Reducing Stack Height – Understanding the Formation of Rooftop Re-circulation Regions

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Introduction

• The fundamental goal of stack design is to prevent contaminated exhaust from entering building air intake systems

• High volume flow and high exit velocity are common methods used to increase stack-to-intake dispersion

• This allows exhaust to escape roof top re-circulation zones, without significant increases in stack height
Introduction

- For specialty type exhaust stacks, low volume flow is often unavoidable
- Tall stacks may then be necessary to achieve the required dispersion
Introduction

- The re-circulation region that forms over the roof of tall rectangular buildings can be very large - *greater than 20 feet in many cases*

- It often engulfs the entire area of the roof

- This requires a combination of tall stacks, high flow rates and high exit velocity

- All of these scenarios can result in high energy costs
Presentation Outline

• Brief overview of how re-circulation regions are formed

• Discuss the concept of effective stack height as it relates to re-circulation regions

• Apply the concept of effective stack height to tall rectangular buildings using wind tunnel data to show that stack location can be optimized to increase exhaust dispersion

• Discuss the advantages for potential energy cost savings
and time permitting, discuss…

- Optimal air intake locations
- Impact of screen walls on re-circulation regions and exhaust dilution
Re-circulation Regions

Overview

- American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) provides guidance on stack design
- Prevent re-entrainment of contaminated air into building air intakes
- Discharge the exhaust at a height that is above the re-circulation region or “bubble” that forms over the roof
Re-circulation Regions

Zone 1 (Roof re-circulation region)
Zone 2 (High turbulence region)
Zone 3 (Roof wake boundary)

RECREATED FROM ASHRAE (1998) APPLICATIONS
Upwind Building Effects
Taller Upwind Building
Effective Stack Height
Short Squat Buildings
Tall Rectangular Buildings
Wind Tunnel Program

Designed to demonstrate that:

- A set-back penthouse on a tall rectangular building results in a smaller and more streamlined re-circulation bubble

- A stack located on the upwind side of the bubble has more effective stack height

- Both effects provide increased exhaust dilution at rooftop receptors
Test Parameters

- Two stack locations (A and B)
- Full scale stack heights 10, 15, 20 and 25 feet above roof
- Full scale building heights 60, 80 and 100 feet
- Full scale building footprint 160 feet by 80 feet
Test Parameters

- Non-buoyant plume, low volume flow rate (1,300 cfm) and high exit velocity (3,000 fpm)
- Full plume bend over was achieved
- Seven rooftop receptors and one down wind side wall receptor
Summary of Building Configurations
Study Buildings
Effects of Roof Step
Stack A – 15 foot

Block Roof

Stepped Roof
Effects of Stack Location
Stack B – Block Roof

10 foot stack

15 foot stack
Stack B

10 foot stack block roof

10 foot stack stepped roof
Stack B – Stepped Roof

Stack Plume

Re-circulation boundary
Discussion

• If a stack can be located so that you don’t need:
  – Significant additional height
  – The provision of induced air
  – Increased exit velocity

• Then the system can be designed to provide more operational efficiency, such as reduced design requirements for exhaust fans

• This can lead to operational savings
Conclusions

• Exhaust stacks can be moved up stream of the re-circulation bubble to increase effective stack height and dilutions

• Stepped back roof helps to reduce bubble height, providing increased effective stack height

• Bubble is also shifted downwind from the stacks also increasing effective stack height

• Increasing effective stack height provides operational flexability
Summary of the Results

Location B is better than location A in all cases.

Set-back roof is better than no set-back roof in all cases.

Taller stacks required for screen wall in all cases.
Intake Locations
Still from video
Still from video
Questions .......