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DESIGN CALCULATIONS TO

HMIP Technical Guidance Note (Dispersion) D1: 1990
EA Guidance Note H1 Annex F – Air Emissions: 2011

CLIENT NORMAN HAY ENGINEERING (for BAE SYSTEMS)

ITEM STACK HEIGHT CALCULATION
FOR WET SCRUBBERS ON DESCALING AND CHROME PLATING LINES

JOB NO. DJF 070-2014

Calcs. by	Checked	Revision	0			
DJF		Date	01.10.14			

Executive Summary:

Emissions from the metal treatment plating lines are treated by wet chemical scrubbers before emission to atmosphere. The location of the factory is in the Ribble Valley, Lancashire at approximately 400 feet (120 m) above sea level. Although the land rises, with hills to the east of the factory, these are considered too distant to affect the stack calculation.

Given the proximity of the discharge stacks to one another, the Technical Note (D1), advises that they are effectively treated as a single discharge with the relevant calculated values added together to give an overall estimate of stack height, as per Clause 6.4.3.

For the given conditions, i.e. post scrubber, overall emission levels are expected to be very low and, as a result, the chimney height proposed, 14.87 m, for the installation exceeds the calculated height from the Technical Guidance Note, D1. The calculated value is 14.8 m. Furthermore, the dominant part of the emission is considered to be NOx, that is Nitrogen Monoxide (NO) and Dioxide (NO_2), due to the difficulty in removing these compounds.

The levels of background pollutants (where available) were obtained from Ribble Valley Borough Council and their Air Quality Progress Report for April 2013. Please note that some of the technical data used has been taken from other references such as Annex F (Air Emissions) of Guidance H1 issued by the Environmental Agency as part of the Environmental Risk Assessment Framework.

Background:

It is understood that a new Chrome Plating Line Plant is being installed at the BAE Systems factory in Salmesbury, located in the Ribble Valley, Lancashire. As part of the scheme, fume extract systems complete with a wet chemical scrubber are to be installed on the PFD and Anodiser Lines. The scrubbers are used to remove acid gases and nitrogen oxides before emission to atmosphere.

Under Local Authority (IPCC) regulations, emissions must be controlled in accordance with ***Process Guidance Note 4/1 (13) – The Surface Treatment of Metal Processes*** - before the extracted air can be released to atmosphere. As part of the system, 15.0 m (14,870 mm overall) high discharge stacks are proposed to ensure that any residual gases are sufficiently diluted and dispersed, taking in to account the effects of any nearby building(s) and / or local terrain.

Levels of contaminant post-scrubbing are based upon previous similar plant since this installation is a new build. Typically, emissions of NOx tend to influence the stack height calculation to the greatest degree. Where this pollutant exceeds a level of 500 mg/m^3 from the process, stack heights increase sharply unless scrubber performance exceeds 95% abatement. In addition, the emission of chromic (VI) acid and its salts can also significantly influence stack height. Chromic emissions tend to be kept to 1 mg/m^3 or less as per the benchmark level stated in the Process Guidance Note.

The Technical Guidance Note, D1, lays out a relatively simple, non-specific method of approximately determining the heights of discharge stacks for polluting emissions, which should be adequate in normal circumstances. It is intended for use by those in industry who have a need to make such calculations, although it is primarily for use with those processes regulated under IPPC. Please note that the height of a stack is only one of several measures that must be considered and employed as part of Best Practice when assessing the emissions from any given process.

The topography of the area is fairly constant but does rise in height (up to 1,000 feet or 300 m) as one progresses east towards the town of Mellor and beyond. However, it is considered that in the immediate vicinity of the factory, that any ground slopes are less than 1 in 10. The type of district where the plant is located is inland and semi-rural. The topology is river valley with hills to the east. Height above sea level is approximately 400 feet (120 m).

Pollutant / Emission Values	**Particulate (mg/m^3)**	**NOx[1] (as NO_2) (mg/m^3)**	**HF (mg/m^3)**	**HCl (mg/m^3)**	**H_2SO_4 (as SO_2) (mg/m^3)**	**HCN (mg/m^3)**	**Chromic (VI) (mg/m^3)**
PG 4/1 (13)	50.0	200.0	2.0	10.0	100.0	5.0	1.0
Values Used*	5.0	75.0	1.0	5.0	5.0	0.0	1.0

'*' Pollutant levels based on previous data from scrubbing plant performance.

'1' Final NO_2 levels should be checked to ensure that the stack is adequately sized to eliminate / minimise the visible plume scenario.

STACK HEIGHT CALCULATIONS TO TECHNICAL NOTE, D1

PFD LINE

Stack Parameters

Air flow	37,864 m^3/h (10.52 m^3/s)		
Internal Air Temperature	20°C (293 K)		
External Air Temperature	Average 10°C (283 K)		
Stack Dimensions	***Main body Ø1,300 x 14,870 mm high; H.V. Cone Ø900 mm***		
Area of Stack (main body)	$\frac{1.3^2 \times \Pi}{4}$	=	1.327 m^2
Air velocity (main body), V_g,	10.52 / 1.327	=	7.93 m/s
Area of Stack Discharge	$\frac{0.9^2 \times \Pi}{4}$	=	0.64 m^2
Air velocity (main body), V_c,	10.52 / 0.64	=	16.5 m/s

ANODISE LINE

Stack Parameters

Air flow	50,576 m^3/h (14.05 m^3/s)		
Internal Air Temperature	Ambient; 20°C (293 K)		
External Air Temperature	Average 10°C (283 K)		
Stack Dimensions	***Main body Ø1,400 x 14,870 mm high; H.V. Cone Ø1,100 mm***		
Area of Stack (main body)	$\frac{1.4^2 \times \Pi}{4}$	=	1.54 m^2
Air velocity (main body), V_g,	14.05 / 1.54	=	9.12 m/s
Area of Stack Discharge	$\frac{1.1^2 \times \Pi}{4}$	=	0.95 m^2
Air velocity (main body), V_c,	14.05 / 0.95	=	14.8 m/s

Calculation of Pollution Index, P_i

Pollutant Concentration Levels (post scrubbing)

Particulates / Droplets	5 mg/m^3
NOx	75 mg/m^3
HF	1 mg/m^3
HCl	5 mg/m^3
H_2SO_4	5 mg/m^3
Chromic Acid	1.0 mg/m^3
(SO_2	100 mg/m^3)*

'*' – Use of SO_2 is for background pollutant purposes.
NB – NOx includes both NO, NO_2 and HNO_3 fume, usually expressed as equivalent to nitrogen dioxide, NO_2.

Pollutant Discharge Rates

$$PDR = \frac{\text{Emission Level x Air Flow}}{1 \times 10^3}$$

$$NO_2 = \frac{75 \times 10.52}{1 \times 10^3} = 0.79 \text{ g/s}$$

POLLUTANT DISCHARGE RATES 'D'		
LINE	***PFD***	***ANODISE***
Pollutant	**g/s**	**g/s**
Particulate / Droplets	0.053	0.07
NO_2	0.79	1.054
HF	0.011	0.014
HCl	0.053	0.07
H_2SO_4	0.053	0.07
Chromic (VI) Compounds	0.011	0.014

Guideline Concentrations

Particulates / Droplets	0.05 mg/m^3
NO_2	0.20 mg/m^3
HF	0.16 mg/m^3
HCl	0.75 mg/m^3
H_2SO_4	0.30 mg/m^3
Chromic Acid*	0.005 mg/m^3
(SO_2	0.35 mg/m^3)

'*' TWA from Material Safety Data Sheet for Chromate (VI) compounds

Background Concentrations

Particulates / Droplets	0.001 mg/m^3
NO_2	0.006 mg/m^3
HF	0.005 mg/m^3
HCl	0.021 mg/m^3
H_2SO_4	0.009 mg/m^3
Chromic Acid	1.43×10^{-4} mg/m^3
(SO_2	0.01 mg/m^3)

The aforementioned values are calculated using Eqn. (2) from the Code, based on sulphur dioxide as 'the background pollutant'.

$$B_e = B_c \times (G_d / G_b)$$

Where, G_d / G_b = various values depending on the pollutant in question
B_c = background concentration of SO_2
B_e = equivalent background concentration of pollutant

$$P_i = \frac{D}{(G_d - B_c)} \times 1000$$

P_i values for both lines are as follows:-

POLLUTION INDEX VALUES 'P_i'		
LINE	***PFD***	***ANODISE***
Pollutant	**m^3/s**	**m^3/s**
Particulate / Droplets	1,083	1,446
NO_2	4,061	5,424
HF	68	90
HCl	72	96
H_2SO_4	180	241
Chromic (VI) Compounds	2,166	2,893

P_i Acid Gases PFD Line	=	1,083 + 68 + 72 + 180 + 2,166	=	3,569 m^3/s
P_i Acid Gases Anodise Line	=	1,446 + 90 + 96 + 241 + 2,893	=	4,766 m^3/s
		TOTAL	**=**	**8,335 m^3/s**

P_i NOx (both lines) = **9,485 m^3/s**

P_i Acid Gases < P_i Nitrogen Dioxide, therefore use P_i value for NO_2, i.e. ***9,485 m^3/s***.

Heat Released, Q

$$Q = \frac{V \times [1 - (283 / T_d)]}{2.9}$$

Discharge momentum

$$M = \frac{\rho_d}{\rho_a} \times V \times w \qquad \text{(Eqn.9)}$$

Where,

ρ_d	=	density of discharging gas (kg/m^3)
ρ_a	=	density of ambient air (kg/m^3)
V	=	volume rate of discharge (m^3/s)
w	=	discharge velocity (m/s)

PFD LINE

$$Q = \frac{10.52 \times [1 - (283 / 293)]}{2.9} = 0.124 \text{ MW}$$

$$M = 166.96 \text{ m}^4/\text{m}^2$$

ANODISE LINE

$$Q = \frac{14.05 \times [1 - (283 / 293)]}{2.9} = 0.165 \text{ MW}$$

$$M = 200.84 \text{ m}^4/\text{m}^2$$

Minimum Discharge Stack Velocity

If $Q < 0.1$ MW, then V_g minimum is 10 m/s
If $Q > 1.0$ MW, then V_g minimum is 15 m/s
For $0.1 < Q < 1.0$, then pro rata accordingly.

For both stacks, Vg => 15 m/s. This corresponds to $Q > 1.0$, therefore OK.

For $M < 10$, then V_g minimum is 10 m/s
For $M > 100$, then V_g minimum is 15 m/s
For $10 < M < 100$, then pro rata accordingly.

For both stacks, Vg => 15 m/s, therefore OK.

NB – In general, process guidance notes don't recommend an exit velocity of greater than 15 m/s due to potential noise issues.

For multiple stacks within 3 stack diameters of one another, they are to be treated as a single discharge, and Clause 6.4.3 must be adhered to. This means values for P_i, Q and M are cumulative in their effect (see Table 4 of D1 Technical Note).

Therefore,

ΣP_i = 9,485 m^3/s; ΣQ = 0.289 MW; ΣM = 367.8 m^4/s^2

Uncorrected Chimney Height for Buoyancy, U_b

U_b = $10^a \times P_i^b$ (Eqn.6)

Where for Q <= 1 MW then,

$a = -1.11 - 0.19 \times \log_{10}Q$
$b = 0.49 + 0.005 \times \log_{10}Q$

a = -1.008
b = 0.487

U_b = $10^{-1.008} \times P_i^{0.487}$ = 8.48 m

Alternatively, Eqn. (7) can be used since the minimum value of U_b cannot be less than 1 m.

U_b minimum $1.95 \times Q^{0.19}$ = 1.54 m

Uncorrected Chimney Height for Momentum, U_m,

$\log_{10}U_m$ = $x + (y \log_{10} \times P_i + z)^{0.5}$ (Eqn.15)

x = $-3.7 + (\log_{10}M)^{0.9}$
y = $5.9 - (0.624 \times \log_{10}M)$
z = $4.24 - (9.7\log_{10}M) + 1.47(\log_{10}M)^2 - 0.07(\log_{10}M)^3$

x = -1.37
y = 4.30
z = 4.24 – 24.88 + 9.68 – 1.18 = -12.14

$\log_{10}U_m$ = $-1.37 + (4.3 \log_{10}P_i + (-)12.14)^{0.5}$

= 0.857

U_m = 7.20 m

Alternatively, Eqn. (16) can be used since the minimum value of U_m cannot be less than 1 m.

U_m minimum $0.82 \times M^{0.32}$ = 5.43 m

Final Discharge Stack Height

$C = H + [0.6 \times (U + (2.5 \times H - U) \times (1 - A^{-U/H}))]$ Eqn.(17)

Where
- H = Height of building (m)
- U = Uncorrected chimney height (lesser of U_b or U_m) (m)
- A = U_m / U_b

$C = 11.87 + [0.6 \times (7.2 + (2.5 \times 11.87 - 7.20) \times (1 - 0.85^{-0.607})$

$= 11.87 + 0.6 \times (7.2 + ((22.48) \times -0.104))$

= **14.79 m; OK, actual (proposed) chimney height is 14.87 m**