

Appendices

1. Recent Trends in control of Sulphur dioxide emission for the manufacture of sulphuric acid in India specially with Co-generation of Power, N G Ashar–Abu Dhabi 1995
2. Liquid Sulphur Dioxide Without Compression or Refrigeration, N G Ashar–Calgary 1999
3. Comparative Study of Techno-Economic Evaluation of the Production of Liquid Sulphur Dioxide, N G Ashar–Berlin 2012
4. Indian Standards of liquid SO₂
5. Indian Standards of liquid SO₃
6. References

See Tables [A.1](#) and [A.2](#).

Table A.1 MB and EB for sulphuric acid plant [Alt 1-(65 TPD Sulphuric Acid + 12 TPD liq. SO₃) Alt 2-80 TPD]

Alt-1 (65 TPD Sulphuric acid + 12 TPD liq. SO ₃)		Alt-2		Alt-3		Alt-4		Alt-5		Alt-6		Alt-7		Alt-8	
St. No.	1	LS-1	LS-2	LS-4	LS-5	LS-6	LS-8	LS-9	LS-11	LS-17	LS-19	LS-19	LS-19	LS-19	LS-11
St. No. as per PFD	LS-1	LS-2	LS-4	LS-5	LS-6	LS-6	LS-8	LS-9	LS-11	LS-17	LS-19	LS-19	LS-19	LS-19	LS-11
Location	Pump discharge APT-1	Pump discharge APT-1-PHE-1	PHE-1-IPAT	IPAT-APT-1	Pump discharge APT-1-PHE-2	Pump discharge APT-1-PHE-2	PHE-2-D.T.	D.T.-APT-1	PHE-2 out-APT-2						
Fluid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid						S. Acid
Concentration (%)	98.5	98.5	98.5	98.84	98.5	98.5	98.5	98.11	98.5						98.5
Flow rate (m ³ /h)	121.419	80	80	80.7	41.419	41.419	40	40.379	40.379						1.419
Flow rate (kg/h)	222197.846	146400	146400	148488.88	75797.846	75797.846	73200	73490.481	73490.481						2597.846
Sp. Gravity	1.83	1.83	1.83	1.84	1.83	1.83	1.83	1.82	1.83						1.83
Temp (°C)	86.5	86.5	75	94.49	86.5	86.5	65	69.66	65						65
Heat Capacity (kcal/kg °C)	0.364	0.364	0.364	0.364	0.364	0.364		0.363	0.364						0.364
Heat flow (kcal/h)	4569.721 × 10 ³	3010.862 × 10 ³	2398.032 × 10 ³	3485.681 × 10 ³	1558.858 × 10 ³	1558.858 × 10 ³	932.568 × 10 ³	1058.011 × 10 ³	33.096 × 10 ³						
Pressure (kg/cm ²)	3	3	1.8	By gravity	3	3	1.8	By gravity	2						2
St. No.	9	10	11	12	13	13	14	15	16						16
St. No. as per PFD	WS-2	LS-12	LS-13	LS-15	LS-16	LS-16	LS-17	LS-19	WS-3						WS-3
Location	Dilution Tank to APT-1	Pump Discharge APT-2	Pump Discharge APT-2 to PHE-3	PHE-3 to FAT	FAT to APT-2	FAT to APT-2	PHE-3 to PHE-4	PHE-4 out to Storages	Dilution Tank to APT-2						
Fluid	Water	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	Water						Water
Concentration (%)	-	98.5	98.5	98.5	98.5	98.5	98.5	98.5	-						-
Flow rate (m ³ /h)	0.509	41.509	41.509	40	40.072	40.072	1.5095	1.5095	0.03226						0.03226
Flow rate (kg/h)	508.966	75962.506	75962.506	73200	73332.4	73332.4	2762.506	2762.506	32.26						32.26
Sp. Gravity	1	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1						1
Temp (°C)	30	85.77	85.77	75	85.77	85.77	75	50	30						30
Heat Capacity (kcal/kg °C)	-	0.364	0.364	0.364	0.364	0.364	0.364	0.364	-						-
Heat flow (kcal/h)	-	1542.060 × 10 ³	1542.060 × 10 ³	1199.016 × 10 ³	954.808 × 10 ³	954.808 × 10 ³	45.250 × 10 ³	20.111	-						-
Pressure (kg/cm ²)	By gravity	3	3	1.8	By gravity	By gravity	2	1.8	By gravity						By gravity

Table A.1 (continued)

MB & EB– Sulphuric acid		Alt-2 (80 TPD Sulphuric Acid)							
St. No.	1	2	3	4	5	6	7	8	
St. No.as per PFD	LS-1	LS-2	LS-4	LS-5	LS-6	LS-8	LS-9	LS-11	
Location	Pump discharge APT-1	Pump discharge APT-1–PHE-1	PHE-1–IPAT	IPAT–APT-1	Pump discharge APT-1–PHE-2	PHE-2–D.T.	D.T.–APT-1	PHE-2 out–APT-2	
Fluid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	
Concentration (%)	98.5	98.5	98.5	98.92	98.5	98.5	98.11	98.5	
Flow rate (m ³ /h)	121.759	80	80	80.972	76419.673	40	40.379	1.759	
Flow rate (kg/h)	222819.673	146400	146400	148988.88	41.759	73200	73490.481	3219.673	
Sp. Gravity	1.83	1.83	1.83	1.84	1.83	1.83	1.82	1.83	
Temp (°C)	89.051	89.051	75	98.48	89.051	65	69.66	65	
Heat Capacity (kcal/kg °C)	0.364	0.364	0.364	0.364	0.364	0.364	0.363	0.364	
Heat flow (kcal/h)	4789.412 × 10 ³	3146.804 × 10 ³	2398.032 × 10 ³	3713.804 × 10 ³	1642.607 × 10 ³	932.568 × 10 ³	1058.011 × 10 ³	41.019 × 10 ³	
Pressure (kg/cm ²)	3	3	1.8	By gravity	3	1.8	By gravity	2	
St. No.	9	10	11	12	13	14	15	16	
St. No.as per PFD	WS-2	LS-12	LS-13	LS-15	LS-16	LS-17	LS-19	WS-3	
Location	Dilution Tank to APT-1	Pump Discharge APT-2	Pump Discharge APT-2 to PHE-3	PHE-3 to FAT	FAT to APT-2	PHE-3 to PHE-4	PHE-4 out to Storages	Dilution Tank to APT-2	
Fluid	Water	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	S. Acid	Water	
Concentration (%)	–	98.5	98.5	98.5	98.543	98.5	98.5	–	
Flow rate (m ³ /h)	0.6308	41.849	41.849	40	40.072	1.849	1.849	0.03226	
Flow rate (kg/h)	630.793	76584.333	76584.333	73200	73332.4	3384.333	3384.333	32.26	
Sp. Gravity	1	1.83	1.83	1.83	1.83	1.83	1.83	1	
Temp (°C)	30	85.77	85.77	75	85.77	75	50	30	
Heat Capacity (kcal/kg °C)	–	0.364	0.364	0.364	0.364	0.364	0.364	–	
Heat flow (kcal/h)	–	1554.683 X 10 ³	1554.683 X 10 ³	1199.016 X 10 ³	954.808 X 10 ³	55.435 X 10 ³	24.638 X 10 ³	–	
Pressure (kg/cm ²)	By gravity	3	3	1.8	By gravity	2	1.8	By gravity	

Table A.2 MB and EB for liquid SO₂ plant (15 TPD)

Sr. No.	Stream Nos.		1	2	3	4	5	6
	Description	DT-101 from storage tank of SAP						
	Component	Mol. wt						
1	Sulfuric acid 98.5 %	98	940 kg/month	470 kg/month	470 kg/month	2600 kg/each startup	2600 kg/each startup	4200 kg/48 h
2	Oleum 25 %	178	-	-	-	-	-	-
3	Liquid sulfur	32	-	-	-	-	-	-
4	Liquid sulfur-tri-oxide	80	-	-	-	-	-	-
5	Sulfur-di-oxide	64	-	-	-	-	-	-
6	Purge gas	-	-	-	-	-	-	-
7	Unreacted SO ₃	80	-	-	-	-	-	-
8	Sulfur lumps	32	-	-	-	-	-	-
9	Acid mist	98	-	-	-	-	-	-
10	Strong acid	98	-	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-	-
14	Moisture	-	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-	-
16	Hot water	-	-	-	-	-	-	-
17	Cooling water	-	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-	-
	Total		940 kg/month	470 kg/month	470 kg/month	2600 kg/each startup	2600 kg/each startup	4200 kg/48 h
	Transfer time (h)		0.5	0.5	0.5	0.75	0.75	2
	Liquid flow (m ³ /h)		1.022	0.5110	0.5110	1.864	1.864	1.2
	Gas flow (m ³ /h)		-	-	-	-	-	-
	Temperature (°C)		35	35	35	35	35	125
	Pressure (kg/cm ² g)		2.5	By gravity	By gravity	2.5	2.5	2.5
	Density (MT/m ³)		1.84	1.84	1.84	1.86	1.86	1.75

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	1 DT-101 from storage tank of SAP	2 DT-101-T-103	3 DT-101-T-104	4 DT-103 from storage tank of SAP	5 DT-103-R-101	6 DT-102 from sulphur pit of SAP
	Viscosity (Cp)	15.00	15.00	15.00	22.50	22.50	10.40
	Sp. Heat (Kcal/Kg °C)	0.37	0.37	0.37	0.33	0.33	0.97
	Phase	L	L	L	L	L	L
	Enthalpy Kcal/h	3478.888	1739.444	1739.444	5720.616	5720.616	193515
	Stream Nos.	7	8	9	10	11	12
Sr. No.	Description	DT-102 when feeding to R-101 is off	DT-102-R-101	T-101 A(B) from V-101 A(B)	T-101 A(B) when feeding to R-101 is off	T-101 A(B)-R-101	R-101-T-106
	Component	Mol. wt	-	-	-	-	-
1	Sulfuric acid 98.5 %	98	-	-	-	-	-
2	Oleum 25 %	178	-	-	-	-	-
3	Liquid sulfur	32	87.5 kg/h	-	-	-	-
4	Liquid sulfur-tri-oxide	80	-	3364 kg/8 h	420.5 kg/h	420.5 kg/h	-
5	Sulfur-di-oxide	64	-	-	-	-	-
6	Purge gas	-	-	-	-	-	-
7	Unreacted SO ₃	80	-	-	-	-	-
8	Sulfur lumps	32	-	-	-	-	-
9	Acid mist	98	-	-	-	-	-
10	Strong acid	98	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	2600 kg/each startup
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	7	8	9	10	11	12
14	Moisture						
15	Sulfur trioxide Gas	80					
16	Hot water						
17	Cooling water						
18	Steam						
	Total	87.5 kg/h	87.5 kg/h	3364 kg/8 h	420.5 kg/h	420.5 kg/h	2600 kg/each startup
	Transfer time (h)	87.5 kg/h	87.5 kg/h	2	Continuous	Continuous	1
	Liquid flow (m ³ /h)	0.05	0.05	0.876	0.219	0.219	1.398
	Gas flow (m ³ /h)						
	Temperature (°C)	125	125	35	35	35	40
	Pressure (kg/cm ² g)	1.5	7	By gravity	1.5	7	By gravity
	Density (MT/m ³)	1.75	1.75	1.92	1.92	1.92	1.86
	Viscosity (Cp)	10.40	10.40	1.50	1.50	1.50	18.00
	Sp. Heat (Kcal/K.g °C)	0.97	0.97	0.16	0.16	0.16	0.33
		L	L	L	L	L	L
	h	8063.125	8063.125	1345.536	336.4	336.4	8580.924
	Stream Nos.	13	14	15	16	17	18
Sr. No.	Description	R-101-PH-101	R-101-PLT-101 A	PLT-101 A From SAP	PLT-101 A-PH-101	PLT-101 A-PLT-101 B	PLT-101 B From SAP
	Component						
	Mol. wt						
1	Sulfuric acid 98.5 %						
2	Oleum 25 %						
3	Liquid sulfur						
4	Liquid sulfur-tri-oxide						

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	13	14	15	16	17	18
5	Sulfur-di-oxide	64	505.624 kg/h	-	-	507.248 kg/h	-
6	Purge gas	-	-	-	0.125 kg/h	-	-
7	Unreacted SO ₃	80	2.126 kg/h	-	-	0.699 kg/h	-
8	Sulfur lumps	32	-	210.24 kg/month	-	-	90 kg/month
9	Acid mist	98	-	-	-	-	-
10	Strong acid	98	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water	-	-	-	-	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-
	Total	0.250 kg/h/2 kg/8 h	507.75 kg/h	210.24 kg/month	0.125 kg/h (1 kg/8hrs)	507.947 kg/h	90 kg/month
	Transfer time (h)	5 s	Continuous	1	2.5 s	Continuous	1 h
	Liquid flow (m ³ /h)	-	-	Manually	-	-	Manually
	Gas flow (m ³ /h)	0.11	223.19	-	0.055	223.273	-
	Temperature (°C)	65	65	30	62	62	30
	Pressure (kg/cm ² g)	6	6	-	5.8	5.8	-
	Density (MT/m ³)	2.275 kg/m ³	2.275 kg/m ³	-	2.275 kg/m ³	2.275 kg/m ³	-
	Viscosity (Cp)	0.000849	0.0008490	-	0.000793	0.000793	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	13	14	15	16	17	18
	Sp. Heat (Kcal/Kg °C)	0.15	0.15	-	0.15	0.15	-
	Phase	G	G	S	G	G	S
	Enthalpy Kcal/h	1.3125	2665.6875	-	0.6	2438.1456	-
	Stream Nos.	19	20	21	22	23	24
Sr. No.	Description	PLT-101 B-PH-101	PLT-101 B-T-102	T-102-T-103	T-103-PH-101	T-103-T-107	T-103-T-104
	Component	-	-	-	-	-	-
	Mol. wt	-	-	-	-	-	-
1	Sulfuric acid 98.5 %	-	-	-	-	-	-
2	Oleum 25 %	-	-	-	-	-	-
3	Liquid sulfur	-	-	-	-	-	-
4	Liquid sulfur-tri-oxide	-	-	-	-	-	-
5	Sulfur-di-oxide	-	507.871 kg/h	507.871 kg/h	-	-	507.746 kg/h
6	Purge gas	0.125 kg/h	-	-	0.125 kg/h	-	-
7	Unreacted SO ₃	-	0.046 kg/h	0.046 kg/h	-	0.144 kg/month	0.0458 kg kg/h
8	Sulfur lumps	-	-	-	-	-	-
9	Acid mist	-	-	-	-	-	0.002 kg/h
10	Strong acid	-	-	-	-	470 kg/month	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	-	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	-	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	-	-	-	-	-	-
16	Hot water	-	-	-	-	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-

(continued)

Table A.2 (continued)

Stream Nos.	19	20	21	22	23	24
Sr. No.						
Description	PLT-101 B-PH-101	PLT-101 B-T-102	T-102-T-103	T-103-PH-101	T-103-T-107	T-103-T-104
Total	0.125 kg/h(1 kg/8 h)	507.917 kg/h	507.917 kg/h	0.125 kg/h(1 kg/8 h)	470.144 kg/month	507.7938 kg/h
Transfer time (h)	2.5 s	Continuous	Continuous	2.5 s	0.5	Continuous
Liquid flow (m ³ /h)	—	—	—	—	0.511	—
Gas flow (m ³ /h)	0.055	223.26	NEAT	0.055	—	223.206
Temperature (°C)	62	62	60	56	40	56
Pressure (kg/cm ² g)	5.6	5.6	5.5	5.3	By gravity	5.3
Density (MT/m ³)	2.275 kg/m ³	2.275 kg/m ³	2.275 kg/m ³	2.275 kg/m ³	1.84	2.275 kg/m ³
Viscosity (Cp)	0.000793	0.000793	0.000583	0.000583	14.00	0.000583
Sp. Heat (Kcal/Kg °C)	0.15	0.15	0.15	0.15	0.37	0.15
Phase	G	G	G	G	L	G
Enthalpy Kcal/h	0.6	2438.0016	1523.751	0.375	3478.888	1523.3814
Stream Nos.	25	26	27	28	29	30
Description	T-104-PH-101	T-104-T-107	T-104-ME-101 A	ME-101 A-T-103 or T-104	ME-101 A-ME-101 B	ME-101 B-T-103 or T-104
Component	Mol. wt	—	—	—	—	—
1	Sulfuric acid 98.5 %	—	—	—	—	—
2	Oleum 25 %	—	—	—	—	—
3	Liquid sulfur	—	—	—	—	—
4	Liquid sulfur-tri-oxide	—	—	—	—	—
5	Sulfur-di-oxide	—	—	—	—	—
6	Purge gas	—	507.621 kg/h	—	507.621 kg/h	—
7	Unreacted SO ₃	—	0.0457 kg/h	—	0.0457 kg/h	—
8	Sulfur lumps	—	—	—	—	—
9	Acid mist	—	0.005 kg/h	—	0.002 kg/h	0.007 kg/h
10	Strong acid	—	—	—	—	—

(continued)

Table A.2 (continued)

	Stream Nos.	25	26	27	28	29	30
Sr. No.	Description	T-104-PH-101	T-104-T-107	T-104-ME-101 A	ME-101 A-T-103 or T-104	ME-101 A-ME-101 B	ME-101 B-T-103 or T-104
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water						
17	Cooling water						
18	Steam						
	Total	0.125 kg/h(1 kg/8 h)	470.072 kg/month	507.6717	0.003 kg/h	507.6687 kg/h	0.007 kg/h
	Transfer time (h)	2.5 s	0.5	Continuous	-	Continuous	Continuous
	Liquid flow (m ³ /h)	-	0.511	-	0.0016	-	0.00376
	Gas flow (m ³ /h)	0.055	-	223.152	-	223.151	-
	Temperature (°C)	51	40	51	46	50	46
	Pressure (kg/cm ² g)	5.1	By gravity	5.1	5.1	4.9	4.9
	Density (MT/m ³)	2.275 kg/m ³	1.84	2.275 kg/m ³	1.86	2.275 kg/m ³	1.86
	Viscosity (Cp)	0.00055	14.00	0.00055	13.00	0.000534	13.00
	Sp. Heat (Kcal/Kg °C)	0.15	0.37	0.15	0.37	0.15	0.37
	Phase	G	L	G	L	G	L
	Enthalpy Kcal/h	0.3375	3478.888	1370.7136	0.01776	1294.555	0.03885
	Stream Nos.	31	32	33	34	35	36
Sr. No.	Description	ME-101 B-EX-102 A&B	EX-102 A&B-PH-101	EX-102 A&B-V-102 A(B)	V-102 A(B)-PH-101	V-102 A(B)-R-101	V-102 A(B)-EX-103 A& B
	Component	-	-	-	-	-	-
	Mol. wt	-	-	-	-	-	-
1	Sulfuric acid 98.5 %	-	-	-	-	-	-
2	Oleum 25 %	-	-	-	-	-	-
3	Liquid sulfur	-	-	-	-	-	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	31	32	33	34	35	36
4	Liquid sulfur-tri-oxide	ME-101 B-EX-102 A&B -	EX-102 A&B-PH-101 -	EX-102 A&B-V-102 A(B) -	V-102 A(B)-PH-101 -	V-102 A(B)-R-101 -	V-102 A(B)-EX-103 A& B -
5	Sulfur-di-oxide	507.621 kg/h	-	507.496 kg/h	-	-	507.371 kg/h
6	Purge gas	-	0.125 kg/h	-	0.125 kg/h	-	-
7	Unreacted SO ₃	0.0457 kg/h	-	0.0457 kg/h	-	109,728 kg/months	0.0203 kg/h
8	Sulfur lumps	32	-	-	-	-	-
9	Acid mist	0.0013 kg/h	-	0.0013 kg/h	-	-	0.0013 kg/h
10	Strong acid	98	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water	-	-	-	-	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-
	Total	507,668 kg/h	0.125 kg/h(1 kg/8 h)	507,543 kg/h	0.125 kg/h(1 kg/8 h)	109,728 kg/months	507,3926 kg/h
	Transfer time (h)	Continuous	2.5 s	Continuous	2.5 s	0.50	Continuous
	Liquid flow (m ³ /h)	-	-	354.925	-	0.1143	-
	Gas flow (m ³ /h)	223.151	0.055	-	0.055	-	222.03
	Temperature (°C)	47	47	36	45	36	45
	Pressure (kg/cm ²)	4.7	4.7	4.3	4.3	4.3	5
	Density (MT/m ³)	2,275 kg/m ³	2,275 kg/m ³	1.43	2,275 kg/m ³	1.92	2,275 kg/m ³

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos.	37	38	39	40	41	42
	Description	EX-103 A&B- PH-101	EX-103 A&B- V-103 A(B)	PH-101-4th bed of envir of SAP	PH-101-T-106	T-106-Phosphate Fritzer plant for sale	SC-101 from T-101 A(B), V-101A(B), EX-101 & T-106
16	Hot water						
17	Cooling water						
18	Steam						
	Total	0.125 kg/h(1 kg/8 h)	507.2676 kg/h	1.125 kg/h(9 kg/8 h)	Traces	2600 kg/each startup	6 kg/ day
	Transfer time (h)	2.5 s	Continuous	0.5	10 s/7 days	2	6 h
	Liquid flow (m ³ /h)	-	354.7325	-	-	0.699	-
	Gas flow (m ³ /h)	0.055	-	0.4945	-	-	-
	Temperature (°C)	45	36	55	40	40	49
	Pressure (kg/cm ² g)	5	4.3	3	5	2.5	ATM.
	Density (MT/m ³)	2.275 kg/m ³	1.43	2.275 kg/m ³	1.920	1.86	2.84 kg/m ³
	Viscosity (Cp)	0.000501	0.34 @ -10 °C and atm pressure	0.000669	1.20	22.00	0.90
	Sp. Heat (Kcal/Kg °C)	0.15	0.15	0.15	0.330	0.3	0.16
	Phase	G	L	G	L	L	G
	Enthalpy Kcal/h	0.28125	456.541	4.219	-	3900.000	3.04
	Stream Nos.	43	44	45	46	47	48
Sr. No.	Description	SC-101 From DT-101	SC-101-APT-2 of SAP	SC-102 from caustic 10 % NaOH lye storage	SC-102 from PH-101	SC-102-Storage of SAP SO ₂ scrubber	T-107-APT-2 of SAP
	Component						
	Mol. wt	-	-	-	-	-	-
1	Sulfuric acid 98.5 %	5778 kg/month	5818.5 kg/month	-	-	-	-
2	Oleum 25 %	-	-	-	-	-	-
3	Liquid sulfur	-	-	-	-	-	-
4	Liquid sulfur-tri-oxide	-	-	-	-	-	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos.	43	44	45	46	47	48
	Description	SC-101 From DT-101	SC-101-APT-2 of SAP	SC-102 from caustic 10 % NaOH lye storage	SC-102 from PH-101	SC-102-Storage of SAP SO ₂ scrubber	T-107-APT-2 of SAP
5	Sulfur-di-oxide	-	-	-	-	-	-
6	Purge gas	-	-	-	1.125 kg/h (11.25 kg/10 h)	-	-
7	Unreacted SO ₃	-	180 kg/month	-	-	-	-
8	Sulfur lumps	-	-	-	-	-	-
9	Acid mist	-	-	-	-	-	-
10	Strong acid	-	-	-	-	-	940.216 kg/month
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	-	-	2486.644 kg/10 h SAP stoppage	-	-	-
13	Na ₂ SO ₃ 15 %	-	-	-	-	2497.894 kg/10 h	-
14	Moisture	40.5 kg/month	-	-	-	-	-
15	Sulfur trioxide gas	-	-	-	-	-	-
16	Hot water	-	-	-	-	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-
	Total	5818.5 kg/month	5998.5 kg/month	2486.644 kg/10 h SAP stoppage	1.125 kg/h (11.25 kg/10 h)	2497.894 kg/10 h	940.216 kg/month
	Transfer time (h)	1	1	1	1h	1	4
	Liquid flow (m ³ /h)	3.16	3.26	2.24	-	NEAT	0.1277
	Gas flow (m ³ /h)	-	-	-	0.4945	-	-
	Temperature (°C)	40	40	40	45	40	40
	Pressure (kg/cm ² g)	2	2	1.5	2	1.5	2
	Density (MT/m ³)	1.84	1.84	1.112	2.275 kg/m ³	NEAT	1.84
	Viscosity (Cp)	14.00	14.00	1.21	0.000669	NEAT	14.00
	Sp. Heat (Kcal/Kg °C)	0.37	0.37	0.911	0.15	NEAT	0.37

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos. Description	43	44	45	46	47	48
	Phase	L	L	L	G	L	L
	Enthalpy Kcal/h	21517.35	22194.45	22653.327	4.21875	NEAT	869.7
	Stream Nos.	49	50	51	52	53	54
Sr. No.	Description	EX-101 from SAP	EX-101-V-101A/B	Hot Water from T-105-Jacket of R-101	Hot Water from Jacket of R-101-T-105	Hot Water from T-105-Jacket of T-102	Hot Water from Jacket of T-102-T-105
	Component	-	-	-	-	-	-
	Mol. wt	-	-	-	-	-	-
1	Sulfuric acid 98.5 %	98	-	-	-	-	-
2	Oleum 25 %	178	-	-	-	-	-
3	Liquid sulfur	32	-	-	-	-	-
4	Liquid sulfur-tri-oxide	80	-	-	-	-	-
5	Sulfur-di-oxide	64	-	-	-	-	-
6	Purge gas	-	-	-	-	-	-
7	Unreacted SO ₃	80	-	-	-	-	-
8	Sulfur lumps	32	-	-	-	-	-
9	Acid mist	98	-	-	-	-	-
10	Strong acid	98	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	500 kg/h	50 m ³ /h	50 m ³ /h	16.667 m ³ /h	16.667 m ³ /h
16	Hot water	500 kg/h	500 kg/h	500 kg/h	500 kg/h	500 kg/h	500 kg/h
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-
	Total	500 kg/h	500 kg/h	500 kg/h	500 kg/h	16.667 m ³ /h	16.667 m ³ /h

(continued)

Table A.2 (continued)

Stream Nos.	49	50	51	52	53	54
Description	EX-101 from SAP	EX-101-V-101A/B	Hot Water from T-105-Jacket of R-101	Hot Water from Jacket of R-101-T-105	Hot Water from T-105-Jacket of T-102	Hot Water from Jacket of T-102-T-105
Transfer time (h)	Continuous	Continuous	1 h	1 h	Continuous	Continuous
Liquid flow (m ³ /h)	-	-	50	50	16.667 m ³ /h	16.667
Gas flow (m ³ /h)	176.056	176.056	-	-	-	-
Temperature (°C)	90	44	80	79.5	80	79.998
Pressure (kg/cm ² g)	0.5	By Gravity	2.5	2.2	2.5	2.3
Density (MT/m ³)	2.84 kg/m ³	2.84 kg/m ³	1	1	1	1
Viscosity (Cp)	0.43	1.50	0.28	0.28	0.28	0.28
Sp. Heat (Kcal/Kg °C)	0.16	0.16	1	1	1	1
Phase	G	L	Liquid	Liquid	Liquid	Liquid
Enthalpy Kcal/h	4800	1120	2500000	2475000	833350	833316.666
Stream Nos.	55	56	57	58	59	60
Description	Hot Water from T-105-Jacket of T-103	Hot Water from Jacket of T-103-T-105	Hot Water from T-105-Jacket of T-104	Hot Water from Jacket of T-104-T-105	Steam from Main header-T-105	Steam from Main header-T-108
Component	-	-	-	-	-	-
Mol. wt	-	-	-	-	-	-
1 Sulfuric acid 98.5 %	98	-	-	-	-	-
2 Oleum 25 %	178	-	-	-	-	-
3 Liquid sulfur	32	-	-	-	-	-
4 Liquid sulfur-tri-oxide	80	-	-	-	-	-
5 Sulfur-di-oxide	64	-	-	-	-	-
6 Purge gas	-	-	-	-	-	-
7 Unreacted SO ₃	80	-	-	-	-	-
8 Sulfur lumps	32	-	-	-	-	-
9 Acid mist	98	-	-	-	-	-
10 Strong acid	98	-	-	-	-	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos.	55	56	57	58	59	60
	Description	Hot Water from T-105-Jacket of T-103	Hot Water from Jacket of T-103-T-105	Hot Water from T-105-Jacket of T-104	Hot Water from Jacket of T-104-T-105	Steam from Main header-T-105	Steam from Main header-T-108
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water	16.667 m ³ /h	16.667 m ³ /h	16.667 m ³ /h	16.667 m ³ /h	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	36.419 kg/h	116.104 kg/h
	Total	16.667 m ³ /h	16.667 m ³ /h	16.667 m ³ /h	16.667 m ³ /h	36.419 kg/h	116.104 kg/h
	Transfer time (h)	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
	Liquid flow (m ³ /h)	16.667 m ³ /h	16.667	16.667 m ³ /h	16.667	-	-
	Gas flow (m ³ /h)	-	-	-	-	26.655	84.976
	Temperature (°C)	80	79.998	80	79.998	126.79	126.79
	Pressure (kg/cm ² g)	2.5	2.3	2.5	2.3	1.5 (g)	1.5 (g)
	Density (MT/m ³)	1	1	1	1	0.7319 m ³ /kg	0.7319 m ³ /kg
	Viscosity (Cp)	0.28	0.28	0.28	0.28	0.14	0.14
	Sp. Heat (Kcal/Kg °C)	1	1	1	1	1	1
	Phase	Liquid	Liquid	Liquid	Liquid	Gas	Gas
	Enthalpy Kcal/h	833350	833316.666	833350	833316.666	19648.281	62637.666
	Stream Nos.	61	62	63	64	65	66
Sr. No.	Description	Hot Water from T-108-Jacket of V-102 A/B	Hot Water from Jacket of V-102 A/B-T-108	Cooling water from header-Jacket of R-101	Cooling water from Jacket of R-101-main Header (Return Line)	Cooling water from header-EX-101	Cooling water from EX-101-main Header (Return Line)
	Component	-	-	-	-	-	-
	Mol. wt	-	-	-	-	-	-
1	Sulfuric acid 98.5 %	98	-	-	-	-	-

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos.	61	62	63	64	65	66
	Description	Hot Water from T-108-Jacket of V-102 A/B	Hot Water from Jacket of V-102 A/B-T-108	Cooling water from header-Jacket of R-101	Cooling water from Jacket of R-101 – main Header (Return Line)	Cooling water from header-EX-101	Cooling water from EX-101-main Header (Return Line)
2	Oleum 25 %	178	-	-	-	-	-
3	Liquid sulfur	32	-	-	-	-	-
4	Liquid sulfur-tri-oxide	80	-	-	-	-	-
5	Sulfur-di-oxide	64	-	-	-	-	-
6	Purge gas	-	-	-	-	-	-
7	Unreacted SO ₃	80	-	-	-	-	-
8	Sulfur lumps	32	-	-	-	-	-
9	Acid mist	98	-	-	-	-	-
10	Strong acid	98	-	-	-	-	-
11	Spent acid	-	-	-	-	-	-
12	NaOH lye 10 %	40	-	-	-	-	-
13	Na ₂ SO ₃ 15 %	104	-	-	-	-	-
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water	50 m ³ /h	50 m ³ /h	15 m ³ /h	15 m ³ /h	20 m ³ /h	20 m ³ /h
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	-	-
	Total	50 m ³ /h	50 m ³ /h	15 m ³ /h	15 m ³ /h	20 m ³ /h	20 m ³ /h
	Transfer time (h)	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
	Liquid flow (m ³ /h)	50	50	15	15	20	20
	Gas flow (m ³ /h)	-	-	-	-	-	-
	Temperature (°C)	70	68.74	34	38	34	38
	Pressure (kg/cm ² g)	2.5	2.2	2.5	2.2	By gravity	By gravity
	Density (MT/m ³)	1	1	1	1	1	1

(continued)

Table A.2 (continued)

	Stream Nos.	61	62	63	64	65	66
Sr. No.	Description	Hot Water from T-108-Jacket of V-102 A/B	Hot Water from Jacket of V-102 A/B-T-108	Cooling water from header-Jacket of R-101	Cooling water from Jacket of R-101 – main Header (Return Line)	Cooling water from header-EX-101	Cooling water from EX-101-main Header (Return Line)
	Viscosity (Cp)	0.32	0.32	0.51	0.53	0.51	0.53
	Sp. Heat (Kcal/Kg °C)	1	1	1	1	1	1
	Phase	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
	Enthalpy Kcal/h	2000000	1937000	60000	120000	80000	160000
	Stream Nos.	67	68	69	70	71	72
Sr. No.	Description	Cooling water from header-EX-102 A & B each	cooling water from EX-102 A&B each-main Header (Return Line)	Cooling water from header-EX-103 A&B each	cooling water from EX-103 A&B each-main Header (Return Line)	Steam from header-jacket of DT-102	Condensate from jacket of DT-102-Recovery system
	Component						
		Mol. wt					
1	Sulfuric acid 98.5 %	98					
2	Oleum 25 %	178					
3	Liquid sulfur	32					
4	Liquid sulfur-tri-oxide	80					
5	Sulfur-di-oxide	64					
6	Purge gas						
7	Unreacted SO ₃	80					
8	Sulfur lumps	32					
9	Acid mist	98					
10	Strong acid	98					
11	Spent acid						
12	NaOH lye 10 %	40					
13	Na ₂ SO ₃ 15 %	104					

(continued)

Table A.2 (continued)

Sr. No.	Stream Nos.	67	68	69	70	71	72
	Description	Cooling water from header-EX-102 A & B each	cooling water from EX-102 A&B each-main Header (Return Line)	Cooling water from header-EX-103 A&B each	cooling water from EX-103 A&B each-main Header (Return Line)	Steam from header-jacket of DT-102	Condensate from jacket of DT-102-Recovery system
14	Moisture	-	-	-	-	-	-
15	Sulfur trioxide gas	80	-	-	-	-	-
16	Hot water	25 m ³ /h	25 m ³ /h	25 m ³ /h	25 m ³ /h	-	-
17	Cooling water	-	-	-	-	-	-
18	Steam	-	-	-	-	22.107 kg/h	22.107 kg/h
	Total	25 m ³ /h	25 m ³ /h	25 m ³ /h	25 m ³ /h	22.107 kg/h	22.107 kg/h
	Transfer time (h)	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
	Liquid flow (m ³ /h)	25	25	25	25	-	22.107 kg/h
	Gas flow (m ³ /h)	-	-	-	-	11.801	-
	Temperature (°C)	34	35	34	35	138.19	112.73
	Pressure (kg/cm ² g)	2.5	2.3	2.5	2.3	2.5 (g)	0.6 (g)
	Density (MT/m ³)	1	1	1	1	0.5338 m ³ /kg	1
	Viscosity (Cp)	0.51	0.51	0.51	0.51	0.10	0.15
	Sp. Heat (Kcal/Kg °C)	1	1	1	1	1	1
	Phase	Liquid	Liquid	Liquid	Liquid	Gas	Liquid
	Enthalpy Kcal/h	100000	125000	100000	125000	14422.6068	2497.2067

Notes

Steam requirement to T-105 to heat T-102,103 & 104 is only during winter season

Steam requirement for T-105 to heat Oleum in R-101 is only during each start-up in 1 h = 183481.149 Kcal/h, 318.807 kg/h @ 1.5 kg/cm² (g) Pressure

Peak Load of steam for T-105 to raise temperature of T-105, T-102,103 & 104 during winter for 1st hour of start-up = 160657.1412 Kcal/h, 279.444 kg/h @ 1.5 kg/cm² (g) Pressure

Peak Load of steam for T-108 to raise temperature of T-108, V-102 A or B for 1st hour of start-up = 45931.838 Kcal/h, 78.166 kg/h @ 1.5 kg/cm² (g) Pressure

Peak Load of steam to DT-102 to raise temperature of DT-102 for 1st hour of start-up = 17713.559 Kcal/h, 29.505 kg/h @ 2.5 kg/cm² (g) Pressure

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