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
101	350,818.4		
102		649,753.3	
105	176.6		
114	41,161.1		
115	118.7		
121	1971.7		
124	0.0		
126	313,651.7		
130		58,145.0	
Total	707,898.3	707,898.3	0.0

Chloride Mass Balance Around Unit 1 Absorbe

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
101	93.6		
102		0.0	
105	0.0		
114	12.3		
115	0.0		
121	0.6		
124	0.0		
126	77.7		
130		184.2	
Total	184.2	184.2	0.0

DBA Mass Balance Around Unit 1

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
115	118.7		
130		58.1	
Consumption		60.6	
Total	118.7	118.7	0.0

Water Mass Balance Around Station

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
101	350,818.4		
102		649,753.3	
201	350,818.4		
202		649,753.3	
302	82,322.1		
310	237.4		
311	3,943.4		
312	517,938.7		
315	353.1		
411		5,901.0	
413		50.2	
414		974.0	
Total	1,306,432	1,306,432	0.0

Chloride Mass Balance Around Station

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
101	93.6		
102		0	
201	93.6		
202		0	
302	24.7		
310	0.0		
311	1.2		
312	155.4		
315	0.0		
411		341.5	
413		26.8	
414		0.0	
Total	368.4	368.3	0.1

DBA Mass Balance Around Station

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
310	237.4		
411		99.1	
413		17.2	
Consumption		121.1	
Total	237.4	237.4	0.0

Water Mass Balance Around Crystallizer

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
401	116,289.9		
403		109,364.8	
411		5,901.0	
413		50.2	
414		974.0	
Total	116,289.9	116,289.9	0.0

Chloride Balance Around Crystallizer

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
401	181.2545		
403		0.1	
411		154.4	
412		26.8	
413		0.0	
Total	181.3	181.3	0.0

DBA Mass Balance Around Crystallizer

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
130	58.1		
230	58.1		
403		0.0	
411		99.1	
412		17.2	
413		0.0	
Total	116.3	116.3	0.0

Water Mass Balance Around Reagent

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
301	0.0		
302	82,322.1		
306		82,322.1	
Total	82,322.1	82,322.1	0.0

Chloride Mass Balance Around Reagent

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
301	0		
302	24.7		
306		24.7	
Total	24.7	24.7	0.0

DBA Mass Balance Around Reagent

Flow Number	In lb/hr	Out lb/hr	Difference lb/hr
301	0.0		
302	0.0		
306		0.0	
Total	0.0	0.0	0.0

Revisions

Date	Numbe	Revision
9/9/99	8	Misc mods to 'Mass Balance'
		Add impurities to crystallizer overheads in 'Mass Balance'
9/29/99	9	Vent ox air to atmosphere (was into flue gas)
		Change evaporation calc for NH3
		Add oxidation air piping sheet
10/15/99	10	3.0 O/SO2 ox air rate
10/26/99	11	Added input for fraction of HCl and SO2 collected in baghouse
		Used ACAPP results in crystallizer mass balance
		Changed unit heat rate, net MW
11/24/99	12	Changes to crystallizer mass balance & ACAPP inputs
		Auto calculate % of SO2 captured in baghouse