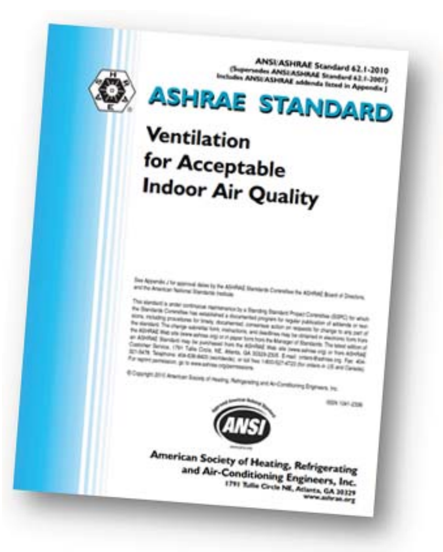
# Trane Engineers Newsletter Live

## ASHRAE Standard 62.1

*Presenters: Paul Solberg, Dennis Stanke, John Murphy, Jeanne Harshaw (host)*



# Agenda

## ASHRAE Standard 62.1

Presenters: Paul Solberg, Dennis Stanke, John Murphy, Jeanne Harshaw (host)

The 2010 version of ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, will likely be the basis for the next version of the International Mechanical Code (IMC), and is expected to be a prerequisite for version 4 of the LEED® Green Building Rating System (to be published in late 2013). This ENL will provide an overview the 2010 version of the standard, and then focus on the calculations of zone and system ventilation airflows according to the standard's Ventilation Rate Procedure.

Viewer learning objectives

1. Understand the relationship between ASHRAE Standard 62.1 and mechanical codes, standards, or building rating systems
2. Learn how to perform zone- and system-level ventilation calculations required by the standard's Ventilation Rate Procedure
3. Identify methods of dynamically resetting outdoor airflow to reduce energy use and maintain acceptable IAQ

Agenda

Welcome,  introduction

ASHRAE Standard 62.1 Overview

- a) Highlights
- b) Realationship of the standard to the IMC,LEED IEQp1 and ASGHRAE 189.1
- c) Introduction to the three procedures in Section 6
- d) Ventilation Rate Procedure

Zone Calculations

- a) Table of ventilation rates
- b) Air distribution effectiveness
- c) LEED IEQc2 requirements

System calculations

- a) Introduce different system types
- b) Single-zone system…review steps and show example
- c) 100% OA system…review steps and show example
- d) Multiple-space, recirculating system…review steps and show example
- e) Compare example results for all four system types

Dynamic reset strategies

- a) Introduce dynamic reset (part-load operation) requirements of ASHRAE 90.1 and 62.1
- b) Demand-controlled ventilation (based on changing Pz)
- c) Ventilation reset (based on changing Ev)

Review of Section 4.0 and 5.0 requirements

Population averaging (Section 6.2.6)

Appendix A calculations for multiple-space, dual-path recirculating system

# Presenter Biographies

**February 2013**

*ASHRAE Standard 62.1*

## Dennis Stanke, staff applications engineer, Trane

With a BSME from the University of Wisconsin, Dennis joined Trane in 1973, as a controls development engineer. He is now a Staff Applications Engineer specializing in airside systems including controls, ventilation, indoor air quality, and dehumidification. He has written numerous applications manuals and newsletters, has published many technical articles and columns, and has appeared in many Trane *Engineers Newsletter Live* broadcasts.

An ASHRAE Fellow, he currently serves as Chairman for ASHRAE Standard 189.1, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*. He recently served as Chairman for ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, and he served on the USGBC LEED Technical Advisory Group for Indoor Environmental Quality (the LEED EQ TAG).

## Paul Solberg, applications engineer, Trane

A mechanical engineer from the University of Wisconsin at Platteville, Paul is a 33-year veteran of Trane. He specializes in compressor and refrigeration systems, and has authored numerous Trane publications on these subjects, including application manuals, engineering bulletins, and Engineers Newsletters.

Paul served in the technical service and applications engineering areas at various manufacturing locations, where he developed particular expertise supporting split systems, small packaged chillers, rooftop air conditioners, and other unitary products.

## John Murphy, applications engineer, Trane

John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. As a LEED Accredited Professional, he has helped our customers and local offices on a wide range of LEED projects. His main areas of expertise include energy efficiency, dehumidification, dedicated outdoor-air systems, air-to-air energy recovery, psychrometry, and ventilation.

John is the author of numerous Trane application manuals and Engineers Newsletters, and is a frequent presenter on Trane's Engineers Newsletter Live series. He also is a member of ASHRAE, has authored several articles for the ASHRAE Journal, and has been a member of ASHRAE's "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. He was a contributing author of the Advanced Energy Design Guide for K-12 Schools and the Advanced Energy Design Guide for Small Hospitals and Health Care Facilities, a technical reviewer for the ASHRAE Guide for Buildings in Hot and Humid Climates, and a presenter on the 2012 ASHRAE "Dedicated Outdoor Air Systems" webcast.

# Bibliography

**February 2013**

***ASHARE Standard 62.1***


## Industry Standards

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# ASHRAE Standard 62.1

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### learning objectives

## After today's program you will be able to:

- Understand the relationship between ASHRAE Standard 62.1 and mechanical codes, standards, or building rating systems
- Learn how to perform zone- and system-level ventilation calculations required by the standard's Ventilation Rate Procedure
- Identify methods of dynamically resetting outdoor airflow to reduce energy use and maintain acceptable IAQ

# Today's Presenters

**Dennis Stanke**
**Applications Engineer**

**Paul Solberg**
**Applications Engineer**

**John Murphy**
**Applications Engineer**

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# Agenda

- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone calculations
  - System calculations
- Exhaust ventilation
- Dynamic reset strategies

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## Supplemental Material (DVD or Online)

- Review of Section 4.0 and 5.0 requirements
- Design for varying operating conditions
- VRP calculations for systems with a secondary recirculation air path


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## Agenda

- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone calculations
  - System calculations
- Exhaust ventilation
- Dynamic reset strategies

## ASHRAE Standard 62.1-2010
# Ventilation for Acceptable IAQ

| | |
|---|---|
| 1.0 | Purpose |
| 2.0 | Scope |
| 3.0 | Definitions |
| 4.0 | Outdoor air quality |
| 5.0 | Systems and equipment |
| 6.0 | Procedures |
| 7.0 | Construction and system start-up |
| 8.0 | Operations and maintenance |
| App A | Multiple-zone systems |


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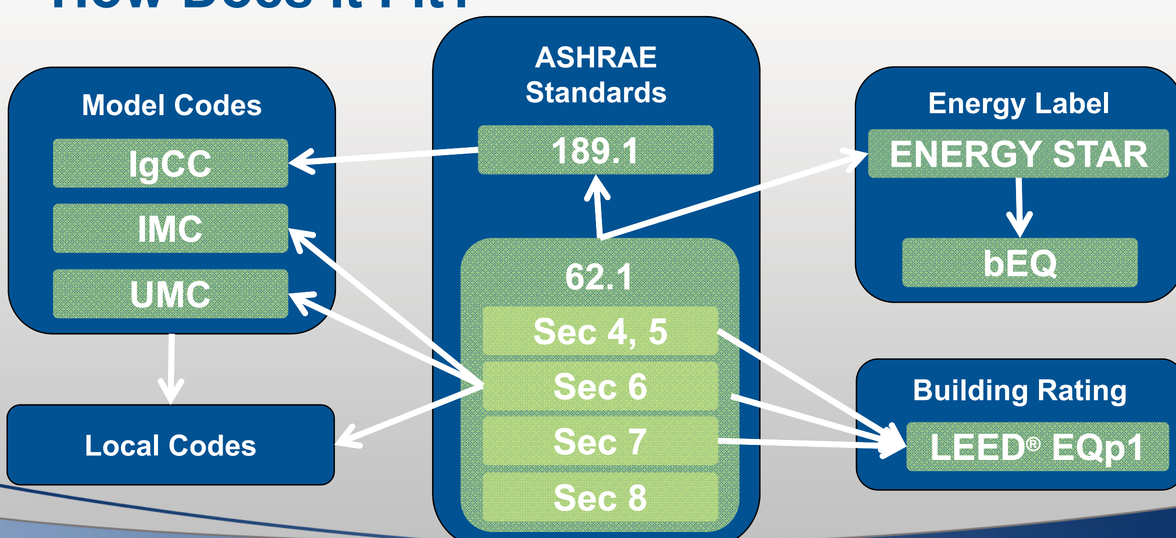
## Standard 62.1
# How Does It Fit?

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## Standard 62.1
# How Does It Fit?

| Standard/Code/Label/Rating | Standard 62.1 Sections Required |
|---|---|
| ASHRAE Standard 189.1 | Sections 4 - 8 |
| IMC, UMC | Section 6 (VRP rates & procedures) |
| IgCC | Sections 4 - 8 (in Standard 189.1 path) |
| ENERGY STAR label | Sections 4 - 8 |
| ASHRAE bEQ label | Sections 4 - 8 (via ENERGY STAR) |
| LEED certification | Sections 4 - 7 |

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## ASHRAE Standard 62.1-2010
# Table of Contents

1.0 Purpose
2.0 Scope
3.0 Definitions
4.0 Outdoor air quality
5.0 Systems and equipment
6.0 Procedures
7.0 Construction and system start-up
8.0 Operations and maintenance
App A Multiple-zone systems


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## Section 6.0
# Procedures

6.1 General
6.2 Ventilation rate procedure
6.3 Indoor air quality (IAQ) procedure
6.4 Natural ventilation procedure
6.5 Exhaust ventilation
6.6 Documentation

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## Section 6.2
# Ventilation Rate Procedure

- Find:
  1. Zone outdoor airflow based on prescribed rates
  2. System outdoor air intake flow using prescribed calculation procedures

Prescribed values from tables + Prescribed equations = Zone and intake OA rates

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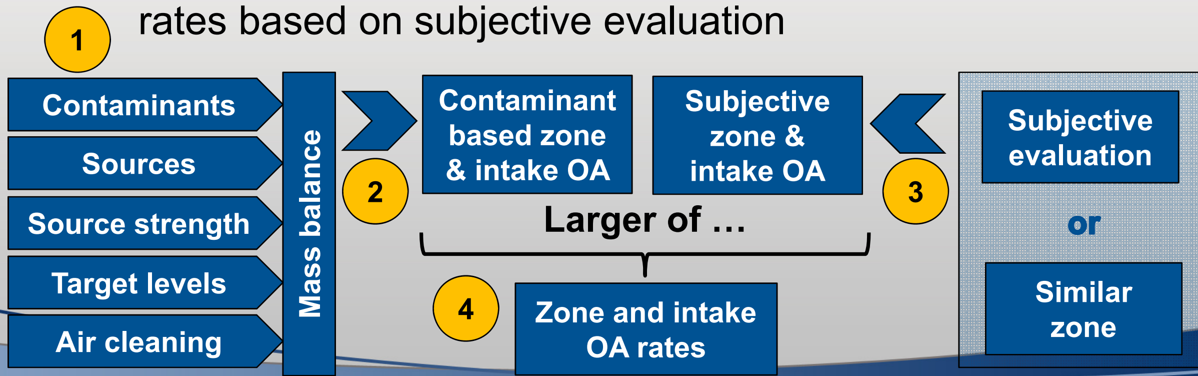
## Section 6.3
# Indoor Air Quality Procedure

- Find zone and/or intake OA rate:
  - As larger of OA rates based on contaminant levels or rates based on subjective evaluation



## Section 6.4
# Natural Ventilation Procedure

- Include mechanical ventilation systems designed in accordance with the VRP or IAQP
- Find maximum NV distance from OA opening, based on opening location and ceiling height (e.g., with one opening & 9 ft. ceiling, NV distance = 2H = 2 × 9 = 18 ft.)
- Find outdoor-opening area ≥ 4% floor area
- Provide accessible means to operate opening and controls to coordinate NV/MV operation (“mixed mode”)

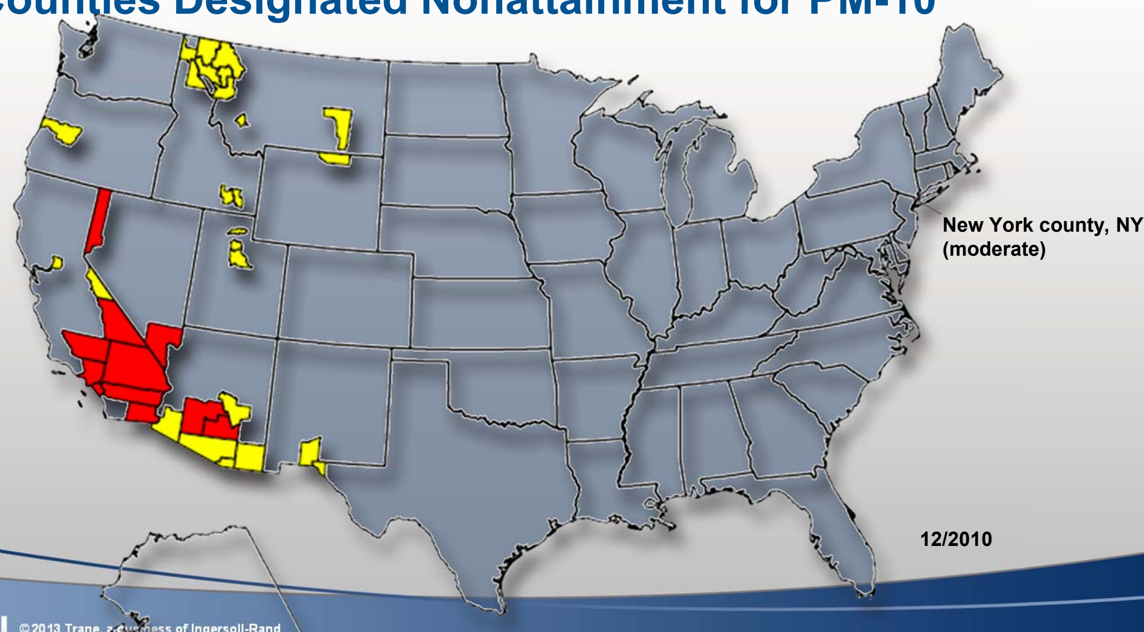
 

Section 6.2
## Ventilation Rate Procedure

6.2.1 Outdoor air treatment
6.2.2 Zone calculations
6.2.3 Single-zone systems
6.2.4 100% outdoor air systems
6.2.5 Multiple-zone recirculating systems
6.2.6 Design for varying operating conditions
6.2.7 Dynamic reset

## Counties Designated Nonattainment for PM-10




PM-2.5 Nonattainment Areas (2006 Standard)
04/2011
21
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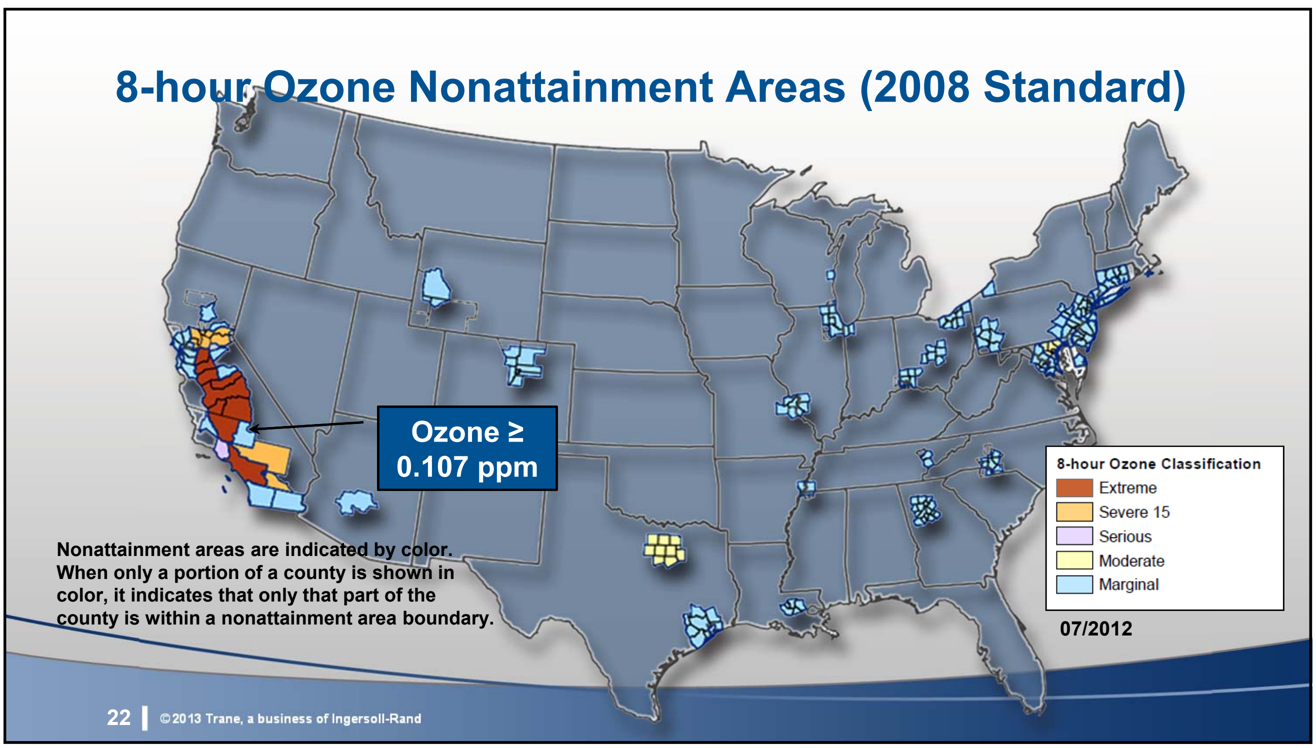
8-hour Ozone Nonattainment Areas (2008 Standard)
Ozone ≥ 0.107 ppm
Nonattainment areas are indicated by color. When only a portion of a county is shown in color, it indicates that only that part of the county is within a nonattainment area boundary.
8-hour Ozone Classification
Extreme
Severe 15
Serious
Moderate
Marginal
07/2012
22
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## Section 6.2.1
# References

PM2.5

- http://www.epa.gov/oar/oaqps/greenbk/rindex.html
- http://www.epa.gov/oar/oaqps/greenbk/mappm25_2006.html

PM10

- http://www.epa.gov/oar/oaqps/greenbk/pindex.html
- http://www.epa.gov/oar/oaqps/greenbk/mappm10.html

Ozone

- http://www.epa.gov/oar/oaqps/greenbk/hindex.html
- http://www.epa.gov/oar/oaqps/greenbk/map8hr_2008.html

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# Agenda

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- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone calculations
  - System calculations
- Exhaust ventilation
- Dynamic reset strategies

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## Section 6.2
# Ventilation Rate Procedure

- Zone calculations
  - Determine breathing-zone outdoor airflow for each zone, based on prescribed rates in Table 6-1
- System calculations
  - Calculate outdoor-air intake flow for the entire system, based on prescribed calculation procedures




## Section 6.2.2
# Zone Calculations

1. Calculate outdoor airflow to the breathing zone, using Table 6-1 rates

   $V_{bz} = R_p \times P_z + R_a \times A_z$

2. Determine zone air-distribution effectiveness, $E_z$

   **Look up $E_z$ in Table 6-2**

3. Calculate outdoor airflow to the zone

   $V_{oz} = V_{bz}/E_z$

## Excerpt from Table 6-1
# Minimum Ventilation Rates

| Occupancy category | $R_p$ cfm/p | $R_a$ cfm/ft² |
|---|---|---|
| **Office** | **5.0** | **0.06** |
| **Classroom** (ages 5-8) | **10.0** | **0.12** |
| **Lecture classroom** | **7.5** | **0.06** |
| **Retail sales** | **7.5** | **0.12** |
| **Auditorium** | **5.0** | **0.06** |
| **Religious Worship** | **5.0** | **0.06** |
| **Motel room** | **5.0** | **0.06** |




## Section 6.2.2
# Zone Calculations

1. Calculate outdoor airflow to the breathing zone, using Table 6-1 rates

   $$V_{bz} = R_p \times P_z + R_a \times A_z$$

2. Determine zone air-distribution effectiveness, $E_z$

   **Look up $E_z$ in Table 6-2**

3. Calculate outdoor airflow to the zone

   $$V_{oz} = V_{bz}/E_z$$

Section 6.2.2
## Zone Calculations

1. Calculate outdoor airflow to the breathing zone, using Table 6-1 rates

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

$R_p$ = outdoor airflow rate required per person, cfm/p

$R_a$ = outdoor airflow rate required per unit area, cfm/ft²

$P_z$ = zone population (largest expected quantity)

$A_z$ = zone floor area (net occupiable area), ft²

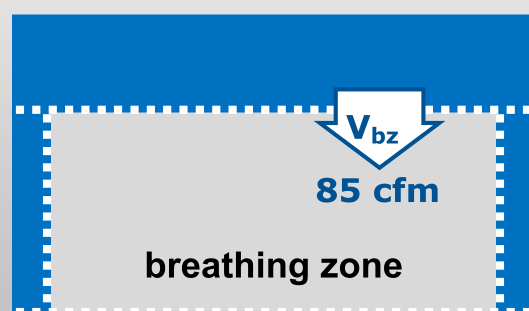


## Breathing-Zone Outdoor Airflow

**Example:**
Office space

- $R_p$ = 5 cfm/person
- $R_a$ = 0.06 cfm/ft²
- $P_z$ = 5 people
- $A_z$ = 1000 ft²

$$V_{bz} = R_p \times P_z + R_a \times A_z$$
$$= 5 \times 5 + 0.06 \times 1000$$
$$= 25 \text{ cfm} + 60 \text{ cfm}$$
$$= 85 \text{ cfm}$$





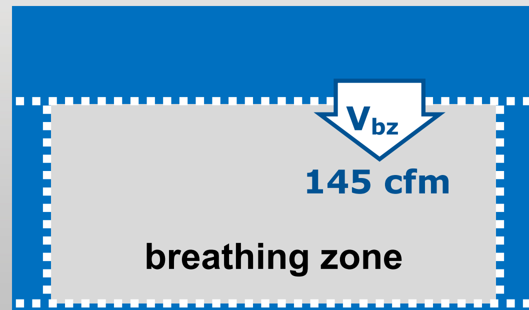

 

## Breathing-Zone Outdoor Airflow

**Example:**
Conference room

- $R_p$ = 5 cfm/person
- $R_a$ = 0.06 cfm/ft²
- $P_z$ = 17 people
- $A_z$ = 1000 ft²

$$
\begin{aligned}
V_{bz} &= R_p \times P_z + R_a \times A_z \\
&= 5 \times 17 + 0.06 \times 1000 \\
&= 85 \text{ cfm} + 60 \text{ cfm} \\
&= 145 \text{ cfm}
\end{aligned}
$$

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Section 6.2.2
## Zone Calculations

1. Calculate outdoor airflow to the breathing zone, using Table 6-1 rates
   $V_{bz} = R_p \times P_z + R_a \times A_z$
2. Determine zone air-distribution effectiveness, $E_z$
   **Look up $E_z$ in Table 6-2**
3. Calculate outdoor airflow to the zone
   $V_{oz} = V_{bz}/E_z$

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| Supply | Return | SA temperature | $E_z$ |
|---|---|---|---|
| Ceiling | Ceiling or floor | Cool | 1.0 |
| Ceiling | Floor | Warm | 1.0 |
| Ceiling | Ceiling | Warm ($< T_{space}$ + 15°F) | 1.0 |
| Ceiling | Ceiling | Hot ($> T_{space}$ + 15°F) | 0.8 |
| Floor | Ceiling | Cool (underfloor air distr) | 1.0 |
| Floor | Ceiling | Cool (displacement) | 1.2 |
| Floor | Ceiling | Warm | 0.7 |
| Floor | Floor | Warm | 1.0 |
| Makeup air drawn in, return/exhaust at opposite side of room | | | 0.8 |
| Makeup air drawn in, return/exhaust near supply | | | 0.5 |

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Section 6.2.2

## Zone Calculations

1. Calculate outdoor airflow to the breathing zone, using Table 6-1 rates

   $$V_{bz} = R_p \times P_z + R_a \times A_z$$

2. Determine zone air-distribution effectiveness, $E_z$

   **Look up $E_z$ in Table 6-2**

3. Calculate outdoor airflow to the zone

   $$V_{oz} = V_{bz}/E_z$$

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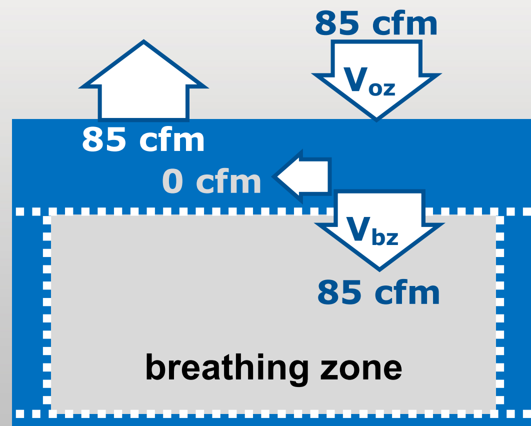
## Zone Outdoor Airflow

**Example:**
Office space with overhead cooling ($E_z$ = 1.0)

$$V_{oz} = V_{bz}/E_z = 85/1.0 = 85 \text{ cfm}$$

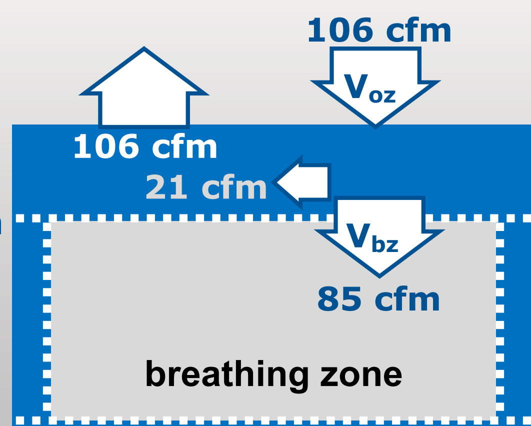


## Zone Outdoor Airflow

**Example:**
Office space with overhead heating ($E_z$ = 0.8)

$$V_{oz} = V_{bz}/E_z = 85/0.8 = 106 \text{ cfm}$$



| Supply | Return | SA temperature | $E_z$ | $V_{oz}$ |
|---|---|---|---|---|
| Ceiling | Ceiling or floor | Cool | 1.0 | 85 |
| Ceiling | Floor | Warm | 1.0 | 85 |
| Ceiling | Ceiling | Warm (< $T_{space}$ + 15°F) | 1.0 | 85 |
| Ceiling | Ceiling | Hot (> $T_{space}$ + 15°F) | 0.8 | 106 |
| Floor | Ceiling | Cool (underfloor air distr) | 1.0 | 85 |
| Floor | Ceiling | Cool (displacement) | 1.2 | 71 |
| Floor | Ceiling | Warm | 0.7 | 121 |
| Floor | Floor | Warm | 1.0 | 85 |
| Makeup air drawn in, return/exhaust at opposite side of room | | | 0.8 | 106 |
| Makeup air drawn in, return/exhaust near supply | | | 0.5 | 170 |

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# Agenda

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- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone calculations
  - System calculations
- Dynamic reset strategies

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## Section 6.2
# Ventilation Rate Procedure

- Zone calculations
  - Determine breathing-zone outdoor airflow for each zone, based on prescribed rates in Table 6-1
- System calculations
  - Calculate outdoor-air intake flow for the entire system, based on prescribed calculation procedures

## Section 6.2
# Ventilation System Configurations

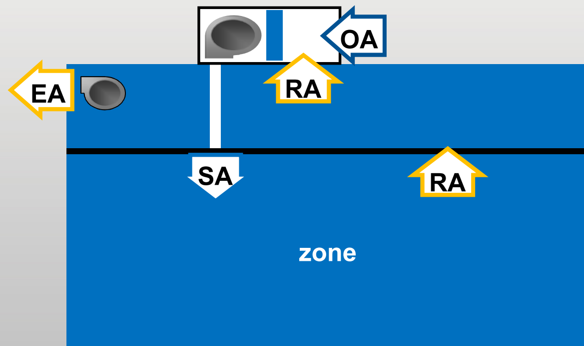
- Single-zone systems
  - One air handler serving one zone
- 100% outdoor air systems
  - One air handler serving many zones (no recirculation)
- Multiple-zone recirculating systems
  - One air handler serving many zones (with recirculation)

## Single-Zone System

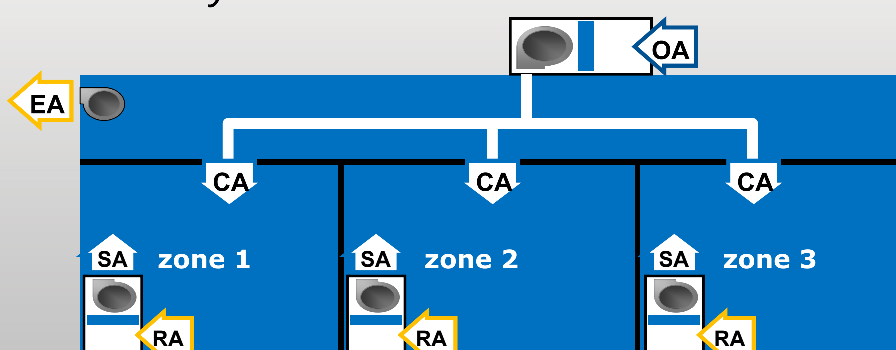
One air handler brings in OA through one intake and distributes it to a single zone



## 100% Outdoor-Air System

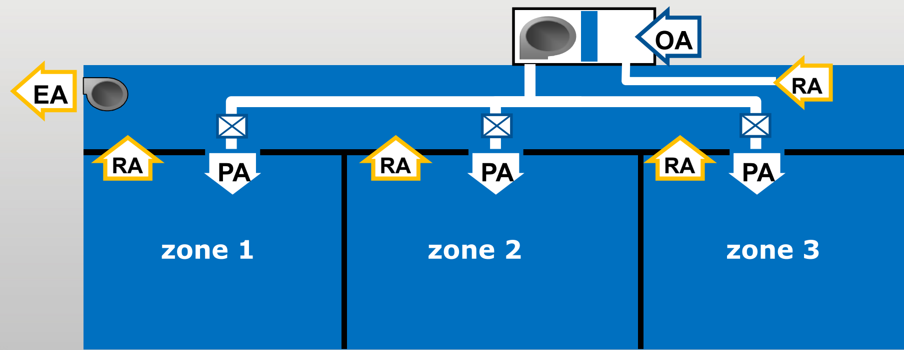
One air handler brings in OA through one intake and distributes *only* OA to more than one zones



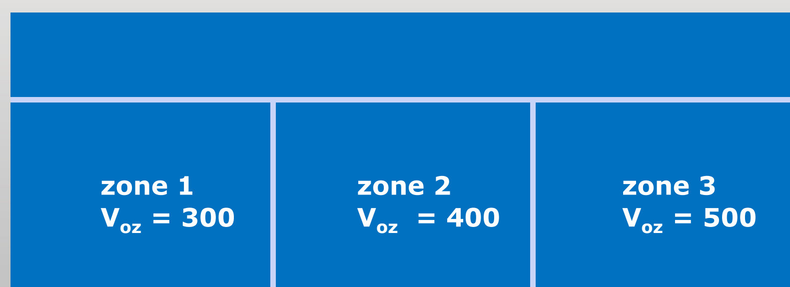
## Multiple-Zone Recirculating System

One air handler brings in OA through one intake, mixes it with recirculated air, and distributes the mixture to more than one zone



### example
## Simple Three-Zone Building

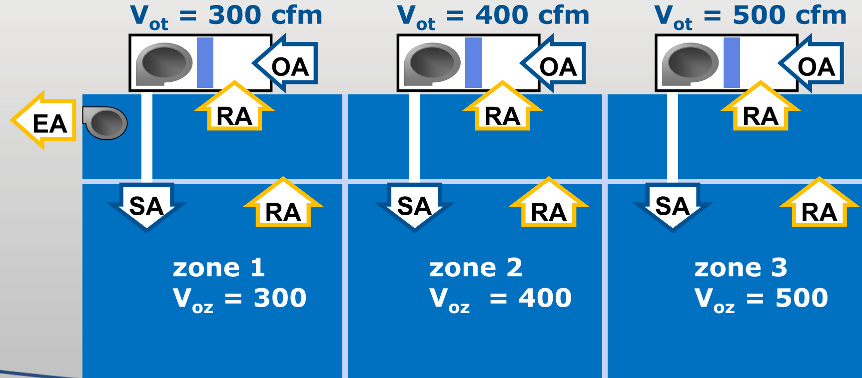


## Section 6.2.3
# Single-Zone System

Find the required outdoor-air intake flow for the system ($V_{ot}$):

$V_{ot} = V_{oz}$

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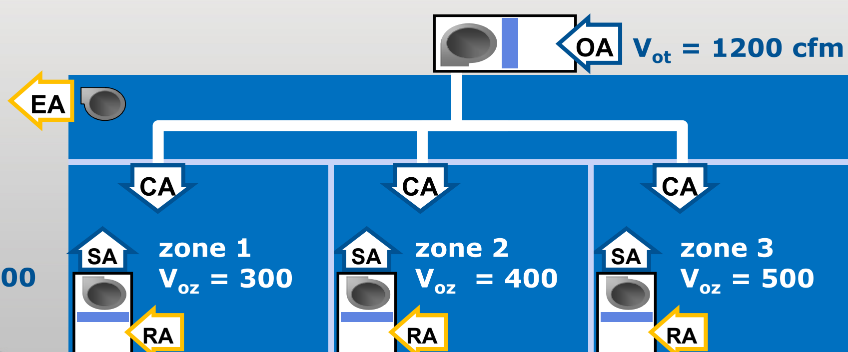
## Section 6.2.4
# 100% OA System

Find the required outdoor-air intake flow for the system ($V_{ot}$):

$V_{ot} = \sum V_{oz}$




= 300 + 400 + 500
= 1200 cfm

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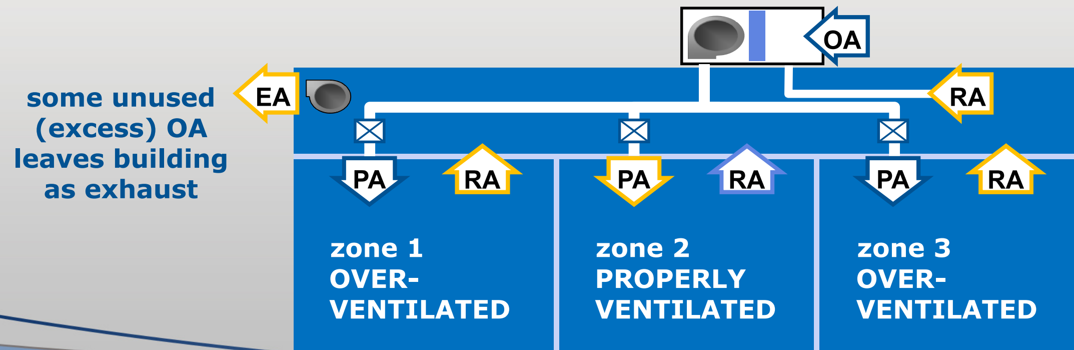
## Section 6.2.5
# Multiple-Zone Recirculating System

All zones receive the same percentage of OA, resulting in some zones being over-ventilated

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# System Ventilation Efficiency

Find system ventilation efficiency ($E_v$) using either:

- Table 6-3, “default” $E_v$ method

  or

- Appendix A, calculated $E_v$ method

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section 6.2.5
## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

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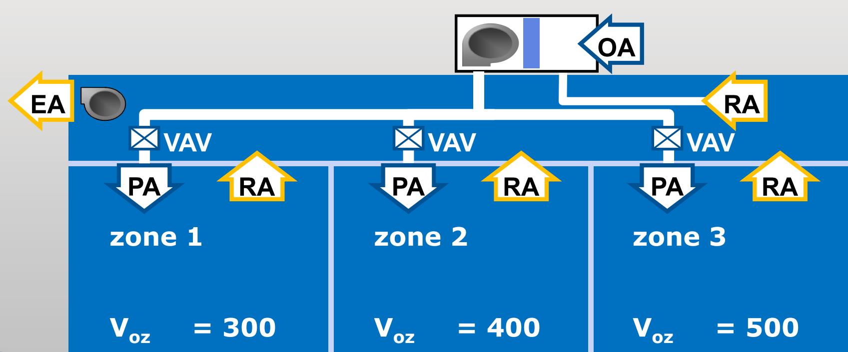
example
## Single-Path VAV System




50 

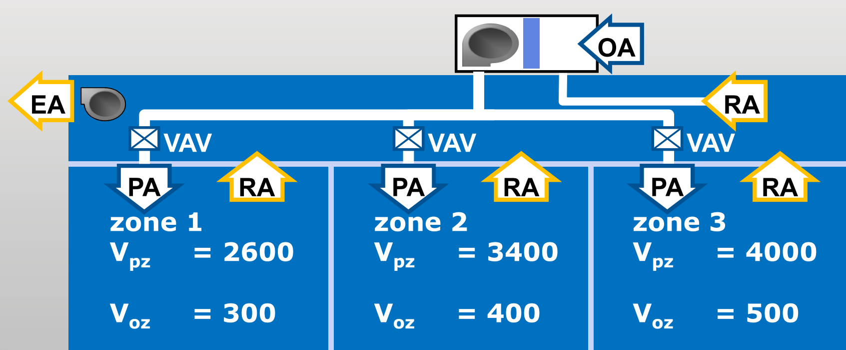
### section 6.2.5
## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

51 | 

### example: single-path VAV system (cooling mode)
## Calculating Zone Outdoor Air Fraction

$$Z_{pz} = V_{oz} / V_{pz}$$




52 | 

## What to Use for $V_{pz}$?

*"Note: For VAV system design purposes, $V_{pz}$ is the lowest zone primary airflow value expected at the design condition analyzed."*

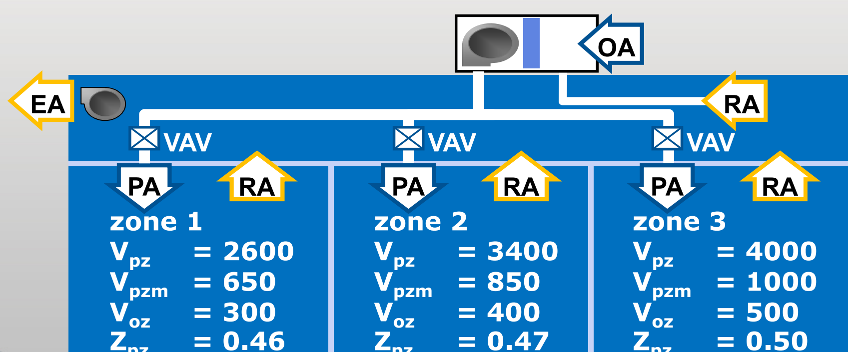
Section 6.2.5.1, ASHRAE 62.1-2010



example: single-path VAV system (cooling mode)

## Calculating Zone Outdoor Air Fraction

$$Z_{pz} = V_{oz} / V_{pz}$$



Section 6.2.5

## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

## Calculating Uncorrected OA Intake

$$V_{ou} = D \times \sum(R_p \times P_z) + \sum(R_a \times A_z)$$

$$D = P_s / \sum P_z$$

where,

$D$ = occupant diversity

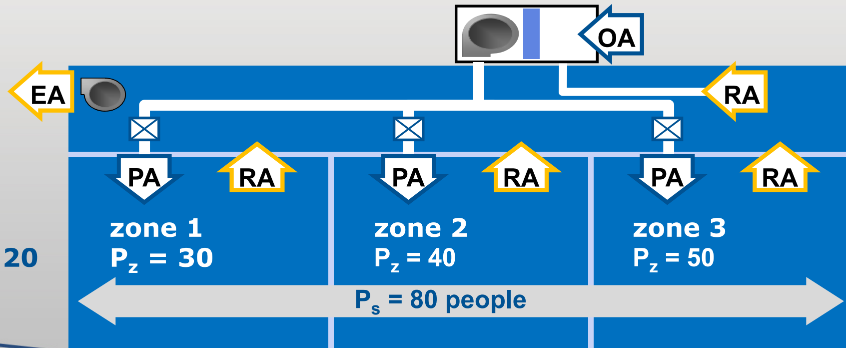
$P_s$ = peak system population

$\sum P_z$ = sum of design zone populations example

## Occupant Diversity

$$D = P_s / \Sigma P_z$$
$$= 80/120$$
$$= 0.66$$

$\Sigma P_z = 120$

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example: single-path VAV system (cooling mode)

## Calculating Uncorrected OA Intake

| zone | $R_p \times P_z$ | $R_a \times A_z$ |
|---|---|---|
| 1 | 5 × 30 = **150** | 0.06 × 2500 = **150** |
| 2 | 5 × 40 = **200** | 0.06 × 3340 = **200** |
| 3 | 5 × 50 = **250** | 0.06 × 4170 = **250** |
| | $\Sigma(R_p \times P_z)$ = **600 cfm** | $\Sigma(R_a \times A_z)$ = **600 cfm** |

$$V_{ou} = D \times \Sigma (R_p \times P_z) + \Sigma (R_a \times A_z)$$
$$= 0.66 \times 600 + 600$$
$$= 1000 \text{ cfm}$$

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section 6.2.5

## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

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Appendix A

## Calculating System Ventilation Efficiency

3a. Average OA fraction ($X_s$)

$$X_s = V_{ou} / V_{ps}$$

3b. Zone ventilation efficiency ($E_{vz}$)

for single-supply systems:

$$E_{vz} = 1 + X_s - Z_{pz}$$

for secondary recirculation systems:

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a$$

3c. System ventilation efficiency ($E_v$)

$$E_v = \text{smallest } E_{vz}$$

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# Calculating Average OA Fraction

3a. Calculate average OA fraction ($X_s$) for system

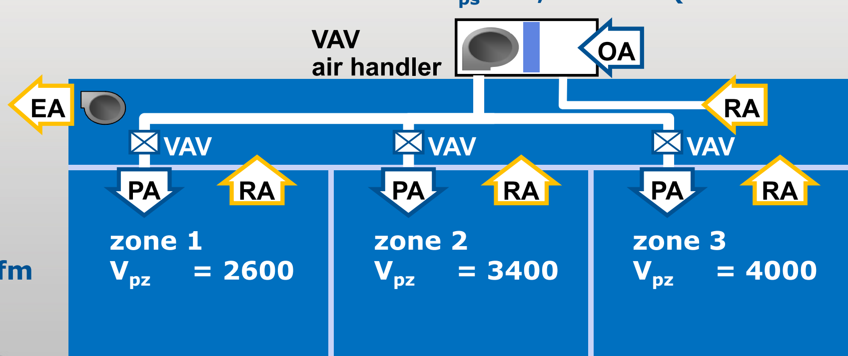
$$X_s = V_{ou} / V_{ps}$$

example: single-path VAV system (cooling mode)

# System Primary Airflow

$V_{ps}$ = 6,000 cfm ("block" airflow)




$\Sigma V_{pz}$ = 10,000 cfm

example: single-path VAV system (cooling mode)

## Calculating Average OA Fraction

3a. Calculate average OA fraction ($X_s$) for system

$$X_s = V_{ou} / V_{ps}$$
$$= 1000 / 6000$$
$$= 0.17$$

Appendix A

## Calculating System Ventilation Efficiency

3a. Average OA fraction ($X_s$)

$$X_s = V_{ou} / V_{ps}$$

3b. Zone ventilation efficiency ($E_{vz}$)

for single-supply systems:

$$E_{vz} = 1 + X_s - Z_{pz}$$

for secondary recirculation systems:

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a$$

3c. System ventilation efficiency ($E_v$)

$$E_v = \text{smallest } E_{vz}$$

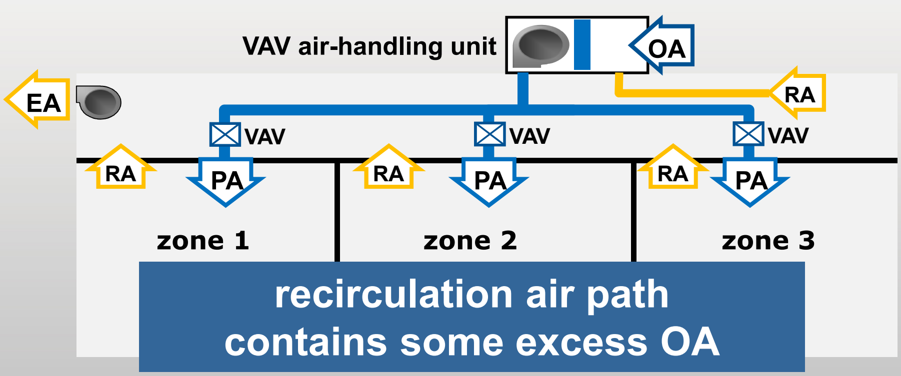
 

### multiple-zone recirculating
## Single-Supply System

- All air supplied to each zone is a mixture of outdoor air and system-level (centralized) recirculated air
  - Single-duct VAV systems
  - Single-fan, dual-duct VAV systems
  - Constant-volume reheat systems
  - Multizone systems

65 | 

### example of a single-supply system
## Single-Duct VAV System



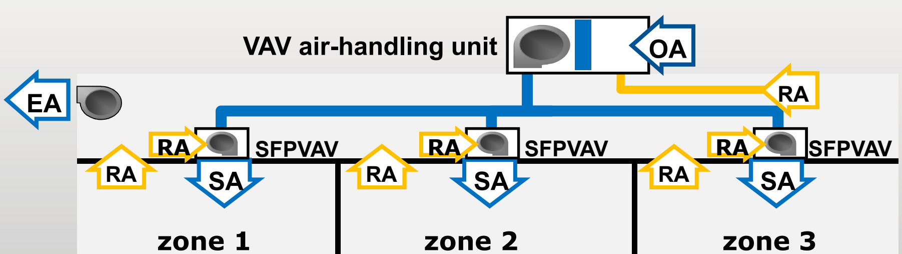

66 | 

### multiple-zone recirculating
## Secondary Recirculation System

- Some (or all) of the air supplied to each zone is recirculated from other zones, and not directly mixed with outdoor air
  - Fan-powered VAV systems
  - Dual-fan, dual-duct VAV systems

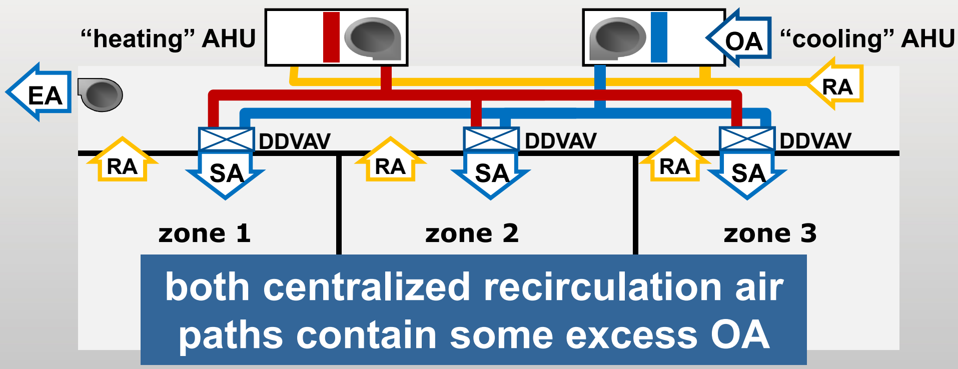
### example of secondary recirculation system
## Series Fan-Powered VAV System




**centralized and local recirculation air paths both contain some excess OA**

## example of secondary recirculation system
# Dual-Fan, Dual-Duct VAV System






## appendix A
# Calculating System Ventilation Efficiency

3a. Average OA fraction ($X_s$)

$$X_s = V_{ou} / V_{ps}$$

3b. Zone ventilation efficiency ($E_{vz}$)

for single-supply systems:

$$E_{vz} = 1 + X_s - Z_{pz}$$

for secondary recirculation systems:

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a$$

3c. System ventilation efficiency ($E_v$)

$$E_v = \text{smallest } E_{vz}$$



example: single-path VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

3b. For each zone, determine zone ventilation efficiency ($E_{vz}$):

$E_{vz} = 1 + X_s – Z_{pz}$ (for single-path systems)

| zone | $X_s$ | $Z_{pz}$ | $E_{vz}$ |
|---|---|---|---|
| 1 | 0.17 | 0.46 | 0.71 |
| 2 | 0.17 | 0.47 | 0.70 |
| 3 | 0.17 | 0.50 | 0.67 |

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example: single-path VAV system (cooling mode)

## Determining System Ventilation Efficiency

3c. Find system ventilation efficiency ($E_v$)

$E_v$ = smallest $E_{vz}$

= 0.67

| zone | $X_s$ | $Z_{pz}$ | $E_{vz}$ |
|---|---|---|---|
| 1 | 0.17 | 0.46 | 0.71 |
| 2 | 0.17 | 0.47 | 0.70 |
| 3 | 0.17 | 0.50 | 0.67 |

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section 6.2.5

## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

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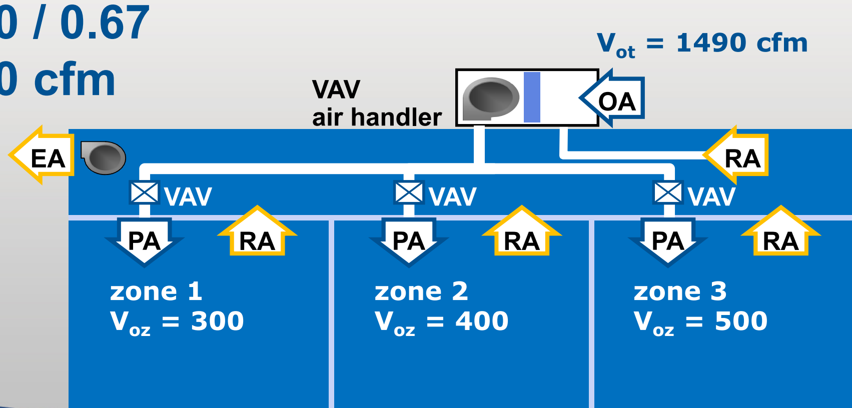
example: single-path VAV system (cooling mode)

## Calculating System Outdoor-Air Intake Flow

$V_{ot}$ = $V_{ou}$ / $E_v$

= 1000 / 0.67

= 1490 cfm

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### Section 6.2.5
## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Default $E_v$ method (Table 6-3)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

### Table 6-3 (default method)
## Determining System Ventilation Efficiency

To find $E_v$ from Table 6-3, use largest $Z_{pz}$ value of all zones

**max $Z_{pz}$ = 0.50**
**➔ $E_v$ = 0.65**

(OK to interpolate)

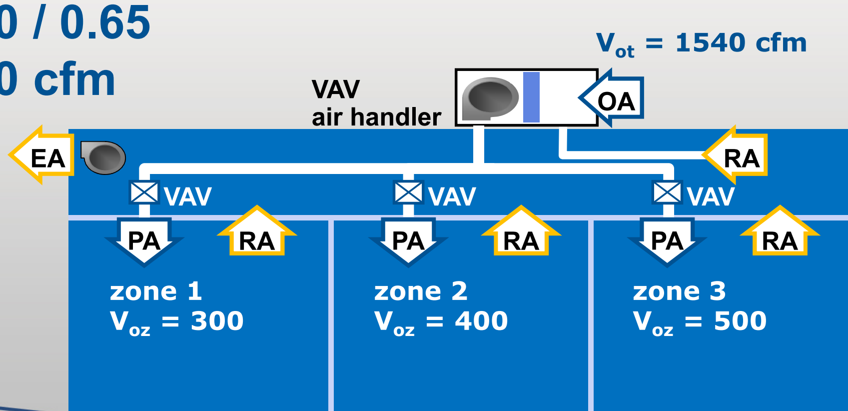
| max $Z_{pz}$ | $E_v$ |
|---|---|
| ≤ 0.15 | 1.0 |
| ≤ 0.25 | 0.9 |
| ≤ 0.35 | 0.8 |
| ≤ 0.45 | 0.7 |
| ≤ 0.55 | 0.6 |
| > 0.55 | Appendix A |

0.50 ➔ ... ➔ 0.65

### example: single-path VAV system (cooling mode)
## Calculating System Outdoor-Air Intake Flow

$$V_{ot} = V_{ou} / E_v$$
$$= 1000 / 0.65$$
$$= 1540 \text{ cfm}$$

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### example: single-path VAV system (cooling mode)
## Appendix A versus Table 6-3

| $E_v$ method | $E_v$ | $V_{ot}$ |
|---|---|---|
| Table 6-3 | 0.65 | 1540 |
| Appendix A | 0.67 | 1490 |

Appendix A generally results in lower $V_{ot}$ than Table 6-3

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example: single-path VAV system

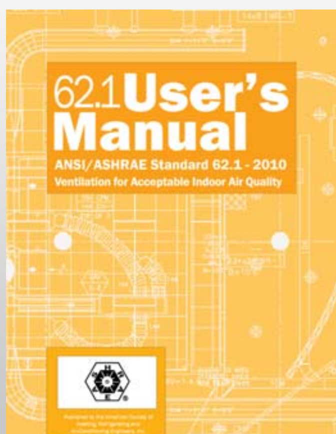
## Heating vs. Cooling

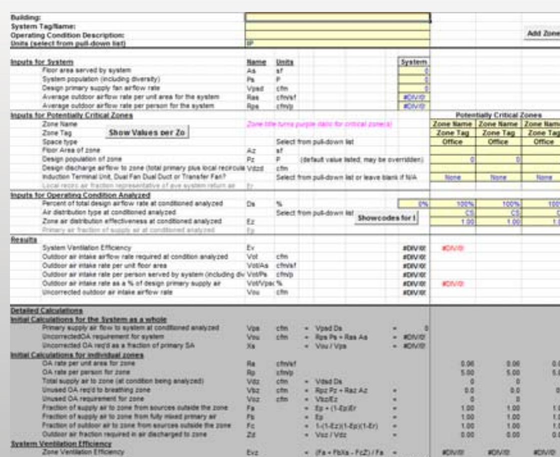
| $E_v$ method | Mode ($E_z$) | $Z_{pz}$ | $E_v$ | $V_{ot}$ |
|---|---|---|---|---|
| Appendix A | Cooling (1.0) | 0.50 | 0.67 | 1490 |
| | Heating (0.8) | 0.63 | 0.77 | 1300 |

$E_z$ = 0.8 in heating results in larger $Z_{pz}$, but $X_s$ is higher because $V_{ps}$ is lower, so $E_v$ is actually higher

## Tools Available from ASHRAE



## VRP Calculations in TRACE™ 700

### System Ventilation Requirements

| AHU Location | Description | | ∑ Vpz cfm | Ps People | ∑ Pz People | D Ps / ∑ Pz | Vou cfm | Vps cfm | Xs | Ev | Vot cfm | %OA Vot / Vps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative 1** | | | | | | | | | | | | |
| System | Single-Duct VAV with Reheat | Cooling | 10,000 | 80 | 120 | 0.67 | 1,001 | 6,000 | 0.167 | 0.667 | 1,501 | 25.0 |
| | | Heating | 2,500 | 80 | 120 | 0.67 | 1,001 | 2,500 | 0.400 | 0.775 | 1,291 | 51.6 |

### Ventilation Parameters

| System Zone Room | Rp cfm/ p | Pz People | Ra cfm/ft² | Az ft² | Vbz cfm | Cooling Ez | Cooling Voz cfm | Heating Ez | Heating Voz cfm |
|---|---|---|---|---|---|---|---|---|---|
| **Alternative 1** | | | | | | | | | |
| Zone 1 | 5.00 | 30.00 | 0.06 | 2,500 | 300 | 1.00 | 300 | 0.80 | 375 |
| Zone 2 | 5.00 | 40.00 | 0.06 | 3,340 | 400 | 1.00 | 400 | 0.80 | 501 |
| Zone 3 | 5.00 | 50.00 | 0.06 | 4,170 | 500 | 1.00 | 500 | 0.80 | 625 |
| Single-Duct VAV with Reheat | 5.00 | 120.00 | 0.06 | 10,010 | 1,201 | | 1,201 | | 1,501 |

### Ventilation Calculations for Cooling Design

| System Zone Room | Box Type | Vpz cfm | Vfan cfm | Vdz cfm | Vpz-min cfm | Voz-clg cfm | Zd | Ep | Er | Fa | Fb | Fc | Evz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative 1** | | | | | | | | | | | | | |
| Zone 1 | Shutoff VAV | 2,600 | 2,600 | 2,600 | 650 | 300 | 0.462 | 1.00 | 0.30 | 1.00 | 1.00 | 1.00 | 0.705 |
| Zone 2 | Shutoff VAV | 3,400 | 3,400 | 3,400 | 850 | 400 | 0.471 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.696 |
| Zone 3 | Shutoff VAV | 4,000 | 4,000 | 4,000 | 1,000 | 500 | 0.500 | 1.00 | 0.90 | 1.00 | 1.00 | 1.00 | 0.667 * |
| **Single-Duct VAV with Reheat** | | 10,000 | 6,000 | 10,000 | 2,500 | 1,201 | | | | | | | 0.667 |

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### example (cooling mode)

## Comparison of Results

| ventilation system | $V_{ot}$ | $E_v$ |
|---|---|---|
| single zone | 1200 | |
| 100% outdoor air | 1200 | |
| single-path VAV | 1490 | 0.67 |
| series FPVAV | 1180 | 0.85 |

19% lower $V_{ot}$ than VAV

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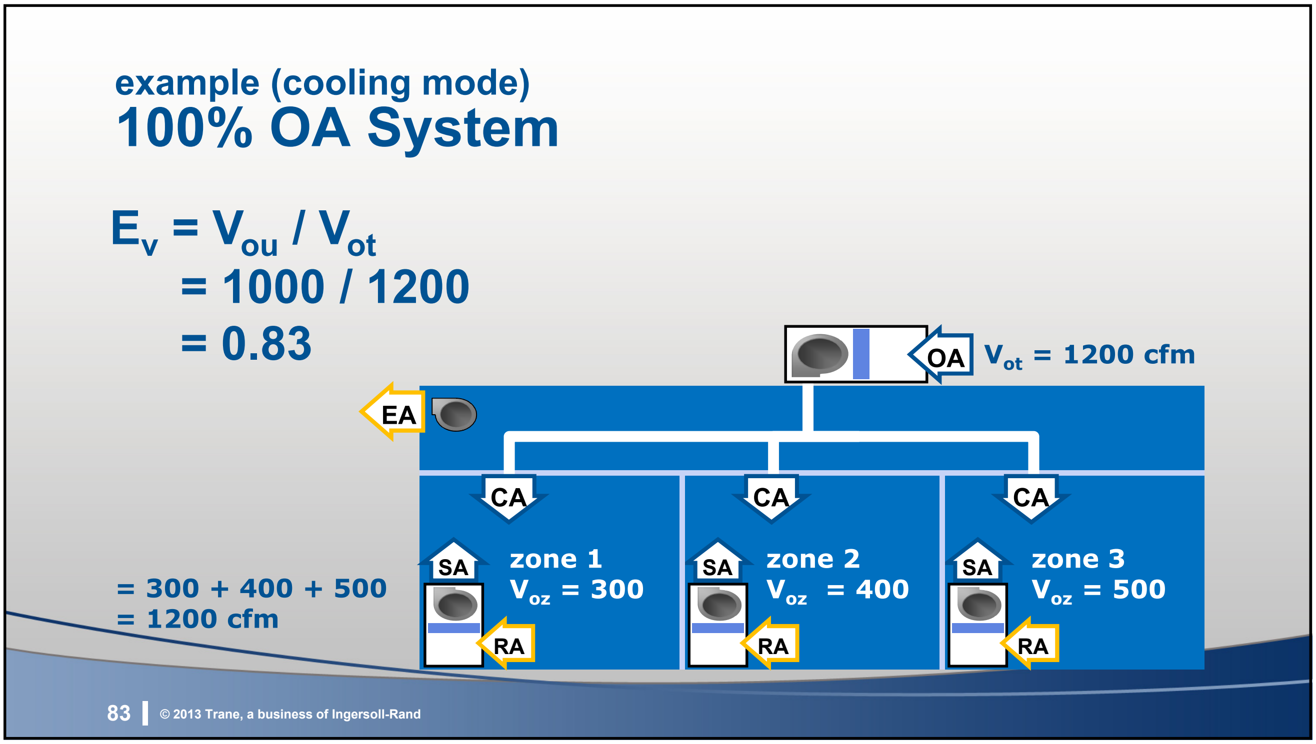
example (cooling mode)
100% OA System
$E_v = V_{ou} / V_{ot}$
$= 1000 / 1200$
$= 0.83$
OA
$V_{ot}$ = 1200 cfm
EA
CA
CA
CA
SA
zone 1
$V_{oz}$ = 300
RA
SA
zone 2
$V_{oz}$ = 400
RA
SA
zone 3
$V_{oz}$ = 500
RA
= 300 + 400 + 500
= 1200 cfm
83
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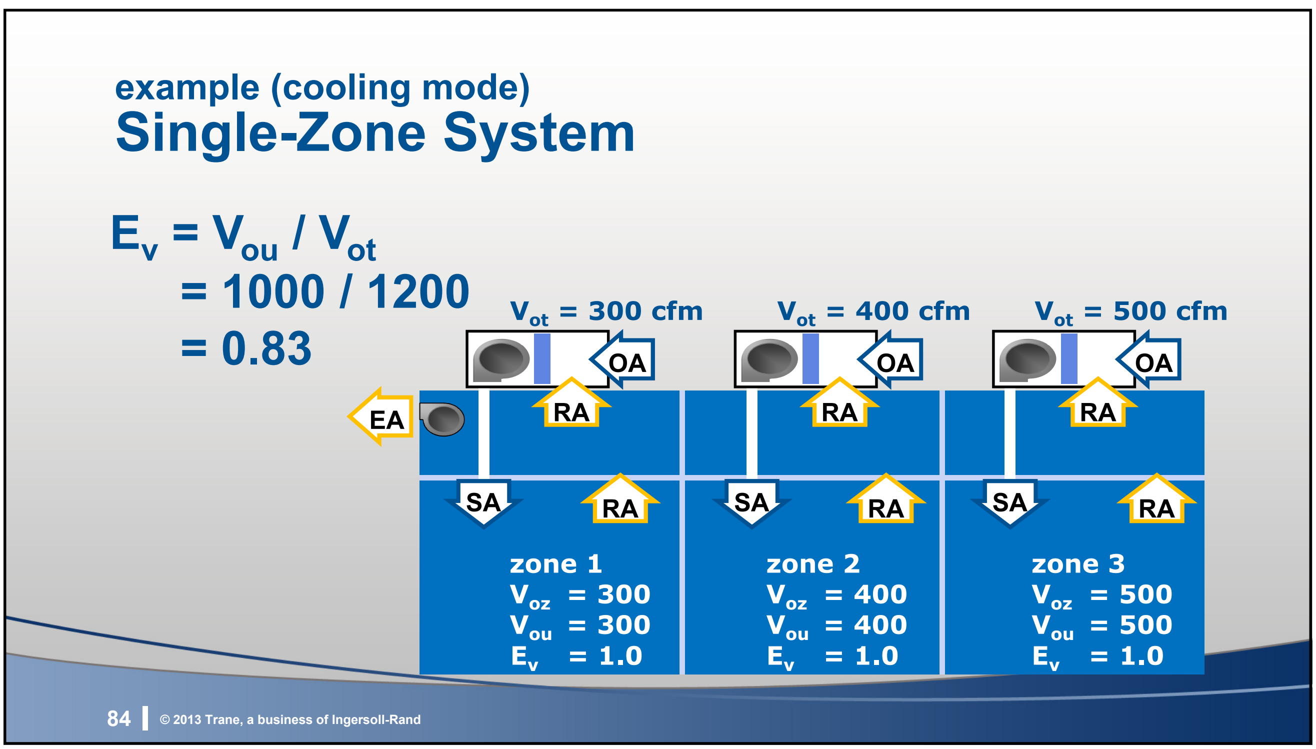
example (cooling mode)
Single-Zone System
$E_v = V_{ou} / V_{ot}$
$= 1000 / 1200$
$= 0.83$
$V_{ot}$ = 300 cfm
$V_{ot}$ = 400 cfm
$V_{ot}$ = 500 cfm
OA
OA
OA
EA
RA
RA
RA
SA
RA
SA
RA
SA
RA
zone 1
$V_{oz}$ = 300
$V_{ou}$ = 300
$E_v$ = 1.0
zone 2
$V_{oz}$ = 400
$V_{ou}$ = 400
$E_v$ = 1.0
zone 3
$V_{oz}$ = 500
$V_{ou}$ = 500
$E_v$ = 1.0
84
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example (cooling mode)

## Comparison of Results

| ventilation system | $V_{ot}$ | $E_v$ |
|---|---|---|
| single zone | 1200 | 0.83 |
| 100% outdoor air | 1200 | 0.83 |
| single-path VAV | 1490 | 0.67 |
| series FPVAV | 1180 | 0.85 |

 

## Agenda

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- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone calculations
  - System calculations
- Exhaust ventilation
- Dynamic reset strategies

 

### Section 6.0
## Procedures

6.1 General
6.2 Ventilation rate procedure
6.3 Indoor air quality (IAQ) procedure
6.4 Natural ventilation procedure
6.5 Exhaust ventilation
6.6 Documentation

 

### excerpt from Table 6-4
## Minimum Exhaust Rates

| Occupancy category | $cfm/ft^2$ |
|---|---|
| Art classroom | 0.70 |
| Beauty and nail salons | 0.60 |
| Copy, printing rooms | 0.50 |
| Kitchenettes | 0.30 |
| Locker/dressing rooms | 0.25 |
| Toilets – public<br>(heavy use areas) | 50 cfm/unit<br>70 cfm/unit |

 

## Section 6.5
# Exhaust Ventilation

- To ensure removal of local contaminants, some zones require exhaust rates (Table 6-4)

  *"…the requirements for exhaust ventilation in Section 6.5 shall be met regardless of the method used to determine minimum outdoor airflow rates."*

  (Section 6.1)

- Exhaust makeup air may be any combination of outdoor air, recirculated air, and transfer air




# Agenda

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- Overview of ASHRAE Standard 62.1
- Ventilation Rate Procedure
  - Zone level calculations
  - System level calculations
- Exhaust ventilation
- Dynamic reset strategies

Section 6.2.7
## Dynamic Reset

Systems "may be designed to reset the outdoor air intake flow ($V_{ot}$) and/or … zone outdoor airflow ($V_{oz}$) as operating conditions change."

- Variations in zone population (DCV)
- Variations in ventilation efficiency due to changes in airflow (ventilation reset control)
- Variations in intake airflow during economizer cooling

 

## Demand-Controlled Ventilation (DCV)

- Permitted by Standard 62.1-2010 (optional in any zone)
- Required by Standard 90.1-2010 in each densely-populated zone (> 40 people/1000 $ft^2$)
- Required by Standard 189.1-2010 in each densely-populated zone (≥ 25 people/1000 $ft^2$)

 

Section 6.2.7.1

## Demand-Controlled Ventilation (DCV)

- Reset $V_{oz}$ based on variations in zone population
  - Cannot reset lower than "area" OA rate ($R_a \times A_z$)
  - Must provide zone OA rate ($V_{bz\text{-}est} = R_p \times P_{z\text{-}est} + R_a \times A_z$) at steady state … no differential equations required
  - When dehumidifying, OA intake must exceed exhaust
  - Document assumptions

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Section 6.2.7.1

## Demand-Controlled Ventilation (DCV)

- Example methods to estimate current **population ($P_{z\text{-}est}$)**
  - Time-of-day schedule: BAS could schedule occupancy
  - Occupancy sensors: indicated peak or no occupants
  - People counters: accurate estimate of people in zone
- Estimating current **breathing zone OA rate** required
  - Use current population to find $V_{bz\text{-}est} = R_p \times P_{z\text{-}est} + R_a \times A_z$
  - Use zone-to-outdoor $CO_2$ difference and a simple controller to find $V_{bz\text{-}est}$ more directly

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DCV

## $CO_2$ Difference and OA per Person

Difference between breathing zone and outdoor $CO_2$ equals the $CO_2$ generation rate (N) divided by the breathing zone OA rate/person ($V_{bz\text{-}est}$ / $P_z$)

$$C_{bz} - C_o = N / ( V_{bz\text{-}est} / P_z ) = N \times P_z / V_{bz\text{-}est}$$

where,

N = 0.0105 cfm of $CO_2$/person (for office work)

$V_{bz\text{-}est}$ = current breathing-zone OA required, cfm

$P_z$ = current zone population

## Simple $CO_2$-Based DCV Controller

If peak population ($P_z$) is 260 people and floor area is 4000 ft$^2$:

$V_{bz\text{-}design} = R_p \times P_z + R_a \times A_z = 7.5 \times \mathbf{65} + 0.06 \times 1000 = 550$ cfm

$V_{bz\text{-}zero} = 7.5 \times \mathbf{0} + 0.06 \times 1000 = 60$ cfm

If $CO_2$ generation rate (N) is 0.0105 cfm/person (light office work):

$\Delta CO_2 = C_{bz} - C_o = N \times P_z / V_{bz}$

$\Delta CO_2$ @ peak $P_z$ = 0.0105 × 65 people / 550 cfm = 0.001240

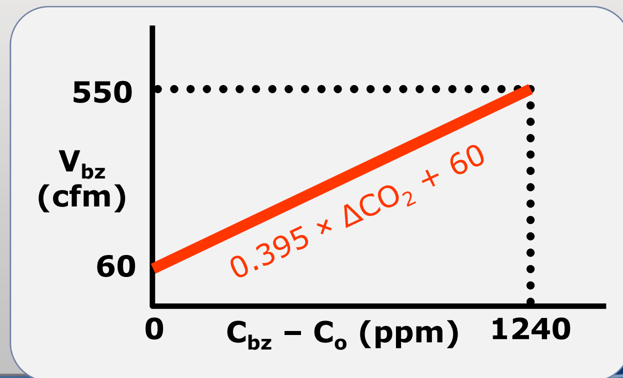
$\Delta CO_2$ @ zero $P_z$ = 0.0105 × 0 people / 60 cfm = 0

## Simple $CO_2$-Based DCV Controller

Establish end point for simple, proportional controller:

- Use $V_{bz\text{-}est}$ signal from simple controller to indicate $V_{bz}$ required by current population
- Note: $V_{bz\text{-}est} \geq V_{bz\text{-}act}$

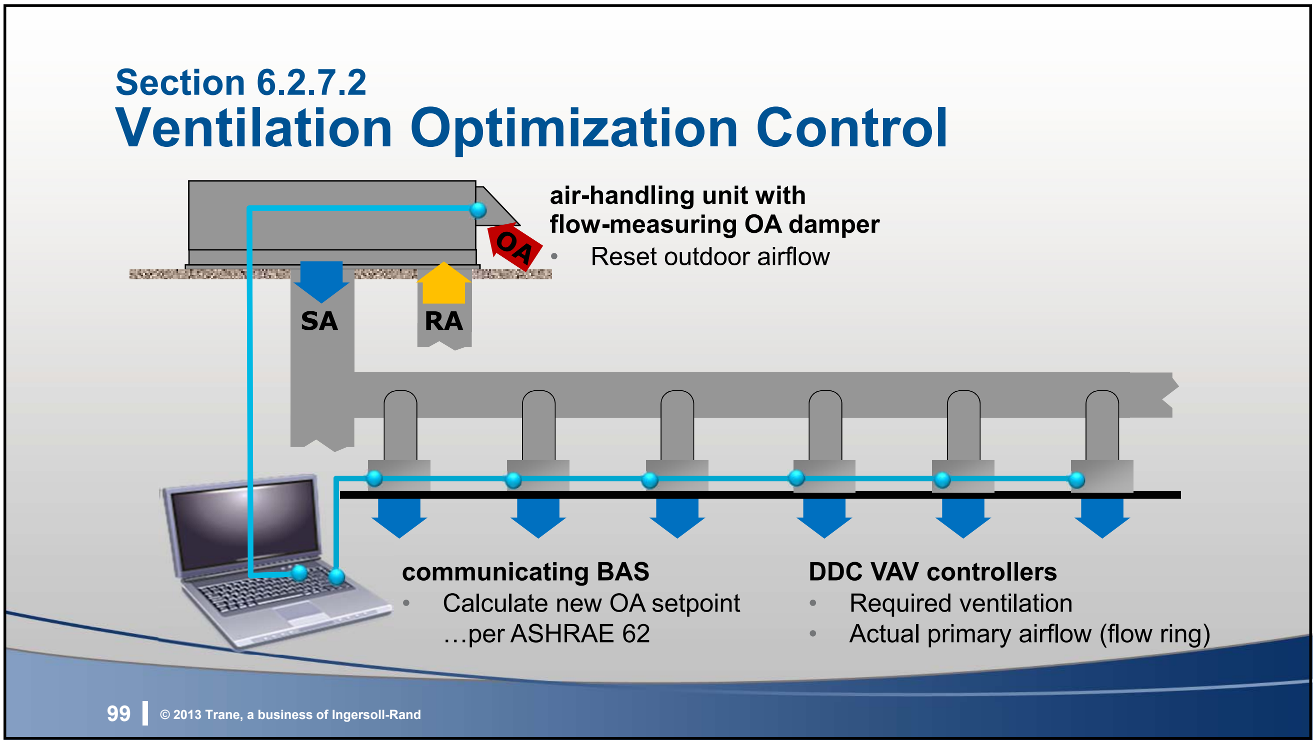





### Section 6.2.7
## Dynamic Reset

Systems "may be designed to reset the outdoor air intake flow ($V_{ot}$) and/or … zone outdoor airflow ($V_{oz}$) as operating conditions change."

- Variations in zone population (DCV)
- Variations in ventilation efficiency due to changes in airflow (ventilation reset control)
- Variations in intake airflow during economizer cooling


Section 6.2.7.2
Ventilation Optimization Control
air-handling unit with
flow-measuring OA damper
• Reset outdoor airflow
OA
SA
RA
communicating BAS
• Calculate new OA setpoint
…per ASHRAE 62
DDC VAV controllers
• Required ventilation
• Actual primary airflow (flow ring)
99
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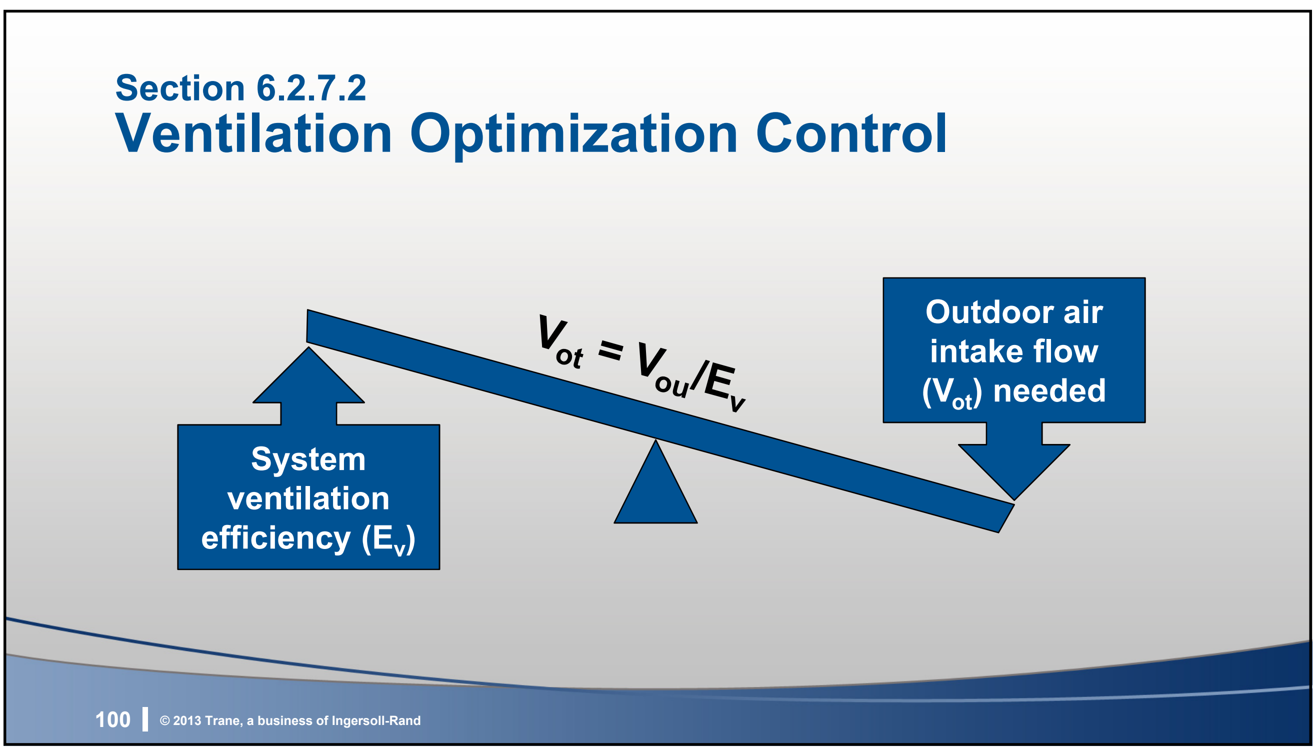
Section 6.2.7.2
Ventilation Optimization Control
$V_{ot} = V_{ou}/E_v$
Outdoor air intake flow ($V_{ot}$) needed
System ventilation efficiency ($E_v$)
100
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## DCV and Ventilation Optimization Control

When some zones use DCV to estimate population

1. Determine the following for each zone
   - Peak population (**$P_z$**) for non-DCV zones or estimated population (**$P_{z\text{-}est}$**) for DCV zones
   - Calculated breathing-zone OA: **$V_{bz\text{-}est}$** $= R_p \times$ **$P_z$** $+ R_a \times A_z$
   - Currently measured zone primary airflow (**$V_{pz}$**)
   - Calculate zone outdoor-air fraction: $Z_{pz} =$ **$V_{bz\text{-}est}$** $/ (E_z \times$ **$V_{pz}$**$)$

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## DCV and Ventilation Optimization Control

When some zones use DCV to estimate population

2. Solve multiple-zone system equations
   - Current outdoor air used: $V_{ou} = \Sigma(R_p \times P_z) + \Sigma(R_a \times A_z)$
   - Current system ventilation efficiency: $E_v = 1 + V_{ou} / V_{ps} - Z_{pz}$
   - Current outdoor air intake flow: **$V_{ot}$** $= V_{ou} / E_v$

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Estimating $V_{ot}$ using DCV in multiple-zone systems:

- Find $V_{bz}$ (= $R_p \times P_z + R_a \times A_z$) for non-DCV zones
- Find $V_{bz\text{-}est}$ (= $R_p \times P_{z\text{-}est} + R_a \times A_z$) for non-$CO_2$ DCV zones
- Find current $V_{oz}$ (= $V_{bz\text{-}est}/E_z$) and $Z_{pz}$ (= $V_{oz}/E_z$) for each zone
- Sense current $V_{pz}$ for each zone and sum to find $V_{ps}$ (= $\Sigma V_{pz}$)
- Find current $V_{ou}$ (apply diversity, D, to only non-DCV zones)
- Find current lowest $E_{vz}$ (= $1 + V_{ou} / V_{ps} - Z_{pz}$) for system
- Find current outdoor-air intake flow, $V_{ot}$ (= $V_{ou} / E_v$)

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## DCV and Ventilation Optimization Control

When some zones use DCV to <u>estimate breathing-zone OA rate</u> per person ($CO_2$-based DCV)

1. Determine the following for each zone
   - Peak population (**$P_z$**) for non-DCV zones
   - Estimated population (**$P_{z\text{-}est}$**) for population-based DCV zones
   - Estimated breathing-zone OA (**$V_{bz\text{-}est}$**) for $CO_2$-based DCV zones
   - Currently measured zone primary airflow (**$V_{pz}$**)
   - Calculate zone outdoor-air fraction: $Z_{pz} = V_{bz\text{-}est} / (E_z \times V_{pz})$

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## DCV and Ventilation Optimization Control

When some zones use DCV to estimate breathing-zone OA rate per person ($CO_2$-based DCV)

2. Solve multiple-zone system equations
   - Current outdoor air used: $V_{ou} = \Sigma(R_p \times P_z) + \Sigma(R_a \times A_z)$
   - Current system ventilation efficiency: $E_v = 1 + V_{ou} / V_{ps} – Z_{pz}$
   - Current outdoor air intake flow: $V_{ot} = V_{ou} / E_v$
3. Set upper limit on OA intake (not to exceed $V_{ot\text{-}design}$)

Estimating $V_{ot}$ using DCV in multiple-zone systems:

- Find $V_{bz}$ (= $R_p \times P_z + R_a \times A_z$) for non-DCV zones
- Find $V_{bz\text{-}est}$ (= $R_p \times P_{z\text{-}est} + R_a \times A_z$) for non-$CO_2$ DCV zones
- Determine $V_{bz\text{-}est}$ for each CO2-based DCV zone
- Find current $V_{oz}$ (= $V_{bz\text{-}est}/E_z$) and $Z_{pz}$ (= $V_{oz}/E_z$) for each zone
- Sense current $V_{pz}$ for each zone and sum to find $V_{ps}$ (= $\Sigma V_{pz}$)
- Find current $V_{ou}$ (apply diversity, D, to only non-DCV zones)
- Find current lowest $E_{vz}$ (= $1 + V_{ou} / V_{ps} – Z_{pz}$) for system
- Find current outdoor-air intake flow, $V_{ot}$ (= $V_{ou} / E_v$)

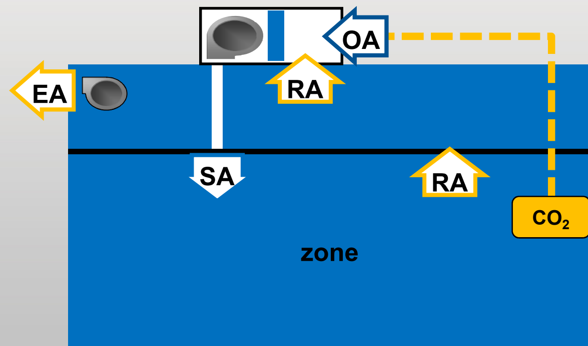
 

### Standards 90.1 (Section 6.4.3.9) and 189.1 (Section 7.4.3.2)
# Single-Zone Systems

- Use estimated population ($P_{z\text{-}est}$) to find estimated breathing zone OA flow ($V_{bz\text{-}est} = R_p \times P_{z\text{-}est} + R_a \times A_z$)

or

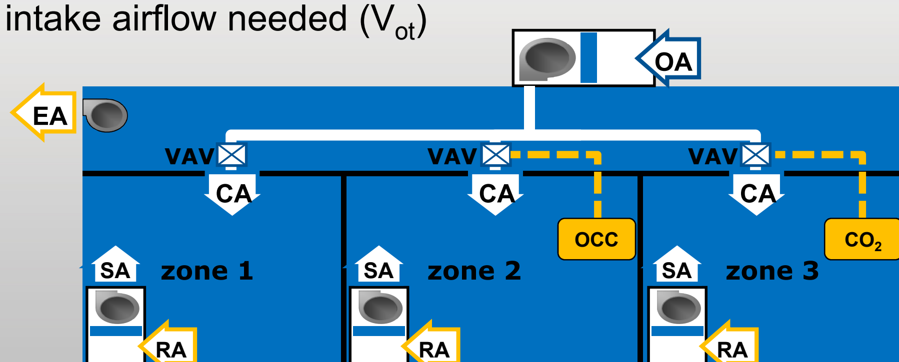
- Use $CO_2$-based DCV to estimate breathing zone OA flow ($V_{bz\text{-}est}$)
- Then calculate current intake airflow needed ($V_{ot} = V_{oz}$)



### Standards 90.1 (Section 6.4.3.9) and 189.1 (Section 7.4.3.2)
# 100% Outdoor-Air Systems

- Use VAV controls for all zones and use either population estimates or $CO_2$-based approaches in DCV zones to find current intake airflow needed ($V_{ot}$)

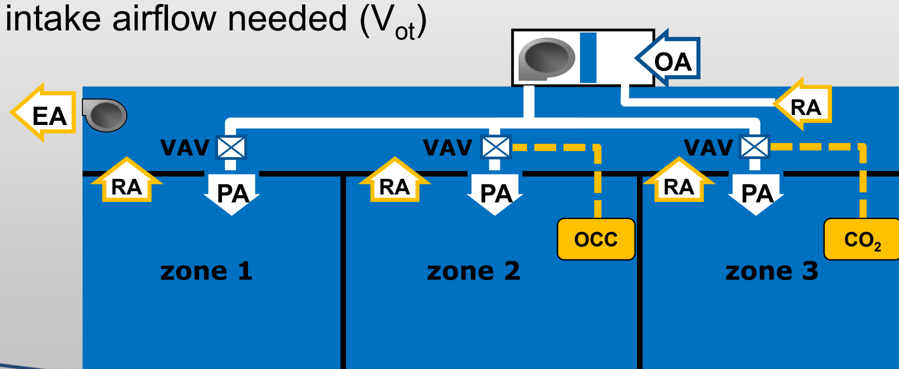


### Standards 90.1 (Section 6.4.3.9) and 189.1 (Section 7.4.3.2)
## Multiple-Zone Recirculating Systems

- Use either population estimates or $CO_2$-based approaches in DCV zones, combined with ventilation optimization control to find current intake airflow needed ($V_{ot}$)



### dynamic reset
## Summary

- Single-zone systems
  - No credit for population diversity
  - Can use **zone DCV** to meet energy standards
- 100% OA systems
  - No credit for population diversity
  - Constant-airflow systems cannot provide **zone DCV**
  - Variable-airflow systems can provide **zone DCV**, but require a VAV box at each zone and AHU controls

### dynamic reset
## Summary

- Multiple-zone systems
  - Credit for population diversity (D) reduces installed cost
  - Dynamic reset of **OA intake flow** is allowed based on:
    - **Ventilation optimization control**
    - **Zone DCV** combined with **ventilation optimization**

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### references for this broadcast
## Where to Learn More


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# Supplemental Material (DVD or Online)

- Review of Section 4.0 and 5.0 requirements
- Design for varying operating conditions
- System VRP calculations for systems with a secondary recirculation air path


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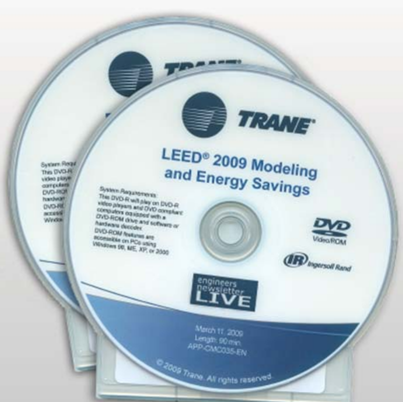


EDUCATION PROVIDER

GBCI CMP

**Past program topics include:**

- ASHRAE Standards 189.1, 90.1, 62.1
- High-performance VAV Systems
- Chilled-water plants
- Air distribution
- WSHP/GSHP systems
- Control strategies
- USGBC LEED®
- Energy and the environment
- Acoustics
- Ventilation
- Dehumidification
- Ice storage
- Central geothermal systems

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## LEED Continuing Education Courses

***on-demand, no charge, 1.5 CE credits***

- ASHRAE Standards 62.1 and 90.1 and VAV Systems
- ASHRAE Standard 62.1: Ventilation Rate Procedure
- ASHRAE Standard 90.1-2010
- ASHRAE Standard 189.1-2011
- High-Performance VAV Systems
- Dedicated Outdoor Air Systems
- Ice Storage Design and Control
- Energy Saving Strategies for WSHP/GSHP Systems

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## Remaining 2013 ENL Programs

- Single-zone VAV Systems
- Variable-speed Chiller Plant Operation

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# ASHRAE Standard 62.1 Supplemental Content

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## Agenda

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**Supplemental content**

- Review of Section 4.0 and 5.0 requirements
- Design for varying operating conditions
- VRP calculations for systems with a secondary recirculation air path

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## ASHRAE Standard 62.1-2010
# Ventilation for Acceptable IAQ

| | |
|---|---|
| 1.0 | Purpose |
| 2.0 | Scope |
| 3.0 | Definitions |
| 4.0 | Outdoor air quality |
| 5.0 | Systems and equipment |
| 6.0 | Procedures |
| 7.0 | Construction and system start-up |
| 8.0 | Operations and maintenance |
| App A | Multiple-zone systems |


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## Section 4
# Outdoor Air Quality

- Regional air quality: **Determine compliance** status with national ambient air quality standards (NAAQS)
- Local air quality: **Survey site** for unusual local sources
- Documentation: Include specific information and review with owner to inform design

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## Section 5.0
# Systems and Equipment



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## Section 5.1
# Ventilation Air Distribution

- Provide means to adjust (balance) airflows to ensure outdoor airflow as required by Section 6 reaches each zone at any load condition
- Design to ensure mixing in floor or ceiling RA/OA mixing plenums
- Specify air balance requirements and state air distribution design assumptions

**Design for balancing, duct outdoor air to each zone**

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## Section 5.2
## Exhaust Duct Location

- Design negative pressure exhaust ducts to prevent leakage of potentially harmful exhaust contaminants into the building

**Room → Duct → Fan → Outdoors**

 

## Section 5.3
## Ventilation System Controls

- Design to ensure minimum ventilation
  - Provide controls to enable fan
  - Provide controls to maintain at least minimum OA flow **at any load or dynamic reset condition**
  - Some CV systems need modulating OA dampers
  - VAV systems need modulating dampers or variable-speed injection fans
  - VAV systems likely need outdoor airflow sensing

 

Section 5.4
## Airstream Surfaces

- Use duct materials that resist microbial growth per UL 181 to reduce space contamination due to air distribution system
- Use duct materials that resist erosion per UL 181 to reduce space contamination due to air distribution system

**Most matte-face finishes meet these requirements**

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Section 5.5
## Outdoor Air Intakes

- Reduce contamination from outdoors
  - Locate the OA intake away from potential outdoor sources
  - Design intakes to limit rain entrainment or to manage entrained rain water
  - Use outdoor equipment designed to prevent rain intrusion when tested per UL 1995
  - Design to manage water from entrained snow
  - Use bird screens to prevent nesting in or near the intake

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| Object (potential source) | Distance (ft.) |
|---|---|
| Class 2 air exhaust/relief outlet | 10 |
| Class 3 air exhaust/relief outlet | 15 |
| Class 4 air exhaust/relief outlet | 30 |
| Plumbing vents < 3 ft. above outdoor air intake | 10 |
| Plumbing vents ≥ 3 ft. above outdoor air intake | 3 |
| Combustion vents, chimneys, and flues | 15 |
| Garage entry, auto loading area, drive-in queue | 15 |
| Truck loading or bus parking/idling area | 25 |
| Driveway, street, or parking place | 5 |
| Thoroughfare with high traffic volume | 25 |
| Roof, landscaped grade, or surface below intake | 1 |
| Garbage storage/pick-up area, dumpsters | 15 |
| Cooling tower intake or basin | 15 |
| Cooling tower exhaust | 25 |

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Section 5.6

## Capture of Contaminants

- Reduce recirculation of indoor contaminants, exhaust locally captured contaminants (e.g., printers) directly to outdoors

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Section 5.7
## Combustion Air

- Reduce pollutants from combustion appliances
  - Provide sufficient combustion air
  - Provide sufficient air for removal of combustion products

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Section 5.8
## Particulate Matter Removal

- Reduce rate of dirt accumulation on condensing coils and other wet surface devices
  - Must use at least a MERV 6 filter upstream of such devices

**MERV 6 is about 20% to 30% Dust Spot Efficiency**

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Section 5.9
## Dehumidification Systems

- Reduce dampness in buildings during mechanical cooling, systems must:
  - Limit space RH to 65% or less when analyzed at design dew point condition without solar load
  - Ensure that design intake exceeds exhaust airflow

**Basic, constant-volume systems with sensible-only thermostats might not comply with the 65% RH limit**

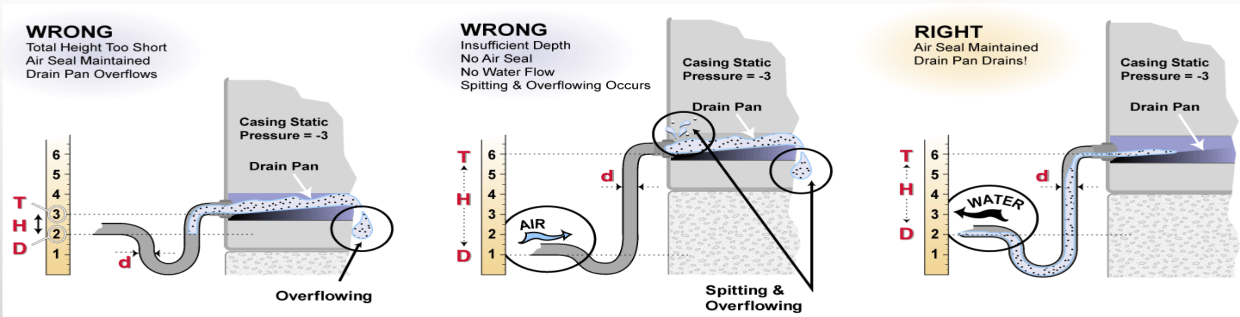
Section 5.10
## Drain Pans

- Ensure condensate drainage without flooding/carryover
  - Slope drain pan at least 1/8 in. per ft.
  - Locate drain opening at lowest point of drain pan
  - Use P-trap or other seal to prevent ingestion of air while allowing complete drainage with fan on or off
  - Size drain pan to limit carryover

**A drain seal that works is probably most important.**

## Drain Seals




**total trap height, T = D + H**

H = air-handler casing pressure + 1 in. wg
D = trap depth = ½ H + d
d = drain pipe diameter

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### Section 5.11
## Finned-Tube Coils and Heat Exchangers

- Select to reduce dirt accumulation and resulting water droplet carryover and potential microbial growth
  - Limit coil pressure drop to **0.75 in. wc at 500 fpm**
  - **Exception:** No pressure drop limit when design provides access to both faces for cleaning

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## Section 5.12
# Humidifiers and Water Spray Systems

- Reduce water-borne contaminants and design to reduce carryover
  - Use potable water
  - No downstream devices within absorption distance




## Section 5.13
# Access: Inspection, Cleaning, Maintenance

- Reduce dirt accumulation in air distribution system
  - Design system with adequate clearance around ventilation equipment
  - Provide access doors/panels for ventilation equipment (air handlers, terminal units)
  - Provide access doors/panels for devices in air distribution system (air plenums, coils, air cleaners, drain pans, fans, humidifiers)

## Section 5.14
# Building Envelope and Interior Surfaces

- Reduce intrusion of water and water vapor and uncontrolled condensation
  - Use a **weather barrier** within the building envelope
  - Use a **vapor retarder** within the building envelope (typically on warm side, but it depends on wall design)
  - **Seal** all envelope seams, joints, and penetrations
  - **Insulate** pipes, ducts, and other cold surfaces

 

## Section 5.15
# Buildings With Attached Parking Garages

- Reduce infiltration of vehicle exhaust
  - Maintain garage pressure below adjacent occupied space

  or
  - Use a vestibule

  or
  - Design to minimize air migration from garage to occupied space

 

## Section 5.16
# Air Classification and Recirculation

- Reduce recirculation of "dirty" air to "cleaner" spaces
  - **Designate** air from each space/location (Table 6-1)
    - Class 1: Low contaminant concentration (office)
    - Class 2: Mild concentration (dining room)
    - Class 3: Significant concentration (daycare sick room)
    - Class 4: Highly objectionable/potentially harmful

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## Section 5.16
# Air Classification and Recirculation

- Reduce recirculation of "dirty" air to "cleaner" spaces
  - Design to limit air recirculation as follows:
    - Class 1 air can be recirculated to any other space or location
    - Class 2 air can be recirculated to the same space, or to any other Class 2 or Class 3 space
    - Class 3 air can be recirculated only to the same space
    - Class 4 air must be exhausted outdoors

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Section 5.17
## Buildings Containing ETS Areas

- Reduce level of ETS in ETS-free areas
  - **Classify** each area as ETS or ETS-free
  - **Pressurize** ETS-free areas with respect to ETS areas
  - **Separate** ETS and ETS-free areas with solid walls/doors
  - **Maintain** transfer airflow paths
  - **Do not recirculate** from ETS to ETS-free at air handler
  - **Exhaust** from ETS areas
  - **Post signs** indicating “This area may contain ETS”

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## Agenda

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**Supplemental content**

- Review of Section 4.0 and 5.0 requirements
- Design for varying operating conditions
- VRP calculations for systems with a secondary recirculation air path

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## Section 6.2.6
# Short-Term Conditions

May use Equation 6-9 to find averaging time and adjust design for short-term conditions

$$T = 3 \times v / V_{bz}$$

where,

$v$ = zone volume, $ft^3$

$V_{bz}$ = breathing-zone OA flow for design $P_z$, cfm

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## design for fluctuating occupancy
# Example: Office Space

**Example**
office space:

- $P_z$ = 5 people
- $A_z$ = 1000 $ft^2$
- ceiling = 10 ft.
- $v$ = 10000 $ft^3$

**Based on *peak* population:**

$$V_{bz} = R_p \times P_z + R_a \times A_z$$
$$= 5 \times 5 + 0.06 \times 1000$$
$$= 25 \text{ cfm} + 60 \text{ cfm}$$
$$= 85 \text{ cfm}$$

**Averaging time period:**

$$T = 3 \times v / V_{bz}$$
$$= 3 \times 10000 / 85$$
$$= 353 \text{ minutes}$$
$$\approx 6 \text{ hours}$$

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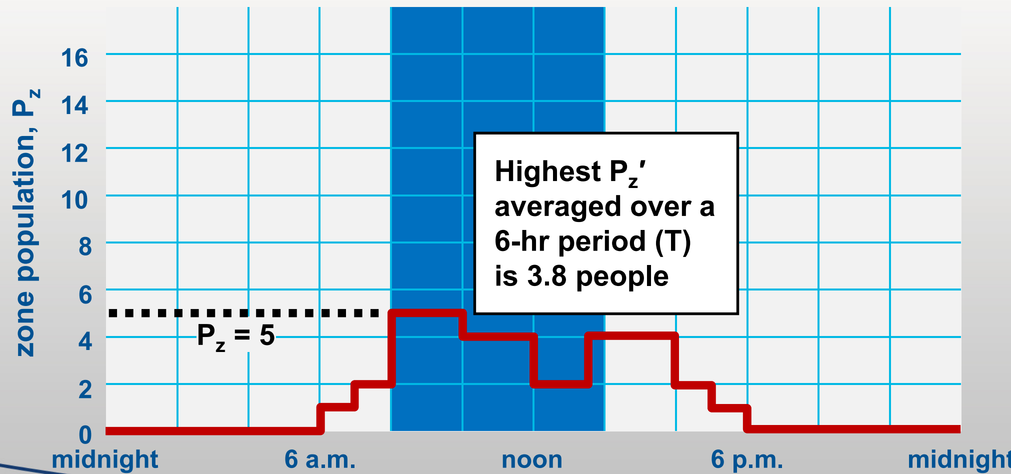
## design for fluctuating occupancy
# Example: Office Space



## design for fluctuating occupancy
# Example: Office Space

**Example** office space:

- $P_z$ = 5 people
- $P_z'$ = 3.8 people
- $A_z$ = 1000 ft$^2$

**Based on *peak* population:**

$$V_{bz} = R_p \times P_z + R_a \times A_z$$
$$= 5 \times 5 + 0.06 \times 1000$$
$$= 25 \text{ cfm} + 60 \text{ cfm}$$
$$= 85 \text{ cfm}$$

**Based on *average* population:**

$$V_{bz} = R_p \times P_z' + R_a \times A_z$$
$$= 5 \times 3.8 + 0.06 \times 1000$$
$$= 19 \text{ cfm} + 60 \text{ cfm}$$
$$= 79 \text{ cfm}$$

design for fluctuating occupancy

## Example: Conference Room

**Example**
conference room:

- $P_z$ = 17 people
- $A_z$ = 1000 ft²
- ceiling = 10 ft.
- v = 10000 ft³

**Based on *peak* population:**

$$V_{bz} = R_p \times P_z + R_a \times A_z$$
$$= 5 \times 17 + 0.06 \times 1000$$
$$= 85 \text{ cfm} + 60 \text{ cfm}$$
$$= 145 \text{ cfm}$$

**Averaging time period:**

$$T = 3 \times v / V_{bz}$$
$$= 3 \times 10000 / 145$$
$$= 207 \text{ minutes}$$
$$\approx 4 \text{ hours}$$

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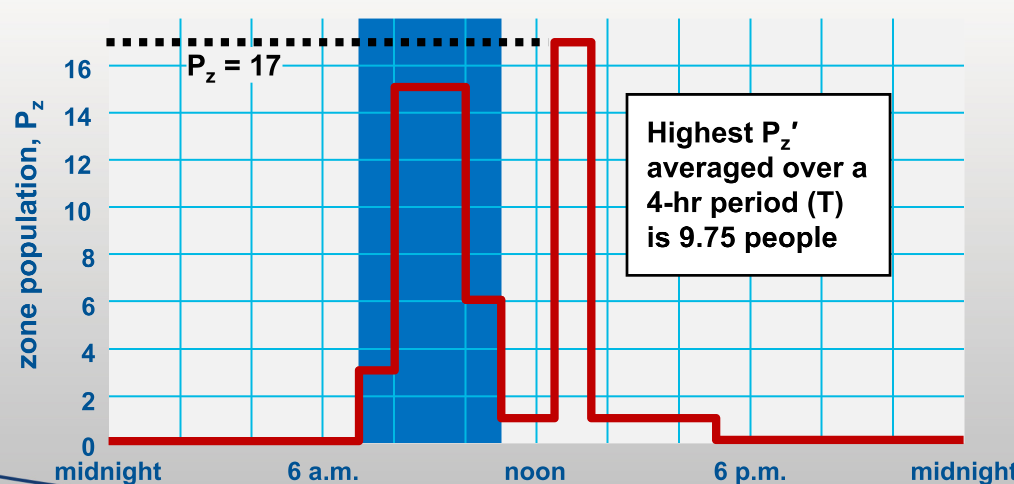
design for fluctuating occupancy

## Example: Conference Room

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### design for fluctuating occupancy

## Example: Conference Room

**Example**
conference room:

- $P_z$ = 17 people
- $P_z'$ = 9.75 people
- $A_z$ = 1000 ft²

**Based on *peak* population:**

$$V_{bz} = R_p \times P_z + R_a \times A_z$$
$$= 5 \times 17 + 0.06 \times 1000$$
$$= 85 \text{ cfm} + 60 \text{ cfm}$$
$$= 145 \text{ cfm}$$

**Based on *average* population:**

$$V_{bz} = R_p \times P_z' + R_a \times A_z$$
$$= 5 \times 9.75 + 0.06 \times 1000$$
$$= 49 \text{ cfm} + 60 \text{ cfm}$$
$$= 109 \text{ cfm}$$

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## Agenda

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**Supplemental content**

- Review of Section 4.0 and 5.0 requirements
- Design for varying operating conditions
- VRP calculations for systems with a secondary recirculation air path

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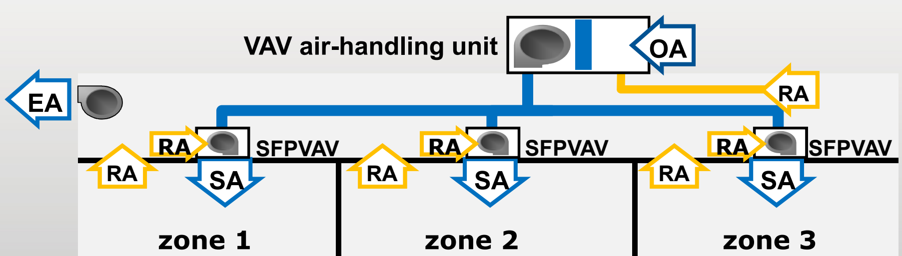
### multiple-zone recirculating
## Secondary Recirculation System

- Some (or all) of the air supplied to each zone is recirculated from other zones, and not directly mixed with outdoor air
  - Fan-powered VAV systems
  - Dual-fan, dual-duct VAV systems

### example of secondary recirculation system
## Series Fan-Powered VAV System




**centralized and local recirculation air paths both contain some excess OA**

### Section 6.2.5

## Multiple-Zone Recirculating

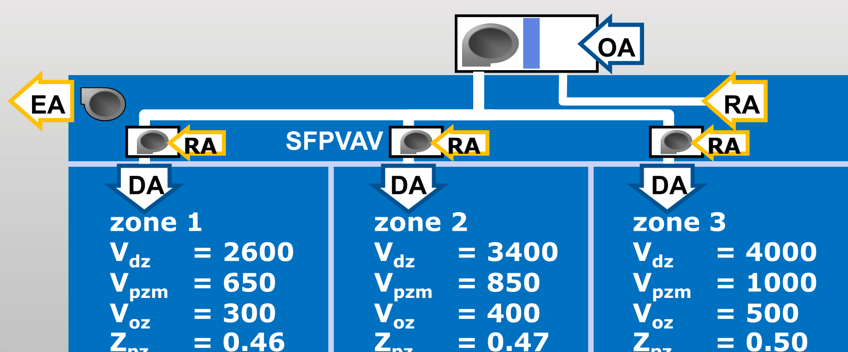
1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)



### example: series fan-powered VAV system (cooling mode)

## Calculating Zone Outdoor Air Fraction

$$Z_{pz} = V_{oz} / V_{pz}$$



Section 6.2.5
## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)

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example: single-path VAV system (cooling mode)
## Calculating Uncorrected OA Intake

| zone | $R_p \times P_z$ | $R_a \times A_z$ |
|---|---|---|
| **1** | 5 × 30 = **150** | 0.06 × 2500 = **150** |
| **2** | 5 × 40 = **200** | 0.06 × 3340 = **200** |
| **3** | 5 × 50 = **250** | 0.06 × 4170 = **250** |
| | $\sum(R_p \times P_z)$ = **600 cfm** | $\sum(R_a \times A_z)$ = **600 cfm** |

$$V_{ou} = D \times \sum (R_p \times P_z) + \sum (R_a \times A_z)$$
$$= 0.66 \times 600 + 600$$
$$= 1000 \text{ cfm}$$

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Appendix A

## Calculating System Ventilation Efficiency

3a. Average OA fraction ($X_s$)

$X_s = V_{ou} / V_{ps}$

3b. Zone ventilation efficiency ($E_{vz}$)

for single-supply systems:

$E_{vz} = 1 + X_s – Z_{pz}$

for secondary recirculation systems:

$E_{vz} = (F_a + X_s \times F_b – Z_{pz} \times E_p \times F_c) / F_a$

3c. System ventilation efficiency ($E_v$)

$E_v$ = smallest $E_{vz}$

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example: series fan-powered VAV system (cooling mode)

## Calculating Average OA Fraction

3a. Calculate average OA fraction ($X_s$) for system

$$X_s = V_{ou} / V_{ps} = 1000 / 6000 = 0.17$$

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example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

3b. For each zone, determine zone ventilation efficiency ($E_{vz}$):

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a$$

| zone | $F_a$ | $X_s$ | $F_b$ | $Z_{pz}$ | $E_p$ | $F_c$ | $E_{vz}$ |
|---|---|---|---|---|---|---|---|
| 1 | | 0.17 | | 0.46 | | | |
| 2 | | 0.17 | | 0.47 | | | |
| 3 | | 0.17 | | 0.50 | | | |

## Calculating Zone Ventilation Efficiency

Fraction of discharge air from sources outside the zone ($F_a$)

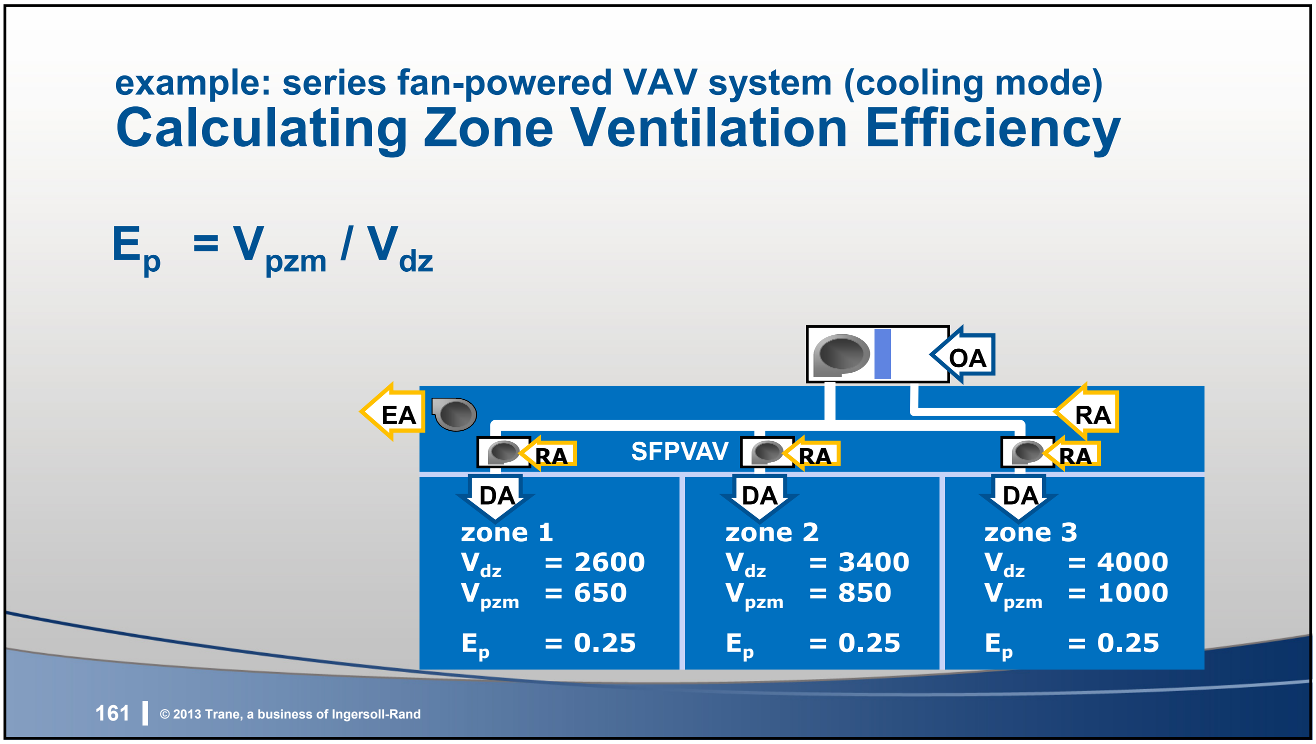
$$F_a = E_p + (1 - E_p) \times E_r$$

where,

$E_p$ = fraction of discharge air ($V_{dz}$) that is comprised of primary air ($V_{pz}$)

$E_r$ = fraction of locally recirculated air that is comprised of average recirculated air rather than recirculated directly from the zone (see example 6-F, *Standard 62.1-2010 User's Manual*)


example: series fan-powered VAV system (cooling mode)
Calculating Zone Ventilation Efficiency
$E_p = V_{pzm} / V_{dz}$
OA
EA
RA
SFPVAV
RA
RA
RA
DA
DA
DA
zone 1
$V_{dz}$ = 2600
$V_{pzm}$ = 650
$E_p$ = 0.25
zone 2
$V_{dz}$ = 3400
$V_{pzm}$ = 850
$E_p$ = 0.25
zone 3
$V_{dz}$ = 4000
$V_{pzm}$ = 1000
$E_p$ = 0.25
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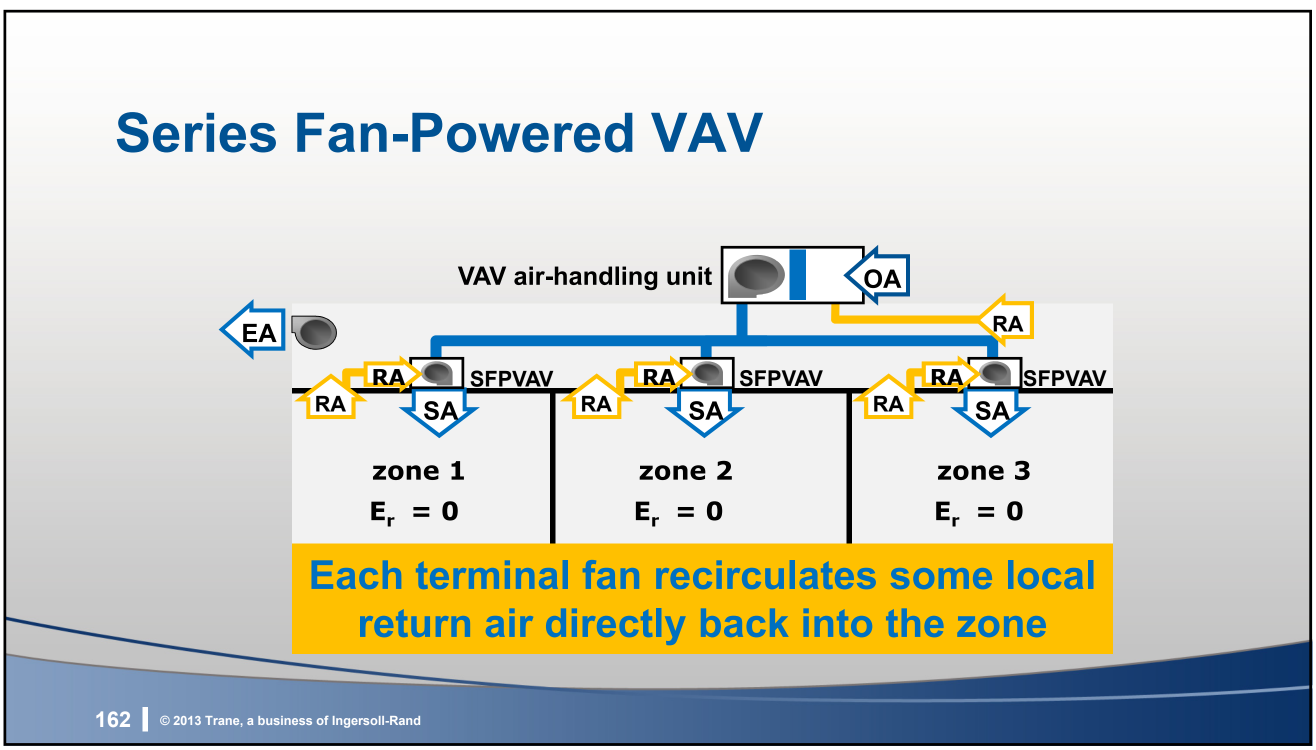
Series Fan-Powered VAV
VAV air-handling unit
OA
EA
RA
RA
SFPVAV
RA
SFPVAV
RA
SFPVAV
RA
SA
RA
SA
RA
SA
zone 1
$E_r$ = 0
zone 2
$E_r$ = 0
zone 3
$E_r$ = 0
Each terminal fan recirculates some local return air directly back into the zone
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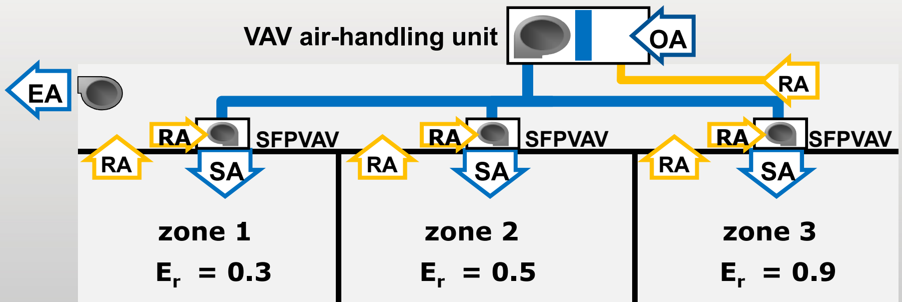
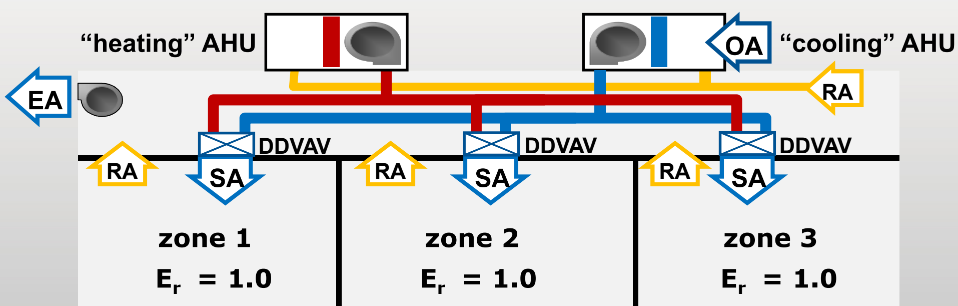
## Series Fan-Powered VAV




**Locally-recirculated air is a mixture of air from many zones**

## Dual-Fan, Dual-Duct VAV




**All return air is routed back through central air handlers**

example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

Fraction of discharge air from sources outside the zone ($F_a$)

$$F_a = E_p + (1 – E_p) × E_r$$

| zone | $E_p$ | $E_r$ | $F_a$ |
|---|---|---|---|
| 1 | 0.25 | 0.3 | 0.48 |
| 2 | 0.25 | 0.5 | 0.63 |
| 3 | 0.25 | 0.9 | 0.93 |




example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

Fraction of discharge air from fully mixed primary air ($F_b$)

$$F_b = E_p$$

| zone | $E_p$ | $F_b$ |
|---|---|---|
| 1 | 0.25 | 0.25 |
| 2 | 0.25 | 0.25 |
| 3 | 0.25 | 0.25 |

example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

Fraction of outdoor air from sources outside the zone ($F_c$)

$$F_c = 1 – (1 – E_z) \times (1 – E_r) \times (1 – E_p)$$

| zone | $E_z$ | $E_r$ | $E_p$ | $F_c$ |
|---|---|---|---|---|
| 1 | 1.0 | 0.3 | 0.25 | 1.0 |
| 2 | 1.0 | 0.5 | 0.25 | 1.0 |
| 3 | 1.0 | 0.9 | 0.25 | 1.0 |

167 | 

example: series fan-powered VAV system (heating mode)

## Calculating Zone Ventilation Efficiency

Fraction of outdoor air from sources outside the zone ($F_c$)

$$F_c = 1 – (1 – E_z) \times (1 – E_r) \times (1 – E_p)$$

| zone | $E_z$ | $E_r$ | $E_p$ | $F_c$ |
|---|---|---|---|---|
| 1 | 0.8 | 0.3 | 0.25 | 0.90 |
| 2 | 0.8 | 0.5 | 0.25 | 0.93 |
| 3 | 0.8 | 0.9 | 0.25 | 0.99 |

168 | 

example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

3b. For each zone, determine zone ventilation efficiency ($E_{vz}$):

$$E_{vz} = (F_a + X_s \times F_b - Z_{pz} \times E_p \times F_c) / F_a$$

| zone | $F_a$ | $X_s$ | $F_b$ | $Z_{pz}$ | $E_p$ | $F_c$ | $E_{vz}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0.48 | 0.17 | 0.25 | 0.46 | 0.25 | 1.0 | 0.85 |
| 2 | 0.63 | 0.17 | 0.25 | 0.47 | 0.25 | 1.0 | 0.88 |
| 3 | 0.93 | 0.17 | 0.25 | 0.50 | 0.25 | 1.0 | 0.91 |

example: series fan-powered VAV system (cooling mode)

## Calculating Zone Ventilation Efficiency

3c. Find system ventilation efficiency ($E_v$)

$$E_v = \text{smallest } E_{vz} = 0.85$$

| zone | $F_a$ | $X_s$ | $F_b$ | $Z_{pz}$ | $E_p$ | $F_c$ | $E_{vz}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0.48 | 0.17 | 0.25 | 0.46 | 0.25 | 1.0 | 0.85 |
| 2 | 0.63 | 0.17 | 0.25 | 0.47 | 0.25 | 1.0 | 0.88 |
| 3 | 0.93 | 0.17 | 0.25 | 0.50 | 0.25 | 1.0 | 0.91 |

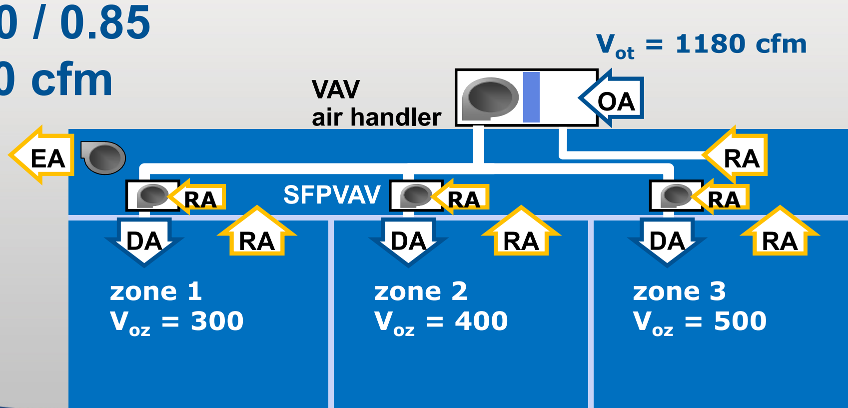
### Section 6.2.5
## Multiple-Zone Recirculating

1. Zone outdoor air fraction ($Z_{pz}$)
2. Uncorrected outdoor air intake ($V_{ou}$)
3. System ventilation efficiency ($E_v$)
   - Calculated $E_v$ method (Appendix A)
4. System outdoor air intake ($V_{ot}$)



### example: series fan-powered VAV system (cooling mode)
## Calculating System Outdoor-Air Intake Flow

$$V_{ot} = V_{ou} / E_v$$
$$= 1000 / 0.85$$
$$= 1180 \text{ cfm}$$



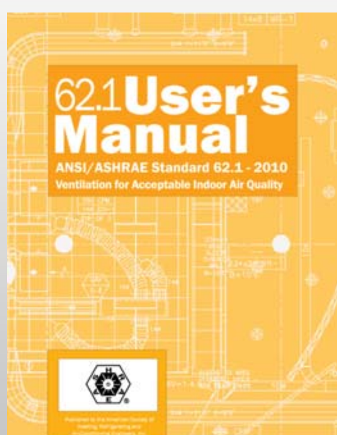
example: series fan-powered VAV system (cooling mode)

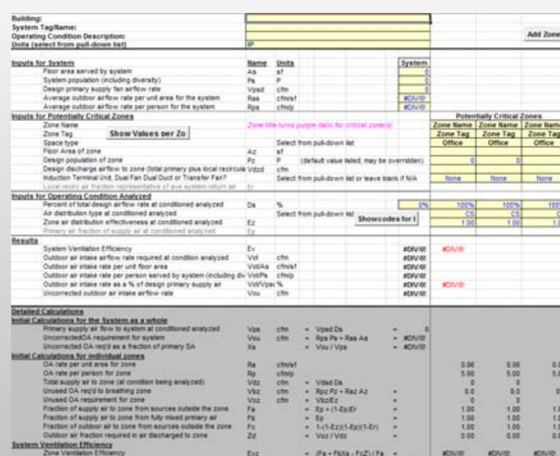
## Comparing Various Approaches

| $E_v$ method | $E_v$ | $V_{ot}$ |
|---|---|---|
| **Table 6-3** | **0.65** | **1540** |
| **Appendix A** (single-path equations) | **0.67** | **1490** |
| **Appendix A** (dual-path equations) | **0.85** | **1180** |

## Tools Available from ASHRAE



## VRP Calculations in TRACE™ 700

### System Ventilation Requirements

| AHU Location | Description | | ∑ Vpz cfm | Ps People | ∑ Pz People | D Ps / ∑ Pz | Vou cfm | Vps cfm | Xs | Ev | Vot cfm | %OA Vot / Vps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative 2** | | | | | | | | | | | | |
| System | System - 001 | Cooling | 10,000 | 80 | 120 | 0.67 | 1,001 | 6,000 | 0.167 | 1.000 | 1,001 | 16.7 |
| | | Heating | 2,500 | 80 | 120 | 0.67 | 1,001 | 2,500 | 0.400 | 0.775 | 1,291 | 51.6 |

### Ventilation Parameters

| | | | | | | — Cooling — | | — Heating — | |
|---|---|---|---|---|---|---|---|---|---|
| System Zone Room | Rp cfm/ p | Pz People | Ra cfm/ft² | Az ft² | Vbz cfm | Ez | Voz cfm | Ez | Voz cfm |
| **Alternative 2** | | | | | | | | | |
| Zone 1 | 5.00 | 30.00 | 0.06 | 2,500 | 300 | 1.00 | 300 | 0.80 | 375 |
| Zone 2 | 5.00 | 40.00 | 0.06 | 3,340 | 400 | 1.00 | 400 | 0.80 | 501 |
| Zone 3 | 5.00 | 50.00 | 0.06 | 4,170 | 500 | 1.00 | 500 | 0.80 | 625 |
| System - 001 | 5.00 | 120.00 | 0.06 | 10,010 | 1,201 | | 1,201 | | 1,501 |

### Ventilation Calculations for Heating Design

| System Zone Room | Box Type | Vpz cfm | Vfan cfm | Vdz cfm | Vpz-min cfm | Voz-htg cfm | Zd | Ep | Er | Fa | Fb | Fc | Evz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative 2** | | | | | | | | | | | | | |
| Zone 1 | SPF VAV | 650 | 650 | 650 | 650 | 375 | 0.577 | 1.00 | 0.30 | 1.00 | 1.00 | 1.00 | 0.823 |
| Zone 2 | SPF VAV | 850 | 850 | 850 | 850 | 501 | 0.589 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.811 |
| Zone 3 | SPF VAV | 1,000 | 1,000 | 1,000 | 1,000 | 625 | 0.625 | 1.00 | 0.90 | 1.00 | 1.00 | 1.00 | 0.775 * |
| **System - 001** | | 2,500 | 2,500 | 2,500 | 2,500 | 1,501 | | | | | | | 0.775 |

$A_z$ net occupiable floor area of the zone, ft² (m²)
D occupant diversity, ratio of system population to sum of zone populations
$E_v$ system ventilation efficiency
$E_z$ zone air-distribution effectiveness
$P_s$ system population, maximum simultaneous number of occupants in area
$P_z$ zone population, expected number of people to occupy zone during typical usage
$R_a$ required outdoor airflow per unit floor area, cfm/ft² (L/s·m²)
$R_p$ required outdoor airflow per person, cfm/person (L/s·person)
T averaging time period, minutes
v volume of the ventilation zone, $ft^3$ ($m^3$)
$V_{bz}$ outdoor airfl w required in breathing zone, cfm (L/s)
$V_{ot}$ outdoor air intake flow, corrected for ventilation efficiency, cfm (L/s)
$V_{ou}$ uncorrected outdoor air intake flow, cfm (L/s)
$V_{oz}$ outdoor airflow provided to zone by air distribution system, cfm (L/s)
$V_{pz}$ primary airflow delivers to ventilation zone by air handler
$Z_p$ fraction of outdoor air in the primary airflow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