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Reputation Resources Results

TECHNOTES

ISSUE NO. 29

OPTIMIZING EXHAUST STACK DESIGN AND PLACEMENT

Using Recirculation Zones, Dilution, and the New RWDI Desktop Dilution Calculator to Limit Contamination of Air Intakes

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INTRODUCTION

The optimal design and placement of exhaust stacks to limit contamination of air intakes and other sensitive locations can be a considerable challenge. Buildings may have several different exhaust types that discharge a variety of contaminants, presenting both health and odor concerns. Often, misconceptions exist that attribute health effects to odors or cause the assumption that a health concern does not exist simply because there is no odor.

This Technote guides you through the importance of rooftop recirculation zones in exhaust stack / intake design. The concept of exhaust dilution is also explained, showing how it can be used as a tool to assess re-entrainment of exhaust at building intakes or sensitive areas. General guidance is provided at the end of this technote to assist in the early stages of building design.

A new and innovative tool, the "RWDI Desktop Dilution Calculator" (page 3) can be used to assist building designers to design, locate, and assess exhaust stacks and intakes early in the design process. The calculator is available free of charge directly from RWDI (visit www.rwdi.com/ddc/).

Often, exhaust streams are re-entrained at outside air intakes without anyone knowing. In this photo, colored dye shows just that.

The RWDI Desktop Dilution Calculator is a free screening-level tool created to help building designers evaluate both existing and proposed exhaust designs.

ROOFTOP RECIRCULATION ZONES

One of the most prominent issues affecting exhaust dispersion is the effect of recirculation zones on buildings. Winds striking the face of a building will separate over the top, re-attaching at the building rooftop or some farther point downwind. This separated zone is called the "recirculation zone". Figure 1 illustrates a recirculation zone and the effect it can have on exhaust plumes.

This recirculation zone on the roof will trap exhaust that is discharged within it. In this scenario, contaminants will accumulate within the zone resulting in high concentrations and low levels of dilution. It is desirable to design stacks that discharge above these recirculation zones.

Sometimes, a stack discharging within a recirculation zone may be deemed acceptable if the separation distance to air intakes or other locations of concern is far enough or if the contaminant source concentration is low enough. Commonly, stacks discharging, at least as high as the tallest local recirculation zone, are required. If short stacks located within a recirculation zone cannot be avoided, then outside air intakes should be placed out of the zone as far away as is practical. The RWDI Desktop Dilution Calculator can be used as a conservative screening-level tool to help specify the required separation distance.

In most cases, a consultation on the exhaust and intake design from the perspective of exhaust re-entrainment is valuable. Such a consultation can provide insight to design strategies aimed at reducing the level of exhaust re-entrainment.

DEFINING DILUTION AND CRITERIA FOR DESIGN

When exhaust is discharged from a stack, it has a certain initial source concentration (C_o). As the exhaust travels, it undergoes atmospheric mixing and dispersion, mixing with clean air, which reduces the concentration (C). If the concentration were measured at some point down wind, it would be lower than at the source. Dilution (D) is the ratio by which the exhaust concentration is reduced from the stack to the point of measurement.

$$D = C_o/C$$

The goal in exhaust stack design is to ensure that contaminant concentrations are reduced sufficiently to ensure that no applicable health limits are exceeded and odors are reduced to acceptable levels.

Dilution is a very simple measure that can be used to establish design criteria for various source types to assess the performance of an exhaust stack. Dilution is a particularly useful measure when numerous contaminants are or can be emitted from the same stack. Since the source concentrations of the various contaminants are typically known (or easily found), they can be compared to applicable air quality standards or limits (C_{limit}).

Once all of the specific standards or limits are known, there will be a level of dilution for which the applicable standards and limits are met for each contaminant. The highest of these dilutions is typically used as a criterion to assess the adequacy of an exhaust stack. This is called a 'Dilution Criterion'.

$$D_{required} = C_o/C_{limit}$$

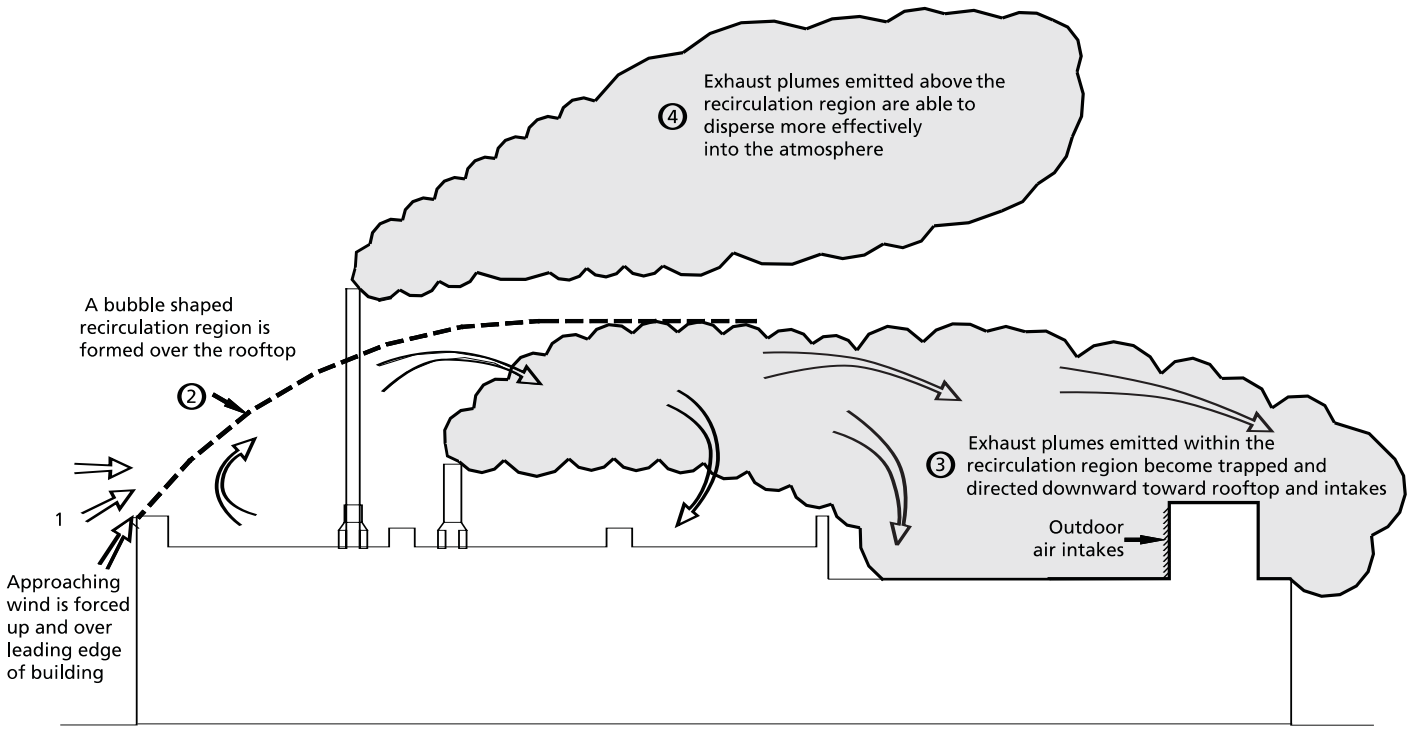


Figure 1: Effects of rooftop re-circulation zones on exhaust plumes.

Many different exhaust sources that exist on buildings can be of concern (e.g., emergency generators, boilers, idling diesel vehicles, biosafety cabinets, specialty chemical and process exhausts, etc.). Many of these sources require a dilution criterion to be determined on a case-by-case basis. RWDI generally applies the following source-specific targets based on typical operating conditions and extensive project experience:

Laboratory Fume Hood	> 3,000:1
Cooling Tower	> 20:1
Animal Holding Rooms and Vivaria (Odors)	> 100:1
Commercial Kitchens (Odors)	> 600:1
Diesel Engines (Odors)	> 4,000:1

Table 1: Summary of dilution criteria for exhaust sources.
* Dilution criterion for laboratory fume hood exhaust based on requirements for approximately 90% of a list of over 300 chemicals compiled by RWDI from past projects. Criterion can vary widely based on specific chemical usage (e.g., 1,000:1 to > 100,000:1). A review of specific chemicals used at the facility is recommended.

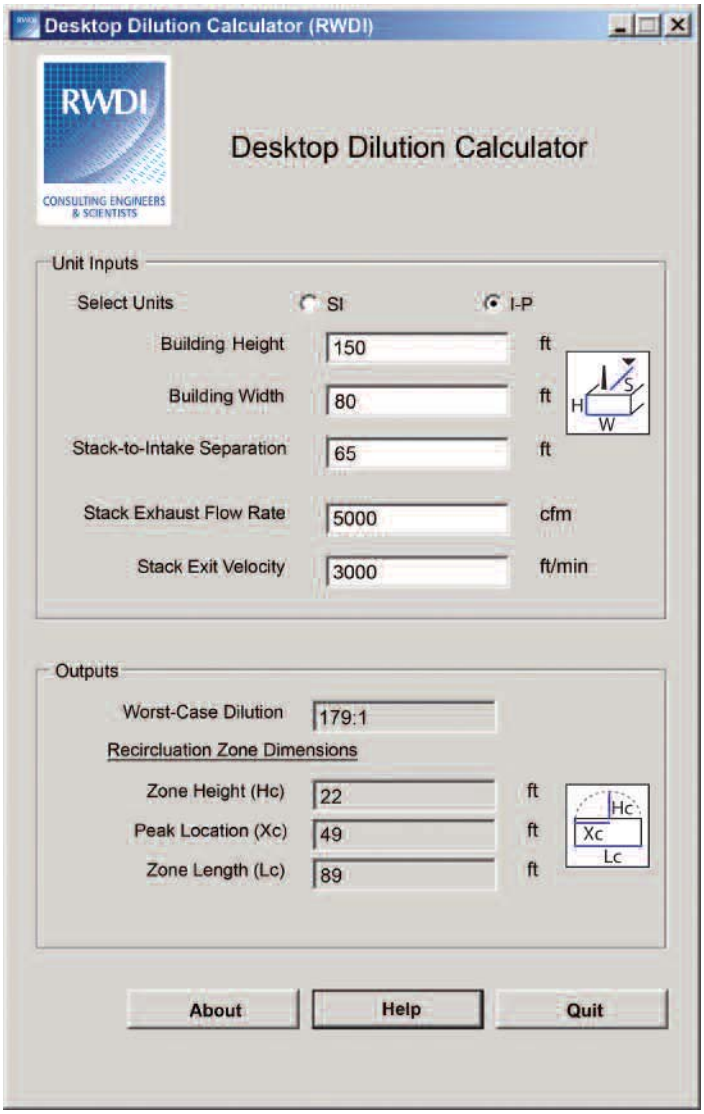


Figure 2: The RWDI Desktop Dilution Calculator user interface

USING THE RWDI DESKTOP DILUTION CALCULATOR

Early in the design process, it is beneficial to determine some approximate exhaust and intake locations. To aid in this process, RWDI has developed a tool that can be used for simple buildings called the "RWDI Desktop Dilution Calculator" (Figure 2).

The Desktop Dilution Calculator is a conservative screening-level tool intended to make conservative 'first cut' dilution and recirculation zone estimates to aid in the design process. More detailed modeling may be required to achieve an optimum design in minimizing exhaust re-entrainment impacts.

Using the dilution estimate furnished by the Calculator, building designers can compare either to dilution criteria, or use the dilution to furnish 'concentration at intake' estimates. These estimates can be derived by dividing the source concentration of a particular contaminant by the dilution (i.e., $C = C_o/D$). If the concentration at the air intake is higher than applicable air quality limits, more detailed modeling should be pursued.

The estimates are based on the Building Wake Dispersion equations published in the ASHRAE HVAC Applications Handbook. The only information that a user is required to input into the Calculator is:

- Stack exit velocity (V)
- Stack exhaust flow rate (Q)
- Stack-to-intake separation distance (S)
- Building dimensions (height, h and width, w)

Figure 3 illustrates a simple building layout showing the required input parameters.

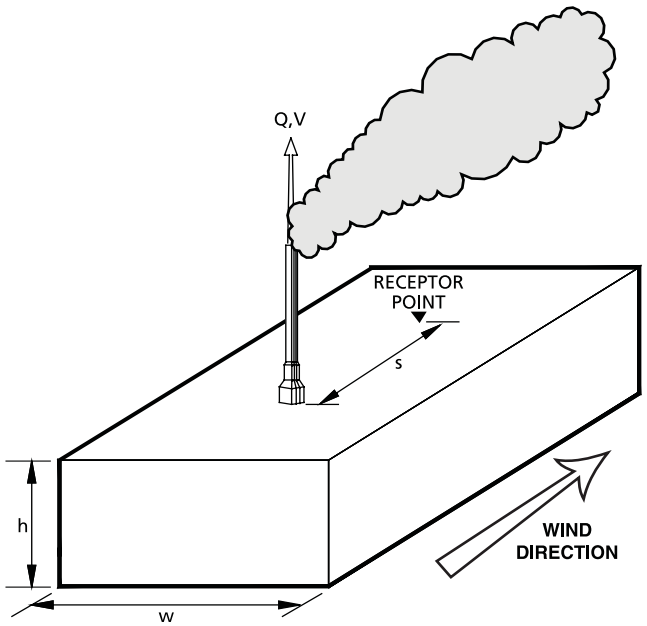


Figure 3: Basic input model for the RWDI Desktop Dilution Calculator

GUIDELINES FOR IMPROVING DISPERSION OF EXHAUST

To achieve a high level of atmospheric dispersion and, therefore, high dilution, the following design features should be considered:

1. Maximize Stack Height
   - This is best accomplished by placing stacks at the highest point on the building.
   - Ensure stack discharge is above rooftop recirculation zones.
2. Maximize Separation Distance to Intakes or Sensitive Locations
3. Maximize Exit Velocity and Vertical Momentum
   - Reduce exit diameter, or increase exhaust flow rate by adding clean air to the exhaust stream.
   - Avoid top-mounted rain caps that eliminate vertical momentum.
   - Avoid horizontal discharge.
4. When appropriate dilution cannot be achieved, other options exist to reduce contaminant concentrations in exhaust streams using either controls or manifolding.
   - Controls can include exhaust scrubbers, electrostatic precipitators, filters, etc.
   - Manifolding with clean, uncontaminated air provides the benefit of pre-dilution (or internal dilution) prior to discharge. This can also be accomplished by using bypass air.

Stack design is often a compromise between maximizing exhaust dispersion and the practical confines of building design. Capital budgets, operating expenses, and aesthetics must be balanced with good stack design. As a minimum, a stack design must provide sufficient dilution to satisfy applicable health standards and limits. Odors are far more subjective. They can often pose a significant nuisance issue.

To obtain a copy of the RWDI Desktop Dilution Calculator free of charge, visit www.rwdi.com/ddc/.

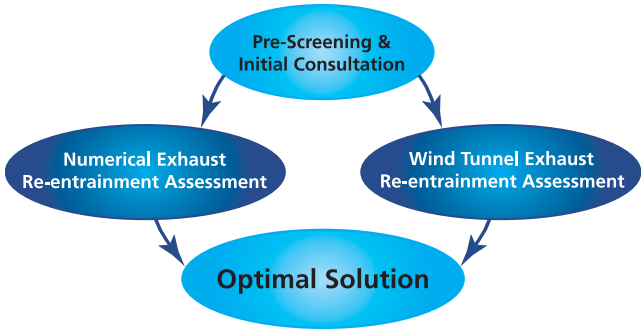
THE IMPORTANCE OF EARLY DESIGN CONSULTATION

The location and design of exhaust stacks should be assessed prior to the completion of design drawings to ensure that applicable dilution criteria are met. An initial design consultation is useful to provide early feedback and provide recommendations of the type of assessment most beneficial for the design. The assessments include Numerical Dispersion for single building geometry or a more detailed and accurate Wind Tunnel Study. At this point, other services offered by RWDI can be scoped to provide guidance on critical aspects of the design.

The assessment of the proposed stack designs and locations is best performed during the initial stages of the building design when there is flexibility in the mechanical and architectural designs. At this point, solutions can be discussed with the design team to ensure they are practical.

MAKING IT SIMPLE...

An **Initial Consultation** with RWDI's design team is beneficial to provide early feedback typically during the schematic design stage. Our experienced consultants will recommend proceeding with either a **Numerical Exhaust,** Physical **Wind Tunnel Exhaust,** or a combination of both to provide the maximum cost / benefit advantage.



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