

ภาคผนวก ค

รายการคำนวณค่าการออกแบบ
Cyclone Wet Scrubber

Project Environment Pulp and Paper Company Limited (EPPCO), Nakornsawan

Design Calculation of Sieve Tray Scrubber for Recovery Boiler Stack

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by

1. Condition:

- 1.1 Amount of scrubber set
- 1.2 Total gas flow rate 22 m³/s
- 1.3 Flow rate of flue gas per set (Q) 22 m³/s
- 1.4 Temperature of inlet gas (T) 120 °C
- 1.5 Density of inlet gas (ρ_g) 0.89 kg/m³
- 1.6 Viscosity of inlet gas (μ_g) 2.27E-05 kg/(m.sec)
- 1.7 Density of ~~flue gas~~ ash (ρ_p) 1400 kg/m³

2. Particle size distribution

Size Category (μm)	Midpoint (μm)	Number of particles, n	% frequency	Cum. % frequency
0-10	5	46	23.00	23.00
10-20	15	96	48.00	71.00
20-30	25	22	11.00	82.00
30-40	35	12	6.00	88.00
40-50	45	6	3.00	91.00
50-60	55	4	2.00	93.00
60-70	65	4	2.00	95.00
70-80	75	5	2.50	97.50
80-90	85	3	1.50	99.00
90-100	95	1	0.50	99.50
>100	100	1	0.50	100.00
Total		200	100	

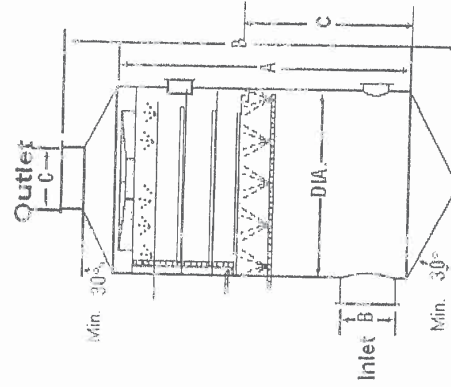
3. Mass Ratio (W)

Equivalent volume diameter (De) = $D_c(6\alpha/\pi)^{1/3}$
 where D_c = Dia. of equal area circle
 α = Volume shape factor = 0.24
 (as bituminous coal, in Ref. 1)

Size Category (μm)	Midsize (μm)	Number of particles, n	De (μm)	nDe ³	πρ _p nDe ³ /6	mass ratio (M), %
0-10	5	46	3.85	2.635E-15	1.93E-12	1.29E-02
10-20	15	96	11.56	1.485E-13	1.09E-10	0.73
20-30	25	22	19.27	1.575E-13	1.16E-10	0.77
30-40	35	12	26.98	2.358E-13	1.73E-10	1.16
40-50	45	6	34.69	2.506E-13	1.84E-10	1.23
50-60	55	4	42.40	3.050E-13	2.24E-10	1.49
60-70	65	4	50.11	5.035E-13	3.69E-10	2.47
70-80	75	5	57.82	9.667E-13	7.09E-09	4.74
80-90	85	1	65.53	2.570E-12	1.88E-09	12.60
90-100	95	3	73.24	5.138E-12	3.77E-09	25.18
>100	100	1	77.10	1.013E-11	7.42E-09	49.63
			Total		1.50E-08	100.00

4. Dimension of each scrubber

4.1 Scrubber dimension



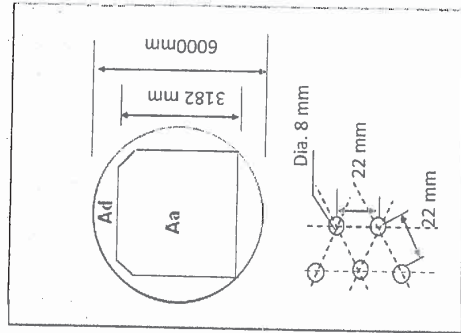
Dimension of scrubber in mm.

D/A	A	B	C	Inlet B	Outlet C
6000	10240	15462	5800	1522X3019	Ø 3000

Cross-section area 28.26 m³
 Superficial velocity 0.78 m/sec

4.2 Sieve tray dimension

Downcomer area, Ad	14.6	m ²
Active area, Aa	12.12	m ²
Hole area (Total)	0.89	m ²
Velocity in hole	24.59	m/sec (design criteria, 15-30 m/sec) Ref. [2]



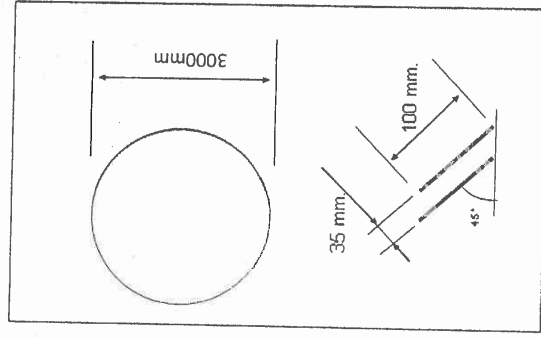
4.3 Mist eliminator dimension

Checking Diameter

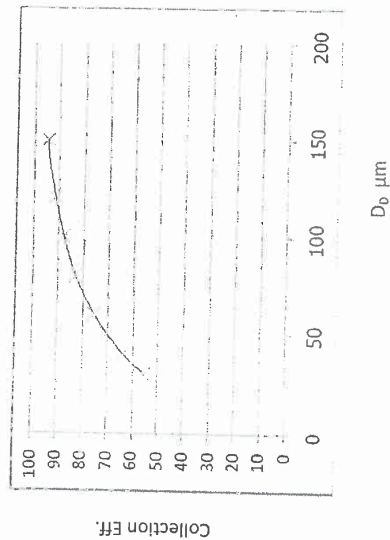
Diameter = 3000 mm.
 Cross-section area = 7.07 m³
 Actual area = 6.4 m³ (loss 10% for actual installation, assumption)
 Flow velocity (V_G) = 3.5 m/sec (design criteria, 2.1-4.8 m/sec) Ref.[3]

Analysis of Collection Efficiency (E) Ref.[3]

$E = 1 - \exp\left\{-(w/b)\left[\left(V_D/V_G\right)^2 + (n-1)\left(V_D/V_G\right)\right]\right\}$
 $V_D/V_G = \left[8 \sin(\theta/2) \rho_D D_D / (3 w \cos^3(\theta/2) C_D \rho_G)\right]^{0.5}$
 $V_D/V_G = \left[8 \sin \theta \rho_D D_D / (3 w \cos^2 \theta C_D \rho_G)\right]^{0.5}$
 where w = baffle width 10 cm
 b = baffle spacing 3.5 cm
 n = number of bends 1
 θ = angle between baffle and flow direction (45°)
 V_D = terminal Stokes centrifugal velocity
 V_G = superficial gas velocity 3.5 m/s
 ρ_D = drop density
 D_D = droplet diameter
 C_D = droplet drag coefficient (depend on Reynolds number, Re) (assumption: Water temperature = 70°C)



D_D (μ m)	Re	C_D	V_D/V_G	E (%)
30	4.07	7.96	0.28	56
40	5.43	6.70	0.36	64
50	6.79	5.86	0.43	71
60	8.15	5.25	0.49	76
80	10.87	4.42	0.62	83
100	13.58	3.87	0.74	88
120	16.30	3.47	0.86	91
150	20.37	3.03	1.03	95



5. Efficiency of Particle Removal (η)

$$Pt = \exp(-40F^2 V_{ch} d_p^2 / 9 \mu D_h) \quad \text{Ref. [4]}$$

$$\eta = 1 - Pt$$

where

Pt = penetration efficiency

η = efficiency

V_{ch} = the gas velocity in the hole of a sieve plate

D_h = the hole diameter (= 0.8 cm)

F = plate efficiency (assumed = 0.65)

Aerodynamic impaction diameter (d_a) =

$$De(p_p C)^{0.5}$$

C = Cunningham correction factor

$$= 1 + [(6.21 \times 10^{-4}) (T) / De]$$

Size Category (μm)	Midpoint (μm)	$De(\mu m)$	C	d_a	mass ratio, % (M)	Pt	η	η_{MI}
0-10	5	3.85	1.07	4.364	1.291E-02	0.995	0.005	6.252E-05
10-20	15	11.56	1.02	12.812	7.277E-01	0.959	0.041	2.981E-02
20-30	25	19.27	1.01	21.258	7.721E-01	0.891	0.109	8.397E-02
30-40	35	26.98	1.01	29.704	1.158E+00	0.799	0.201	0.233
40-50	45	34.69	1.01	38.150	1.228E+00	0.690	0.310	0.380
50-60	55	42.40	1.01	46.596	1.495E+00	0.575	0.425	0.635
60-70	65	50.11	1.01	55.042	2.467E+00	0.462	0.538	1.327
70-80	75	57.82	1.00	63.487	4.738E+00	0.358	0.642	3.041
80-90	85	65.53	1.00	71.933	1.260E+01	0.268	0.732	9.226
90-100	95	73.24	1.00	80.379	2.518E+01	0.193	0.807	20.324
>100	100	77.10	1.00	84.802	4.963E+01	0.161	0.839	41.618
								76.898

Particle removal efficiency of the scrubber = 75.90 %

Ash Removal at Wet Scrubber

Scrubber Efficiency

Concentration of particles enter scrubber

Ash removal by scrubber

Emission concentration

76.90 %

188 mg/Nm³

145 mg/Nm³

43.4 mg/Nm³

Max. of concentration (Factor 1.12)

48.6 mg/Nm³

Soot-blowing Condition

Max. of dust concentration (Factor 1.20 of normal operation)

52.1 mg/Nm³

6. Conclusion

Maximum dust emission at normal operation is not excess 49 mg/Nm³
Maximum dust emission at soot blowing is not excess 52 mg/Nm³

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1. Hinds C. W., *Aerosol Technology*, 2nd, John Wiley & Sons, 1999.
2. Gordon D. Sargent, "Gas/Solid separation", *Industrial Air Pollution Engineering*; Cavaceno ed., Chemical Engineering McGraw-Hill Pub. Co., 1980.
3. Kenneth E. Noll, *Fundamental of Air Quality Systems*; Design of Air Pollution Control Devices, American Academy of Environmental Engineers, 1999.
4. Dullein F. A. L., *Introduction to Industrial Gas Cleaning*, Academic Press, Inc., 1989.

