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TECHNICAL NOTE

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1 Introduction

A Part(A2) Environmental Permit application has been submitted for an installation at the Ball Packaging site in Kettering. The Environmental Permit application was accompanied by an Air Quality Assessment[1] which undertook dispersion modelling of emissions to air from the regenerative thermal oxidiser (RTO). The impacts of NO_x emissions and VOC emissions (as Xylene) were assessed and no significant impacts were predicted.

As part of the permit determination process a D1 stack height calculation[2] has been requested and this technical note provides the results of the assessment.

2 D1 Stack Height Calculation

2.1 Dispersion model inputs

The following table summarises the data input that is relevant for the D1 stack height calculation, with the data taken from the Vanguardia report.

[1] Kettering 4B Air Quality Assessment. VC-103500-AQ-RP-0001. R01 June 2021. Vanguardia
[2] HMIP Technical Guidance Note (Dispersion) Guidelines on Discharge Stack Heights for Polluting Emissions D1. June 1993 HMSO

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Parameter	Value
Internal stack diameter*	1.756 m
Stack height	14.5 m
Stack area	2.42 m^2
Release temperature	150 ºC
Normalised Volume flow	
– 4 line	15.64 Nm^3/s
- 6 line	23.46 Nm^3/s
Actual Volume flow	
- 4 line	24.23 m^3/s
- 6 line	36.35 m^3/s
Emission velocity	
- 4 line	10 m/s
- 6 line	15 m/s
Emission concentration	
- NO_x	50 mg/Nm^3
- VOC as C	20 mg/Nm^3
Emission rate	
- 4 line	NO_x 0.7819 g/s; VOC 0.3454 g/s
- 6 line	NO_x 1.1729 g/s; VOC 0.5180 g/s
Building height (closest)	16.2 m
Building length x width (closest)	334.3 m x 169.5 m
Background NO_2 concentration	11.67 $\mu g/m^3$ annual mean 23.35 $\mu g/m^3$ 1 hour mean
Conversion NO_x to NO_2	0.7 annual mean, 0.35 hourly mean

* The Vanguardia modelling used the normalised flowrate to calculate the required stack diameter for an exit velocity of 10 m/s for the 4 line case, rather than the actual flowrate which would be higher.

2.2 D1 calculation

2.2.1 Guideline Concentrations

The guideline concentrations are the short-term ambient pollutant concentration limits:

NO_2 – 0.2 mg/m^3, 1 hour average
VOC (Xylene) – 66.2 mg/m^3, 1 hour average (from EA guidance)

On the basis that the release rate of NO_x is greater than that of the VOCs, and the NO_2 guideline concentration is a factor of 331 lower, the impacts on NO_2 concentrations will be the governing criteria for the stack height calculation in terms of the Pollution Index.

Short-term NO_2 background concentration – 0.02335 mg/m^3

2.2.2 Pollution index

Pi = 1000 x D/(Gd-Bc)

D = discharge rate NO_2 = 0.35 x discharge rate NO_x
Gd-Bc = guideline concentration minus background concentration = 0.2-0.02335 = 0.1766 mg/m^3

Pi (4 line) = (1000 x 0.35 x 0.7819)/0.1766 = 1,550 m^3/s
Pi (6 line) = (1000 x 0.35 x 1.1729)/0.1766 = 2,325 m^3/s

2.2.3 Heat release

The heat release is calculated as follows:

$Q = V (1-(283/T_d))/2.9$ MW

V = volume discharge, m^3/s
T_d = discharge temperature, K

Q (4 line) = 24.23 x (1-(283/423))/2.9 = 2.77 MW
Q (6 line) = 36.35 x (1-(283/423))/2.9 = 4.15 MW

2.2.4 Discharge momentum

The discharge momentum is calculated as follows:

$M = (283/T_d) \times (\pi.w^2.d^2/4)$ m^4/s^2

w = discharge velocity, m/s
d = internal diameter, m

M (4 line) = (283/423) x (3.142 x 10^2 x 1.756^2/4) = 162.0 m^4/s^2
M (6 line) = (283/423) x (3.142 x 15^2 x 1.756^2/4) = 364.6 m^4/s^2

2.2.5 Uncorrected stack height (Ub, Um)

<u>Ub for buoyancy is calculated from</u>:

$Ub = 10^a.Pi^b$

As Q is greater than 1MW:

$a = -0.84 - 0.1.\exp(Q^{0.31})$; $b = 0.46 + 0.011.\exp(Q^{0.32})$

a (4 line) = -1.234, b (4 line) = 0.504
a (6 line) = -1.313, b (6 line) = 0.513

Ub (4 line) = $10^{-1.234}$ x $1{,}550^{0.504}$ = 2.4 m
Ub (6 line) = $10^{-1.313}$ x $2{,}325^{0.513}$ = 2.6 m

Ub minimum (4 line) = 1.7 + $0.25.Q^{0.9}$ = 1.7 + $0.25x2.77^{0.9}$ = 2.3 m
Ub minimum (6 line) = 1.7 + $0.25.Q^{0.9}$ = 1.7 + $0.25x4.15^{0.9}$ = 2.6 m

Ub is therefore associated with the 6 line case and is 2.6 m.

<u>Um for discharge momentum is calculated from</u>:

$Log_{10}Um = x + (y.log_{10}Pi + z)^{0.5}$

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

x (4 line) = -1.659
x (6 line) = -1.368
y (4 line) = 4.521
y (6 line) = 4.301
z (4 line) = -10.77
z (6 line) = -12.14

Um (4 line) = $log_{10}^{-1}(-1.659 + (4.521 \times log_{10}1{,}550 – 10.77)^{0.5}$ = 1.8 m
Um (6 line) = $log_{10}^{-1}(-1.368 + (4.301 \times log_{10}2{,}325 - 12.14)^{0.5}$ = 1.5 m

Um minimum (4 line) = $0.82.M^{0.32}$ = 0.82 x $162^{0.32}$ = 4.2 m
Um minimum (6 line) = $0.82.M^{0.32}$ = 0.82 x $364.6^{0.32}$ = 5.4 m

The minimum height over-rides the calculated value based on the Pi, and the uncorrected stack height for discharge momentum is therefore 5.4 m for the 6 line case.

2.2.6 Corrected stack height

Building height within 5.Um, H = 16.2 m
Building width within 5.Um, B = 169.5 m
Lessor of H or B, K = 16.2 m
T_m = H + 1.5.K = 40.5 m
U = lessor of Um or Ub, = 2.6 m
A = Um/Ub = 5.4/2.6 = 2.08

C = corrected stack height = $H + 0.6.(U +(2.5.H-U).(1 – A^{-U/H}))$
C= $16.2 + 0.6 \times (2.6 + (2.5 \times 16.2 – 2.6) \times (1 – 2.08^{-2.6/16.2}))$ = 18.9 m

3 Discussion

The calculated D1 stack height using the D1 methodology is 18.9 m which compares with a stack height of 14.5 m that was used in the dispersion modelling. The primary factor influencing the calculated D1 stack height is the influence of the adjacent building.

The D1 calculation method was developed before the widespread adoption of dispersion modelling for the use in permit applications, and it is based on calculating compliance with the 1 hour mean NO_2 concentration national air quality objective. Section 2.1 of the D1 methodology states: *'The calculation method assumes that the discharge stack height is governed by the need to limit local ground level pollutant concentrations below a maximum level that might occur for short periods. By 'local' is meant the region within a distance of about one hundred stack heights where the occasional contribution of a single pollution source to short term pollution levels can be large. It is not intended to deal with long range pollutant transport or to long period pollution levels due to multiple sources, where different conditions apply. The target period is 15-30 mins, but this covers acceptably a range between about five minutes and an hours duration.'*

In addition, Section 2.9 states: *'Heights determined using the method should be regarded as a guide rather than a mathematically precise definition of discharge stack height. The conclusion may need to be modified in the light of particular local circumstances or of practical experience.'*

D1 is not a method that is specified in Environment Agency guidance for determining the impacts of stack emissions. Environment Agency guidance specifies detailed dispersion modelling as the approach to be used when screening criteria in the H1 spreadsheet are not met[3]. In addition, the normal practice when using dispersion modelling for stack height determination is to base the stack height on the predicted annual mean concentrations, with a subsequent check that the selected stack height provides adequate dispersion for short term concentrations.

The dispersion modelling method incorporates specific meteorological factors that impact upon dispersion as well as the relative distances of receptors from the emission point. These are not taken into account in the D1 tool where the methodology is only based on generalised, local short-term impacts.

The results of the dispersion modelling with a 14.5 m stack height showed negligible impacts for both the 4 line and 6 line scenarios even assuming the installation operates continuously all year round at the emission limit value. Predicted environmental concentrations at the nearest receptors to the site were all well below the assessment criteria.

4 Conclusion

The uncorrected stack height for the 6 line scenario using the D1 methodology is 5.4 m; when corrected for the influence of nearby buildings the recommended stack height increases to 18.9 m. The calculated D1 stack height is a guideline only, and can be modified based on specific local circumstances.

The D1 stack height is taller than the 14.5 m stack height used in the dispersion modelling. The dispersion modelling is more accurately able to take account of local circumstances such as the influence of buildings on dispersion and the relative location of receptors to the emission point than the

[3] Air emissions risk assessment for your environmental permit. https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#detailed-modelling

D1 methodology. As the impacts at receptors using dispersion modelling are all predicted to be negligible, then it is concluded that a stack height of 14.5 m provides an acceptable level of dispersion of the emissions from the RTO.