Haden Regenerative Thermal Oxidiser

- D1 Stack Height Calculations

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SUMMARY

WZ Packaging Ltd plan to relocate an existing Haden Drysys Regenerative Thermal Oxidiser (RTO) from Bury to their site location in Telford (Post Code TF7 4JS, Ordnance Survey map reference SJ7005SE).

As a condition of the Local Authority Consent for the relocated RTO, WZ Packaging Ltd instructed Polutek Ltd to prepare Oxidiser Stack Height calculations in accordance with the D1 Guidelines – Technical Guidance Note (Dispersion) D1, June 1993.

Conclusions

1) Based on the consent exhaust gas composition, the Pollution Index (**Pi)** is greatest for NOx and so the maximum value of 17,000 m^3/s for **Pi** is used in the subsequent calculations (4,900 m^3/s at minimum flow).

2) The uncorrected stack heights **Ub** (based on heat release) are 8.0m at maximum flow and 5.5m at minimum flow.

3) The uncorrected stack heights **Um** (based on momentum) are 11.0m at maximum flow and 9.5m at minimum flow,.

4) Taking account of the downwash from the nearby factory building, the corrected stack heights **C** are 17m at maximum flow and 16m at minimum flow.

5) In accordance with Clause 6.3 of the D1 Guidelines, for plant with a high turndown ratio, the “highest calculated discharge stack should be used” - **namely, a stack height of 17m.**

6) It has been concluded under “Other Considerations” that no further stack height corrections are necessary.

REPORT CONTENTS

1.0 EXHAUST GAS DATA

1.1 Stack Discharge Flow Conditions

Maximum Flow:	104,000 Nm^3/hr
Minimum Flow:	30,000 Nm^3/hr
Discharge Temperature:	90 deg C
Stack Diameter:	1750 mm

1.2 Maximum Pollutant Concentrations

Volatile Organic Compounds (VOC's)	50 mg/Nm^3 (as Carbon)
Carbon Monoxide (CO):	100 mg/Nm^3
Nitrogen Oxides (NOx):	100 mg/Nm^3
Isocyanate:	0.1 mg/Nm^3 (Not Applicable)

The above Environmental Permit values are based on 15 minute means.

1.3 Process Solvents Used

Etac (Ethyl Acetate):	60%
Meths (mainly Ethanol):	30%
MEK (Methyl Ethyl Ketone):	10%

1.4 Reference Sources

1) WZ Packaging Email dated 16 Nov 2017 – flow rate values stated as Nm^3/s and discharge temperure deg C
2) WZ Packaging Email dated 17 Nov 2017 – extract from the environmental permit
3) WZ Packaging Email dated 17 Nov 2017 – listing solvents used (coatings do not contain Isocynate - food packaging)

2.0 POLLUTION INDEX CALCULATIONS

2.1 <u>Calculate Maximum Discharge Rate of Pollutants</u> (D gm/s)

Based on the maximum flow rate of 104,000 Nm^3/hr (28.9 Nm^3/s):

D (VOC)	50/1000 x 28.9	=	1.445 gm/s
D (CO)	100/1000 x 28.9	=	2.890 gm/s
D (NOx)	100/1000 x 28.9	=	2.890 gm/s

For the minimum flow condition of 30,000 Nm^3/hr, in subsequent calculations, the above D values are adjusted on a pro-rata basis.

2.2 <u>Determine Guideline Concentrations</u> (G mg/m^3)

D1 Guidelines clause 4.3.3 recommends values are based on 1/40th of Short-Term Exposure Limits (STEL). The following reflects the published HSE guidance, namely, EH40/2011 "Workplace Exposure Limits" and/or Supplier MSDS data:

Ethyl Acetate (VOC):	1460/40 mg/m^3 x 0.6	=	21.9 mg/m3
Ethanol (VOC):	5750/40 mg/m^3 x 0.3	=	43.1 mg/m^3
Methyl Ethyl Ketone (VOC)	899/40 mg/m^3 x 0.1	=	2.25 mg/m^3
Total for VOC's	(21.9+43.1+2.25) mg/m^3	=	<u>67.25</u> mg/m^3
Carbon Monoxide (CO):	232/40 mg/m^3	=	5.8 mg/m^3

EH40/2011 does not provide a value for NOx so, taking account of the DEFRA D1 Guidance Note dated 01-03-2010, we have used the target 1 hour mean value provided in the latest UK Air Quality Strategy Objective:

Nitrogen Oxides (NOx): 0.2 mg/Nm^3 (based on Nitrogen Dioxide)

2.3 Calculate Pollution Indices

Using formula (1) in clause 4.1 of the D1 Guidelines (based on data provided in 2.1 & 2.2 above):

Pi (VOC's) = 1.445 / 67.25 x 1,000 = 21.49 m^3/s

Pi (CO) = 2.890 / 5.8 x 1,000 = 498.28 m^3/s

Pi (NOx) = 2.890 / 0.2 x 1,000 = 14,450 m^3/s

It should be noted that the above values have not been adjusted to take account of background pollutant levels.

Given the uncorrected **Pi (NOx)** is 29 times greater than **Pi (CO),** we have taken the average daily maximum NOx level measured at the Telford Hollinswood AURN (from 1-20 November 2017, namely, 0.03 mg/m^3) and applying the correction:

Pi (NOx) = 2.890 / (0.2-0.03) x 1,000 = 17,000 m^3/s

2.4 Combinations of Pollutants

Clause 4.5.3 of the D1 Guidelines states NO_2 should be treated separately (namely, not combined with the other Pollution Indices) and so we have used the following in our subsequent calculations:

Max Flow Pi (NOx) = 17,000 m^3/s (at 104,000 Nm^3/hr)

Min Flow Pi (NOx) = 4,900 m^3/s (at 30,000 Nm^3/hr)

The Min Flow Pi has been computed on a pro-rata basis.

3.0 UNCORRECTED STACK HEIGHTS

3.1 Calculate Ub - based on Heat Release

3.1.1 Minimum Flow Rate

Applying temperature correction to the minimum flow rate of 30,000 Nm^3/hr, total volume flow rate (**V**) at the 90 deg C discharge condition is given by the following:

V = (30,000 x 363/273) / (60 x 60) = **11.08 m^3/s**

Using formula (3) given in clause 5.2 of the D1 Guidelines:

Heat Release (Q) = $11.08 \frac{(1 - 283/363)}{2.9}$ = **0.84 MW**

Using the above calculated value for **Q**, reading from Fig 2 (for **Pi** of 4,900 m^3/s) in Appendix D of the D1 Guidelines:

Stack Height, Ub = 5.5m

3.1.2 Maximum Flow Rate

Applying temperature correction to the maximum flow rate of 104,000 Nm^3/hr at the 90 deg C discharge condition:

V = (104,000 x 363/273) / (60 x 60) = **38.41 m^3/s**

Using formula (3) given in clause 5.2 of the D1 Guidelines:

Heat Release (Q) = $38.41 \times \frac{(1 - 283/363)}{2.9}$ = **2.91 MW**

Using the above calculated value for **Q**, reading from Fig 2 (for **Pi** of 17,000 m^3/s) in Appendix D of the D1 Guidelines:

Stack Height, Ub = 8.0m

3.2 Calculate Um - based on Momentum

3.2.1 Minimum Flow Rate

Based on a stack diameter of 1750mm and minimum flow rate of 30,000 Nm3/hr at 90 deg C (**V** = 11.08 m^3/s):

X-section Area	=	22/7 x (1.75 x 1.75)/ 4	=	2.4 m^2
Stack Velocity (w)	**=**	11.08 / 2.4	=	**4.6 m/s**

Using formula (11) in clause 5.2 of the D1 Guidleines:

Discharge Momentum (M)	=	(283/363) x 11.08 x 4.6	=	**39.7 m^4/s^2**

Using the above calculated value for **M**, reading from Fig 4 (for **Pi** of 4,900 m^3/s) in Appendix D of the D1 Guidelines:

Stack Height, Um = **9.5m**

3.2.2 Maximum Flow Rate

Based on the maximum flow rate of 104,000 m^3/hr at 90 deg C (**V** = 38.41m^3/s) and using formula (11) in clause 5.2 of the D1 Guidleines:

Stack Velocity (w)	**=**	38.41 / 2.4	=	**16.0 m/s**
Discharge Momentum (M)	=	(283/363) x 38.41 x 16.00	=	**479.1 m^4/s^2**

Using the above calculated value for **M**, reading from Fig 4 (for **Pi** of 17,000 m^3/s) in Appendix D of the D1 Guidelines:

Stack Height, Um = **11m**

4.0 CORRECTED STACK HEIGHT, C

4.1 <u>General</u>

Referring to the definitions provided in clause 5.4.1 of the D1 Guidelines:

4.1.1 Minimum Flow Rate

U	=	Uncorrected stack discharge height (lesser of **Um** or **Ub**)			=	**5.5m**
A	**=**	Um/Ub	=	9.5 / 5.5	=	**1.73**

According to clause 5.4.4 in the D1 Guidelines, consider all buildings within a distance of 5 x **Um:**

5 x 9.5 = **47.5m**

It is only necessary to consider the effect of the main factory building (but not the building in the next plot to the East which is over 60m away)

4.1.2 Maximum Flow Rate

U	=	Uncorrected stack discharge height (lesser of **Um** or **Ub**)			=	**8.0m**
A	**=**	Um/Ub	=	11 / 8	=	**1.38**

According to clause 5.4.4 in the D1 Guidelines, consider all buildings within a distance of 5 x **Um:**

5 x 11 = **55m**

As previously, it is only necessary to consider the effect of the main factory building (but not the building in the next plot to the East which is over 60m away)

4.2 <u>Calculate T for the Factory Building</u>

Again, referring to clause 5.4.1 of D1 the Guidelines:

4.2.1 Calculate T for each Building

H **=** Building Height (measured to the ridge, or, other highest point)

B = Building Width (projected elevation perpendicular to stack)

T = Disturbed Flow Height = H + 1.5K = 25m

(where K is lesser of H or B)

Building	**H**	**B**	**K**	**T**
Main Factory	10m	75m	10m	25m

Thus, for subsequent calculations to determine **C**:

H/T = 10/25 = **0.4**

4.3 Determine C

4.3.1 Minimum Flow Rate

Therefore, reading the **C/H** correction from Fig 7 in the D1 Guidelines and **U** is the smaller of **Ub** and **Um**, where:

U/H = 5.5/10 = 0.55
A = 1.73 (from **4.1.1**)

C/H = 1.5 (from Fig 7)

Hence, C **=** 1.6 x 10 = **16m**

4.3.2 Maximum Flow Rate

Again, reading the **C/H** correction from Fig 7 in the D1 Guidelines and **U** is the smaller of **Ub** and **Um**, where:

U/H = 8/10 = 0.8
A = 1.38 (from **4.1.2**)

C/H = 1.65 (from Fig 7)

Hence, C **=** 1.65 x 10 = **17m**

In accordance with clause 5.4.7 in the D1 Guidelines, the calculated discharge stack heights have been rounded up to the nearest metre.

In accordance with clause 6.3 in the D1 Guidelines, the value of C is greater for the maximum flow rate condition, so the latter determines the corrected stack height – **namely, the corrected stack height to be used is 17m.**

5.0 OTHER CONSIDERATIONS

5.1 Nearby Buildings

According to clause 6.2.2 in the D1 Guidelines, the stack height should be at least 3m higher than adjacent roof areas.

Based on this criteria, the minimum stack height would need to be 13m (maximum ridge/apex height of Factory Building is 10m).

5.2 Nearby Stacks

When the RTO has been installed, the existing stacks on the South Elevation of the factory building will be used for by-pass purposes only, for short periods, during start-up and shutdown of the Oxidiser. On this basis, they do not need to be considered in the D1 Calculations.

On the East Elevation of the building, there is an existing LEV Stack with flow rate of approximately 40,000 m^3/hr. This stack is between 2Um (22m) and 5Um (55m) of the Oxidiser stack; however, it provides Local Exhaust Ventilation only for the factory so the Pollution Index of this stack will be minimal and does not need to be further considered.

On the above basis, Clause 6.4.4 of the D1 Guidelines is not applicable.

5.3 Discharge Velocity

5.3.1 Minimum Flow Rate

For a heat release of 0.84 MW (refer 3.1.1), on a pro-rata basis, clause 6.1.1 of the D1 Guidelines recommends a stack discharge velocity (**w**) of 13.7m/s.

For a discharge momentum of 39.7m^4/s^2, a stack discharge velocity (**w**) of 11.65m/s is recommended.

5.3.2 BRE Velocity Correction at Minimum Flow

The BRE Client Report – CR 103/95 (Correcting Discharge Stack Height to Account for Low Discharge Velocities, May 1995) refers to the D1 Guidelines. The BRE report was prepared for the Local Authority Unit, Air Quality Unit Division, Department of the Environment to consider the potential problems of plume downwash for D1 stacks when the discharge velocities are low.

Although clause 6.1.1 of the D1 Guidelines states “use whichever gives the greater velocity", the later BRE Report states that, due to plant turndown, it is permissible to accept a reduced discharge velocity down to 40% of the recommended value for Um only where there is a significant heat release.

Based on discharge momentum, 40% of the D1 recommended velocity of 11.65m/s is 4.66 m/s – namely, the actual stack velocity of 4.6 m/s (refer 3.2.1) is 98.7% of the BRE recommended minimum.

Also, the Oxidiser stack location proposed is near the corner of the South/East elevation of the factory building, so the downwash effect of the latter will be reduced compared the D1 Guidance layout shown in Fig 6 (top left hand corner).

Finally, the corrected stack height (refer 4.3) for minimum flow of 16m compares to a stack height of 17m for maximum flow.

On the basis of the above considerations, it is not necessary to apply a further stack height correction for the Minimum Flow condition.

5.3.3 Maximum Flow Rate

For a heat release above 1 MW, clause 6.1.1 in the D1 Guidelines recommends a minimum stack discharge velocity (w) of 15 m/s.

For a discharge momentum above $100m^4/s^2$, again, a stack discharge velocity (w) of 15 m/s is recommended.

The actual flue discharge velocity (**w**) at maximum flow rate is 16.0 m/s (as calculated under 3.2.2).

Given the velocity is slightly in excess of the recommended, there is no requirement to make a correction.