STACK DOWNWASH

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The flow and pressure field around a stack can influence the effective height of the release by reducing the mean height of an emitted plume just downwind of emission. Only releases of relatively small upward momentum are affected, since all other emissions rise rapidly away from the zone of influence. The following algorithms are used to correct for stack downwash.

The correction is similar to that used in many other models (e.g. Hanna et al., 1982) and only applies when the emission velocity ratio, w_s/U_h, is less than 1.5:

$$\begin{aligned} \Delta z_s^{Stack} &= 2\left(\frac{w_s}{U_h} - 1.5\right)D_s \qquad && \text{when } \frac{w_s}{U_h} < 1.5 \\ &= 0 && \text{otherwise} \end{aligned} \qquad (1)$$

where:

D_s	stack outside diameter
U_h	approach flow speed at height of stack top
w_s	vertical emission speed
Δz_s^{Stack}	correction to stack height

In ADMS, the default is for this correction to be applied to all point sources, although the user may specify a subset of point sources to which it will not be applied. The algorithm is only intended for use with stack emissions. Strictly speaking, the stack should be circular in cross section, although the correction could be applied at the user's discretion to other cases, such as stacks of square cross section.

The stack downwash correction is not a model of building induced downwash and should not be used as such.

Snyder and Lawson (1991) undertook detailed wind tunnel measurements of the stack downwash phenomenon and showed that a simple stack height correction is not an entirely correct representation. They showed that in some cases the plume trajectory was modified to distances up to about $30D_s$ from the stack, and that the effect was a function of the stack Reynolds number, $\mathrm{Re}=U_hD_s/\nu_a$, where ν_a is the kinematic viscosity of air at the stack height. They presented results for the plume centreline height at $30D_s$, as a function of the emission velocity ratio, for both sub-critical and super-critical flow. For present purposes we can define these regimes by $\mathrm{Re} < 2\times10^5$ and $\mathrm{Re} > 2\times10^5$, respectively. Some typical stack Reynolds Numbers are shown in Table 1.

Stack Diameter (m)	Wind speed (ms^{-1})	Reynolds Number	Regime
0.2	2	$27\text{x}10^3$	sub-critical
0.2	5	$67\text{x}10^3$	sub-critical
1	2	$130\text{x}10^3$	sub-critical
1	5	$330\text{x}10^3$	super-critical
5	2	$670\text{x}10^3$	super-critical
5	5	$1.7\text{x}10^6$	super-critical
25	2	$3.3\text{x}10^6$	super-critical
25	5	$8.3\text{x}10^6$	super-critical

Table 1 Stack Reynolds numbers and flow regimes

In a turbulent flow the onset of critical conditions occurs at lower Reynolds numbers; free stream turbulence and cylinder surface roughness decrease the critical Reynolds number, to an unknown degree, suggesting that super-critical conditions dominate in practice. This tentative working assumption is reinforced by the observation that stack downwash is most likely in strong winds.

Snyder and Lawson conclude that:

(i) the magnitude of the downwash at a given emission velocity ratio is greatest in sub-critical conditions, and

(ii) the algorithm described here is conservative for both sub- and super-critical conditions (i.e. it tends to over-predict stack downwash).

References

Hanna, S.R., Briggs, G.A. & Hosker, R.P. (1982) Handbook of Atmospheric Diffusion, U S Dept. of Energy Office of Scientific and Technical Information Publication DOE/TIC-11223.

Snyder, W.H. & Lawson, R.E. (1991) Fluid Modeling Simulation of Stack-Tip Downwash for Neutrally Buoyant Plumes. *Atmos. Environ.* **25A**, 2837-2850.