Texas Natural Resource Conservation Commission

INTEROFFICE MEMORANDUM

To:	NSRPD Staff	Date:	September 29, 1997
From:	Dom Ruggeri, Team Leader Air Dispersion Modeling Team		
Subject:	Modeling Emissions from Tilted Stacks		

Procedure

As part of our modeling technique refinement process, we have developed a new procedure for modeling emissions from tilted stacks. A tilted stack is defined as any stack that releases emissions into the atmosphere at any angle from the vertical greater than zero but less than or equal to 45 degrees.

Use the following parameters with both the SCREEN and ISC models, as applicable:

- Stack Velocity: For both SCREEN and ISC, set the velocity equal to the vertical velocity component, v_v. This component is calculated by multiplying the velocity provided by the applicant by the cosine (cos) of the offset angle from the vertical, or $v_v = v_s \cos \theta$.

- Stack Gas Exit Temperature:

  SCREEN. Set the exit temperature equal to the temperature provided by the applicant—or the default ambient temperature—if the temperature is given as "ambient."

  ISC. Set the exit temperature equal to the temperature provided by the applicant. Or set the exit temperature equal to 0 K if the temperature is given as "ambient" and the applicant means that the exit temperature will always equal the outside air temperature. Set the temperature to 293 K (68°F) if the applicant means that the exit temperature will always be equal to the "standard" temperature.

- Stack Diameter: For both SCREEN and ISC, set the diameter equal to the diameter provided by the applicant.

Background

Why did we make the change? The plume rise calculation algorithms in the SCREEN and ISC models are based on the assumption that emissions are released vertically. Under the old procedure we treated emissions from tilted stacks as if they were emitted horizontally—in other words, as fugitive emissions. The old procedure caused the models to over predict concentrations because it gave no credit for the vertical component of the stack gas exit velocity.

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Why did we limit the definition of tilted stack? *What if the angle is 46 degrees*? The use of this technique for tilted stacks with angles greater than 45 degrees will be considered on a case-by-case basis due to the potential effects of stack-tip downwash. As the angle increases, stack-tip downwash effects due to a vertical stack configuration are not appropriate, yet the model algorithms may calculate them. Our intent was to develop a more representative technique, so we need to be careful that we do not add back more conservatism than we removed.

What feature caused the models to over predict? The models over predicted the concentrations because potential plume rise due to momentum and buoyancy was set to zero. The models calculate momentum and buoyancy flux from the following equations:

$$F_m = (v_s^2 d_s^2) (T_a / 4 T_s) \text{ and } F_b = g v_s d_s^2 (T_s - T_a / 4 T_s)$$

where:

F_m = momentum flux (m^4/s^2).
F_b = buoyancy flux (m^4/s^2).
v_s = stack gas exit velocity (m/s).
d_s = stack diameter (m).
T_a = outside air temperature (K).
T_s = outside air temperature (K).
g = acceleration due to gravity (m/s^2).

The stack gas exit velocity (v_s) is a factor in each equation. The velocity has both a vertical and a horizontal component. Figure 1 depicts a simplified version of the relationship, where $v_v = v_s \cos \theta$ and $v_h = v_s \sin \theta$. For a vertical stack with unobstructed flow, $v_s = v_v$ since v_h equals zero.

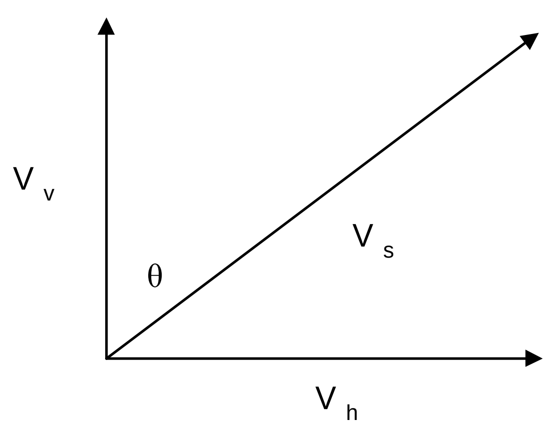

Figure 1

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For tilted stacks, the magnitude of v_v and v_h are both greater than zero. However, we would not expect that the horizontal component's contribution to plume rise would be as important in predicting concentrations as the reduction in the vertical momentum or buoyancy flux. Also, we ignored the horizontal component since friction effects and overall wind flow will limit plume rise.

How does the over prediction occur? The procedure to model emissions from non-vertical stacks as fugitive sources require stack parameters that cause the SCREEN and ISC models to calculate no plume rise. No plume rise means that the plume will stay at the height of release. For low-level stacks the resultant ground-level concentrations can be quite high. These lower plume heights can result in significant over predictions depending on the source height and the source distance from the property line and downwind receptors.

How did we fix this shortfall? By allowing for some of the vertical component of the stack gas velocity to be considered, we reduce the level of conservation in the predicted results. The magnitude of the vertical component can be calculated as approximately $v_v = v_s \cos \theta$, where, θ is the offset angle from the vertical direction of 45 degrees or less. This value is placed in the model as a substitute for the actual v_s. The value is approximate because there will be some minor losses due to friction as the gas moves through the bend in the stack.

For example, if $\theta = 25°$, then $\cos 25° = .906$. If $v_s = 32.8$ f/s (10 m/s), then $v_v = (32.8)(.906)$ or 29.7 f/s (9.06 m/s). As θ increases, the cosine of θ decreases which results in a lower value of v_v. For example, if the offset angle is 45°, $\cos 45° = .707$.

What will the difference in concentration be between the old procedure and the new procedure? The predicted concentrations will be lower. The centerline of the plume will be higher using the new procedure, thereby reducing the ground-level concentration to a more representative value.

For example, assume a 15-foot (4.57 m) stack tilted at 25° with an ambient exit temperature. Using SCREEN3, the predicted concentration with the new procedure may range from a value 19 percent lower than the predicted concentration using fugitive parameters and a velocity of 3.28 f/s (1 m/s), to as much as 84 percent lower for the same stack and a velocity of 32.8 f/s (10 m/s). As θ increases, there will not be as much difference between the procedures. As the values of v_v approach the default value used to model fugitive emissions, plume rise will be less, thereby increasing ground-level concentrations.

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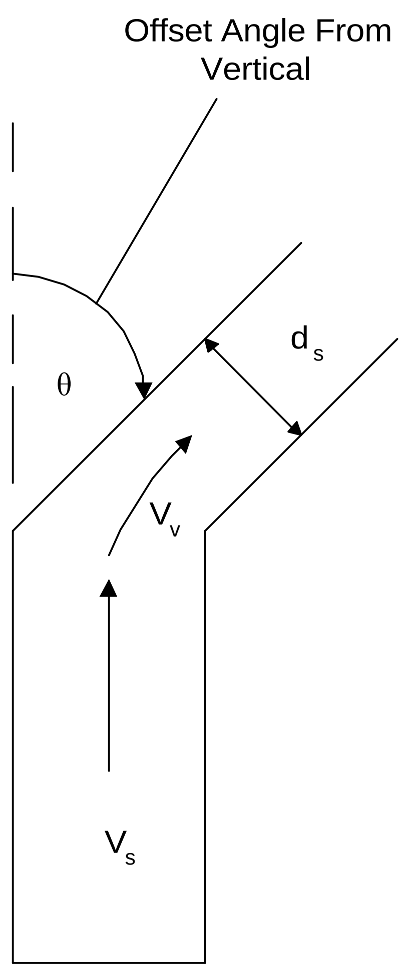

Figure 2