
Applying ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality

Ventilation refers to the introduction of an adequate amount of fresh outdoor air to dilute contaminants that are generated inside the building (by people, equipment, processes, or furnishings). This requires the removal of an equal quantity of air from the building.

The “Ventilation Rate Procedure” (Section 6.2) in ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, prescribes the quantity of outdoor air that must be delivered to each zone, based on the expected use of that zone, and then prescribes how to calculate the outdoor airflow needed at the system-level intake.

To demonstrate this procedure, we’ll use an example VAV system with three breathing zones. We’ll also discuss how these calculations are implemented in TRACE™ 700.

Zone-level ventilation requirements

ASHRAE Standard 62.1 outlines the following procedure to determine the outdoor airflow required for each ventilation zone.

Determine minimum outdoor airflow requirement, V_{bz} , for each breathing zone(s)

The breathing zone outdoor airflow (V_{bz}), is determined using Equation 6-1 from ASHRAE Standard 62.1.

$$V_{bz} = (R_p \cdot P_z) + (R_a \cdot A_z)$$

where

V_{bz} = breathing zone outdoor airflow

A_z = zone floor area: the net occupiable floor area of the ventilation zone ft² (m²)

R_a = outdoor airflow rate required per unit area as determined from Table 6-1

P_z = zone population: the number of people in the ventilation zone during typical usage.

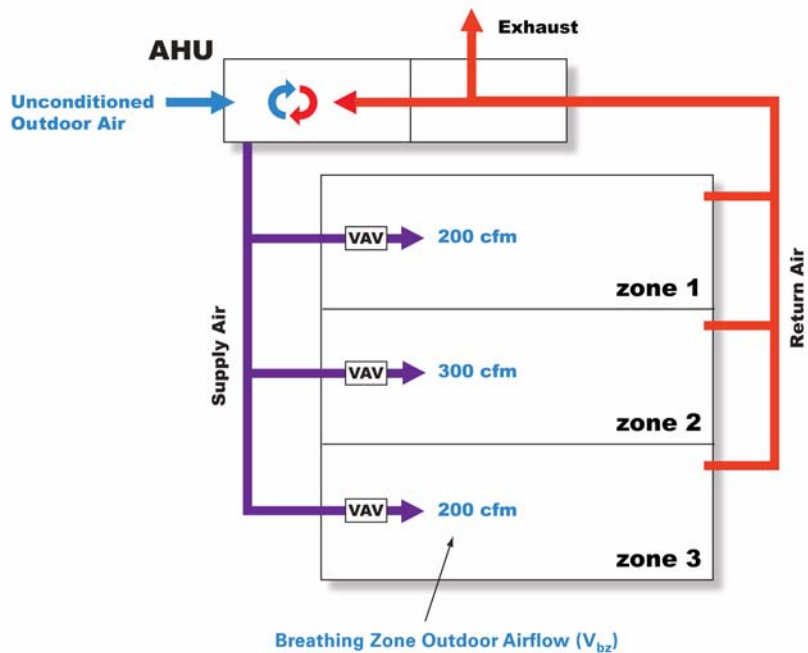
R_p = outdoor airflow rate required per person as determined from Table 6-1

These values are calculated for each room in TRACE when the **Apply ASHRAE Std62-1-2004/2007** field is set to "Yes" on the **Create Rooms - Airflows** tab.

The screenshot shows the 'Create Rooms - Airflows' dialog box. The 'Ventilation' section is highlighted with a green box. The settings are as follows:

- Apply ASHRAE Std62-1-2004/2007: Yes
- Type: Office space
- Peop-based: 5 cfm/person
- Area-based: 0.06 cfm/sq ft
- Schedule: Vent - Office

For this example, the required ventilation airflow has been calculated for each zone to be:



Calculate the zone outdoor airflow

The next step is to calculate the zone outdoor airflow (V_{oz}), which is the outdoor airflow rate that must be provided to the ventilation zone by the supply air distribution system. The zone outdoor airflow accounts for the zone air distribution effectiveness (E_z) found in Table 6-2.

The zone outdoor airflow is calculated using the following equation:

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

where

V_{oz} = zone outdoor airflow

V_{bz} = breathing zone outdoor airflow

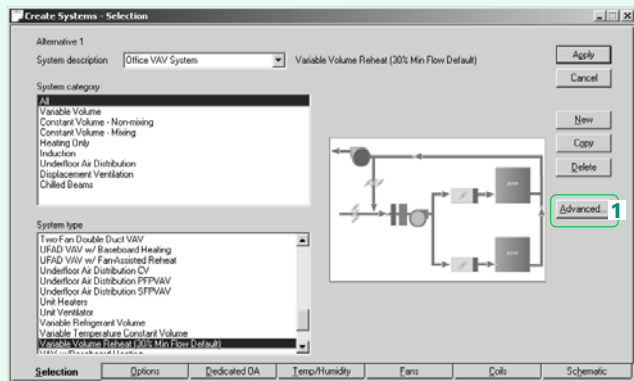
E_z = zone air distribution effectiveness

In this example, a VAV system supplies cool air to each zone from the ceiling, so the zone air distribution effectiveness is 1.0. As a result, $V_{oz} = V_{bz}$.

System-level ventilation requirements

ASHRAE Standard 62.1 also defines procedures for calculating the outdoor airflow needed at the system-level intake (V_{ot}) to make sure that the required quantity of outdoor air is delivered to each zone (V_{oz}). Which procedure to use depends on the configuration of the ventilation system.

- 1 To enable the ASHRAE Standard 62.1 calculations at the system level in TRACE, go to **Create Systems** and click the **Advanced** button.



2 In the **System Ventilation** field, select either **ASHRAE Std 62.1 2004/2007** or **ASHRAE Std 62.1 2004/2007 w/Vent Reset**.

TRACE performs the calculations behind the scenes and displays the results on the **ASHRAE Standard 62.1** report.

Calculate the system-level outdoor air intake flow

A VAV system is a *multiple-zone recirculating system*, so the outdoor air intake flow is determined in accordance with Sections 6.2.5.1 through 6.2.5.4 of the standard.

Begin by determining the *uncorrected* outdoor air intake flow (V_{ou}) for the system by totaling the breathing zone outdoor airflow requirements from all of the spaces served by a common system using Equation 6-6.

$$V_{ou} = D \sum_{all\ zones} (R_p \cdot P_z) + \sum_{all\ zones} (R_a \cdot A_z)$$

where

V_{ou} = uncorrected outdoor air intake

A_z = zone floor area: the net occupiable floor area of the ventilation zone ft² (m²)

R_a = outdoor airflow rate required per unit area as determined from Table 6-1

P_z = zone population: the number of people in the ventilation zone during typical usage

R_p = outdoor airflow rate required per person as determined from Table 6-1

D = occupant diversity determined using Equation 6-7 to account for variations in population within the ventilation zones served by the system

For this example, a diversity ratio of 1.0 is assumed and the uncorrected outdoor air intake (V_{ou}) is calculated as follows:

$$200\text{ cfm} + 300\text{ cfm} + 200\text{ cfm} = 700\text{ cfm}$$

If the calculations ended here, and the air handler only delivered 700 cfm of outdoor air to the occupied spaces, it is almost certain that at least one of the breathing zones would be inadequately ventilated. The reason is that after the outdoor air drawn into the air handler is fully mixed with recirculated air, it is impossible to deliver discrete quantities (cfm) of outdoor air to the individual breathing zones. Instead, the supply air is delivered as a homogenous mixture of outdoor air and recirculated air, which means that all of the breathing zones receive the same percentage of outdoor air.

To determine what that percentage needs to be, the primary outdoor air fraction (Z_p) must be calculated for each zone.

Calculate the primary outdoor air fraction Z_p

The primary outdoor air fraction is the amount of outdoor air that must be supplied to each breathing zone as a percentage of the minimum expected primary airflow (outdoor air and recirculated air), at design conditions, delivered to the breathing zone. It is calculated using Equation 6-5.

$$Z_p = V_{oz} / V_{pz - min}$$

where

Z_p = primary outdoor air fraction

V_{oz} = zone outdoor airflow

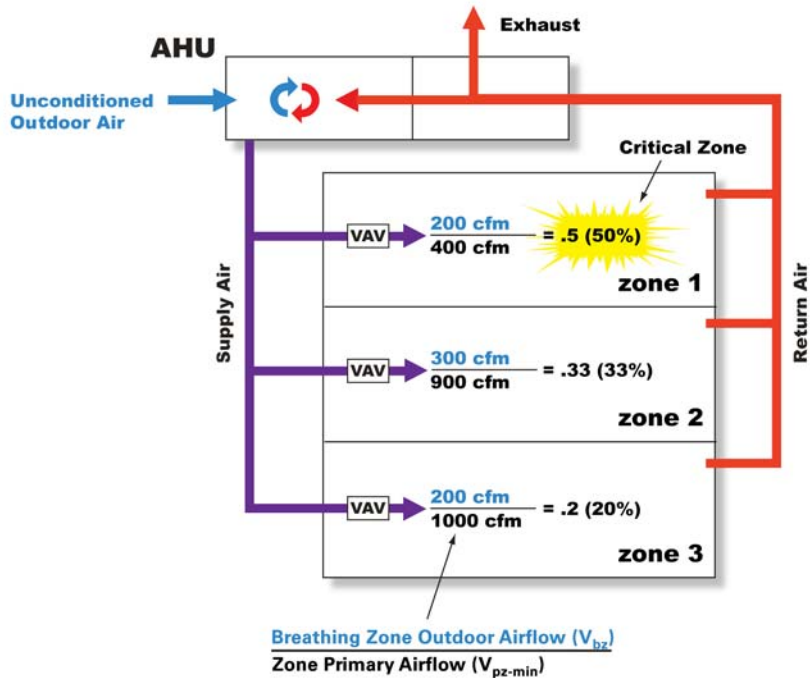
$V_{pz - min}$ = minimum expected zone primary airflow at the design condition analyzed

In TRACE 700, V_{pz-min} is set in the **VAV Minimum Rate** field on the **Create Rooms – Airflows** tab. For most systems the default value is 30%.

Note: In TRACE 700, V_{pz-min} is also equal to the VAV minimum heating airflow.

The screenshot shows the 'Create Rooms - Airflows' dialog box. The 'VAV minimum...' field is highlighted with a green box, indicating the minimum VAV rate is set to 30%.

In the figure below, the minimum zone primary airflows have been added to the example and the primary outdoor air fraction has been calculated for each breathing zone:



In this example, 50% of the system primary air must be outdoor air to properly ventilate the critical zone. This means that all of the zones will receive 50% outdoor air and any zone with a lower primary outdoor air fraction than the critical zone will be overventilated. This overventilation results in “unused” outdoor air that is recirculated in the return air coming from these zones and can be used to offset the ventilation requirements of the system.

Determine system ventilation efficiency E_v

ASHRAE Standard 62.1 accounts for this unused outdoor air by means of a system ventilation efficiency (E_v). The system ventilation efficiency may be determined using either of two methods:

- read the value from Table 6-3, or
- calculate it using the approach found in Appendix A.

TRACE 700 determines the system ventilation efficiency using both methods and then selects the higher of the two efficiencies.

Method 1: Table 6-3

To use Table 6-3, compare the primary outdoor-air fractions for the zones that the ventilation system serves. Use the largest value (maximum Z_p) to determine the system ventilation efficiency.

Note: For values of Max (Z_p) between 0.15 and 0.55, the corresponding value of E_v may be determined by interpolating the values in Table 6-3.

For the VAV system in this example, the E_v for a primary outdoor air fraction of 50% would be 0.65 (65%).

Table 6-3 System Ventilation Efficiency

Max (Z_p)	E_v
≤ 0.15	1
≤ 0.25	0.9
≤ 0.35	0.8
≤ 0.45	0.7
≤ 0.55	0.6
> 0.55	Use Appendix A

Table 6-3 may result in unrealistically low values of E_v for systems with higher average outdoor air fraction values, and the use of Appendix A may yield more practical results.

Method 2: Appendix A

Section A1.2.1 from Appendix A states:

“For ‘single supply’ systems, wherein all of the air supplied to each *ventilation zone* is a mixture of outdoor air and system-level recirculated air, zone ventilation efficiency (E_{vz}) shall be determined in accordance with Equation A-2.”

$$E_{vz} = 1 + X_s - Z_d$$

where

E_{vz} = efficiency with which a system distributes outdoor air from the intake to an individual breathing zone

X_s = average outdoor air fraction for the ventilation system

Z_d = the percentage of outdoor air in the air discharged to the zone

The discharge outdoor air fraction (Z_d) is calculated for each zone using the equation:

$$Z_d = V_{oz} / V_{dz}$$

where

V_{oz} = design outdoor airflow required in the zone

V_{dz} = expected discharge airflow to the zone

where

V_{dz} = the primary zone airflow (V_{pz}) + any locally recirculated airflow

For this example, it is assumed that all of the VAV boxes are shutoff boxes and as a result: $V_{dz} = V_{pz}$ and $Z_d = Z_p$ for all of the zones.

In TRACE 700,

$$V_{pz} = V_{pz - min} / (\text{VAV Minimum Rate})$$

Applying the default **VAV Minimum Rate** of 30% to all three zones, the resulting primary zone airflows will be:

- Zone 1 $V_{pz} = 1333$ cfm
- Zone 2 $V_{pz} = 3000$ cfm
- Zone 3 $V_{pz} = 3333$ cfm

The average outdoor air fraction (X_s) is calculated by dividing the uncorrected outdoor air intake by the system primary airflow (V_{ps}).

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

In TRACE 700, V_{ps} is reported as “Vfan” on the **ASHRAE Standard 62.1** report and is equal to the “Main Fan” airflow found on the **System Checksums** report.

For this example:

$$V_{ps} = \Sigma V_{pz} = 7667 \text{ cfm}$$

$$X_s = 700 \text{ cfm} / 7667 \text{ cfm} = 0.0913$$

The system ventilation efficiency may now be calculated for each zone using Equation A-2:

- Zone 1: $E_{vz} = 1 + 0.0913 - 0.5 = 0.5913$
- Zone 2: $E_{vz} = 1 + 0.0913 - 0.3333 = 0.7580$
- Zone 3: $E_{vz} = 1 + 0.0913 - 0.2 = 0.8913$

After the ventilation efficiency (E_{vz}) has been calculated for all of the zones, the system ventilation efficiency (E_v) is determined to be the smallest zone ventilation efficiency per Equation A-3:

$$E_v = \text{minimum } (E_{vz})$$

For this example, $E_v = 0.5913$.

Comparison of the results

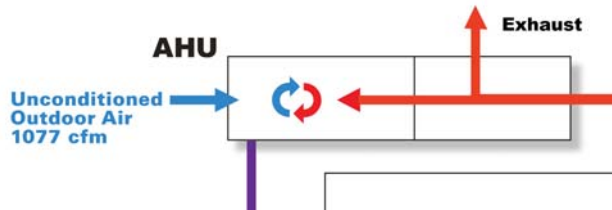
Since the system ventilation efficiency of 0.65 from Table 6-3 is higher than the calculated value of 0.5913, the system ventilation efficiency is chosen to be 0.65 (65%).

Find outdoor-air intake flow V_{ot}

The final step is to calculate the outdoor air intake flow (V_{ot}) by dividing the uncorrected outdoor air intake (V_{ou}) by the highest system ventilation efficiency (E_v):

$$V_{ot} = 700 \text{ cfm} / 0.65 = 1077 \text{ cfm}$$

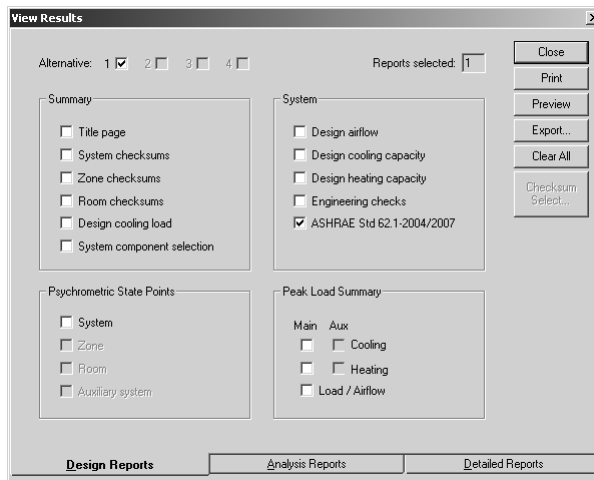
For this example, **1077 cfm** of unconditioned outdoor air is required to adequately ventilate all spaces.



TRACE 700 - ASHRAE Standard 62.1 report

A report showing the ASHRAE Standard 62.1 calculations is available in TRACE 700.

Note: This report is only available when ASHRAE Standard 62.1 calculations have been enabled. (See the sidebar on pages 3-4.)



ASHRAE Standard 62.1-2004/2007

By Trane

System Ventilation Requirements

AHU Location	Description		$\sum V_{pz}$ cfm	P_s People	$\sum P_z$ People	D $P_s / \sum P_z$	V_{ou} cfm	V_{ps} cfm	X_s	E_v	V_{ot} cfm	%OA V_{ot} / V_{ps}
Alternative 1												
System	Office VAV System	Cooling	16,126	140	140	1.00	1,899	16,793	0.113	0.512	3,712	22.1
		Heating	5,048	140	140	1.00	1,899	5,048	0.376	0.624	3,042	60.3

Ventilation Parameters

System Zone Room	Rp cfm/ p	Pz People	Ra cfm/ft²	Az ft²	Vbz cfm	—Cooling—		—Heating—	
						Ez	Voz cfm	Ez	Voz cfm
Alternative 1									
North Office	5.00	13.29	0.06	1,900	180	1.00	180	0.80	226
East Office	5.00	6.29	0.06	900	85	1.00	85	0.80	107
South Office	5.00	13.29	0.06	1,900	180	1.00	180	0.80	226
West Office	5.00	6.29	0.06	900	85	1.00	85	0.80	107
Interior Office	5.00	100.70	0.06	14,400	1,367	1.00	1,367	0.80	1,709
Office VAV System	5.00	139.66	0.06	20,000	1,899		1,899		2,374

Ventilation Calculations for Cooling Design

System Zone Room	Box Type	V_{pz} cfm	V_{fan} cfm	V_{dz} cfm	V_{pz-min} cfm	V_{oz-clg} cfm	Z_d	E_p	E_r	F_a	F_b	F_c	E_v
Alternative 1													
North Office	Shutoff VAV	300	300	300	300	180	0.601	1.00	0.00	1.00	1.00	1.00	0.512 *
East Office	Shutoff VAV	1,706	1,706	1,706	512	85	0.167	1.00	0.00	1.00	1.00	1.00	0.946
South Office	Shutoff VAV	3,521	3,521	3,521	1,056	180	0.171	1.00	0.00	1.00	1.00	1.00	0.942
West Office	Shutoff VAV	2,013	2,013	2,013	604	85	0.142	1.00	0.00	1.00	1.00	1.00	0.972
Interior Office	Shutoff VAV	8,565	8,565	8,565	2,576	1,367	0.531	1.00	0.00	1.00	1.00	1.00	0.662
Office VAV System		16,126	16,793	16,126	5,048	1,899							0.512

Frequently Asked Questions

What's the difference between ASHRAE Std 62.1 2004/2007 and ASHRAE Std 62.1 2004/2007 w/Vent Reset?

These two options are available from the **System Ventilation Flag** field on the **Create Systems - Advanced** screen (accessed from the **Create Systems** screen by clicking the **Advanced** button).

Create Systems - Advanced

System description: Office VAV System

System type: Variable Volume Reheat (30% Min Flow Default)

Supply fan motor location: Supply

Return fan motor location: Return

Fan configuration: Draw Thru

Fan sizing method: Block

Supply air path / duct location: Return Air

Return air path: Plenum

Block cooling airflow: cfm

Cooling coil sizing method: Block

Cooling coil location: System

Ventilation deck location: Return/Outdoor Deck

System ventilation flag: ASHRAE Std 62.1-2004/2007

Apply ASHRAE Std 62.1-2004/2007 People Averaging: ☐ Yes ☒ No

ASHRAE Std62 Max Vent (Z) Ratio Allowed: %

Population Diversity (non-DCV Rooms only): 100 %

CO2-based DCV: ☒ None ☐ Proportional Control ☐ Single Setpoint

Warning: The fields marked in red are core components of this system. Changing these values can drastically affect how the system operates. Please make sure you are aware of the total ramifications before you make such a change.

When **ASHRAE Std 62.1 2004/2007** is selected, the outdoor air intake flow (V_{ot}) is maintained at a constant flow rate established at design conditions while TRACE™ 700 performs the building simulation calculations.

When **ASHRAE Std 62.1 2004/2007 w/Vent Reset** is selected, TRACE 700 recalculates the outdoor air intake flow on an hourly basis as the population changes in the individual rooms.

In the following example, the population in the West Office is changing during a weekday according to the People – Office schedule.

Create Rooms - Internal Loads

Alternative 1

Room description: West Office

Templates...

Room: Wing 1 People... Activity: General Office Space Density: 143 sq ft/person

Internal: Wing 1 Schedule: People - Office

Airflow: Wing 1 Sensible: 250 Btu/h Latent: 200 Btu/h

Schedule Library

Schedule type: Utilization

Description: People - Office

Simulation type: ☒ Reduced year ☐ Full year (day types only)

Comments:

January - December: Cooling design to Weekday

Heating design: January - December: Saturday to Sunday

Schedule Definition

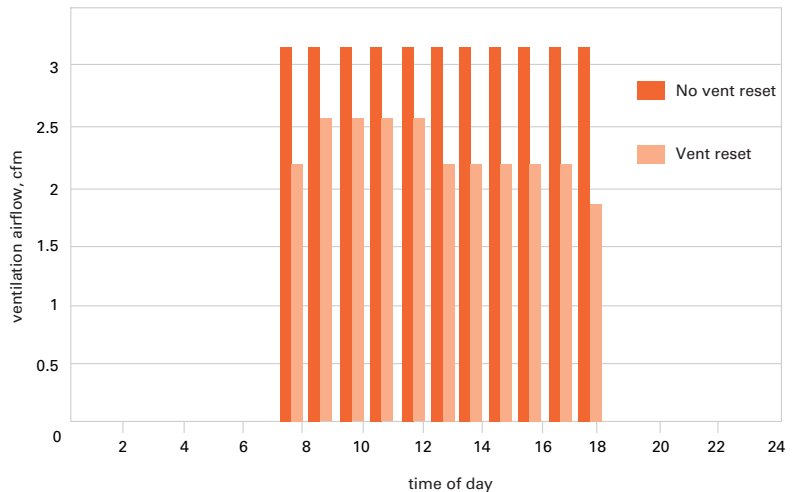
Start: Month: January End: December

Day type: Cooling design Weekday

Start time	End time	Percentage
Midnight	7 a.m.	0
7 a.m.	8 a.m.	30
8 a.m.	5 p.m.	100
5 p.m.	6 p.m.	30
6 p.m.	7 p.m.	1
7 p.m.	Midnight	0

Buttons: Save, Close, New Sched, Copy Sched, Del Sched, New Definition

The graph below shows the difference in the ventilation airflow (cfm) for a typical weekday in January without ventilation reset (alt 1) and with ventilation reset (alt 2).

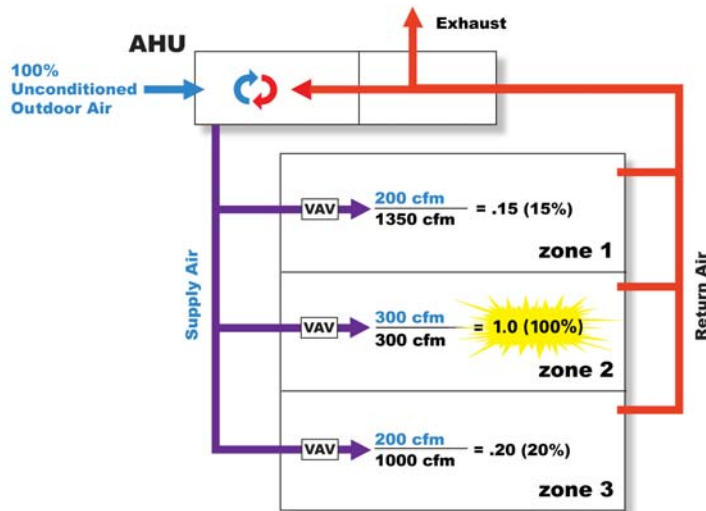


Why does the system call for 100% outdoor air when ASHRAE Standard 62.1 is implemented?

This condition occurs if at any time the zone outdoor airflow (V_{oz}) is equal to the lowest zone primary airflow value expected at the design condition analyzed (V_{pz}). The System Checksums report below shows an example of this.

Variable Volume Reheat (30% Min Flow Default)									
COOLING SPACE PEAK			HEATING COIL PEAK			TEMPERATURES			
Mo/Hr: 7 / 17 OADB: 86			Mo/Hr: Heating Design OADB: -9						
Space	Percent		SpacePeak	CoilPeak	Percent				
Sensible	Of Total		SpaceSens	TotSens	Of Total				
Btu/h	(%)		Btu/h	Btu/h	(%)				
						SADB			
						RaPlenum			
						Return			
						Ret/OA			
						FnMtr TD			
						Fn Bld TD			
						Fn Frict			

In this situation, the only way to satisfy the outdoor air requirement of the critical zone is for the system to supply 100% outdoor air to all of the zones.



To prevent this situation from occurring, you can set a maximum outdoor air fraction limit in TRACE. This value can be entered in the **ASHRAE Std62 Max Vent (Z) Ratio Allowed** field on the **Create Systems-Advanced** screen.

Create Systems - Advanced

System description: Office VAV System

System type: Variable Volume Reheat (30% Min Flow Default)

Supply fan motor location: Supply

Return fan motor location: Return

Fan configuration: Draw Thru

Fan sizing method: Block

Supply air path / duct location: Return Air

Return air path: Plenum

Block cooling airflow: cfm

Cooling coil sizing method: Block

Cooling coil location: System

Ventilation deck location: Return/Outdoor Deck

System ventilation flag: ASHRAE Std 62.1-2004/2007

Apply ASHRAE Std 62.1-2004/2007 People Averaging: ☐ Yes ☒ No

ASHRAE Std62 Max Vent (Z) Ratio Allowed: 60 %

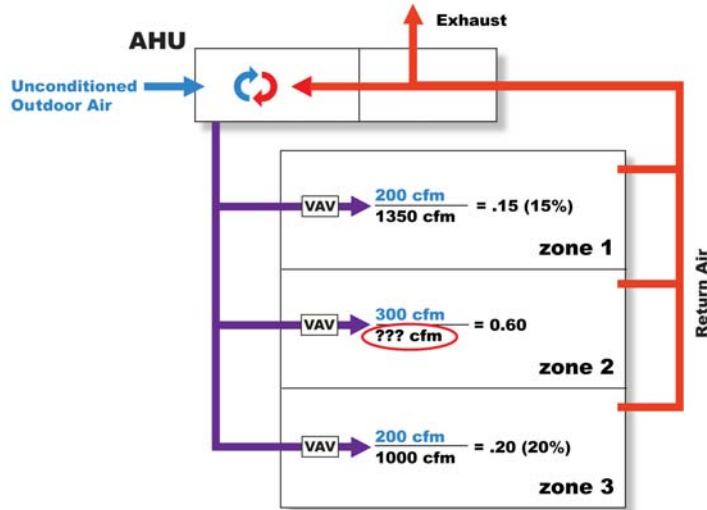
Population Diversity (non-DCV Rooms only): 100 %

CO2-based DCV: ☒ None ☐ Proportional Control ☐ Single Setpoint

Warning: The fields marked in red are core components of this system. Changing these values can drastically affect how the system operates. Please make sure you are aware of the total ramifications before you make such a change.

Entering a value in this field prevents the primary outdoor air fraction (Z_p) for any zone from exceeding this value. Because the amount of outdoor air that must be supplied to each zone (V_{oz}) is fixed, the only way the equation $Z_p = V_{oz} / V_{pz - min}$ can be solved is by increasing the minimum expected zone primary airflow ($V_{pz - min}$). As a result, the outdoor air requirement of the critical zone is met with a lower concentration of outdoor air in the primary airflow.

In the following example, the **ASHRAE Std62 Max Vent (Z) Ratio Allowed** value has been set to 60%. Zones 1 and 3 are unaffected because their respective calculated Z ratios are both less than 60%. Zone 2, however, is affected because its calculated Z ratio of 1.0 (100%) is greater than the imposed limit of 0.60 (60%). As a result, the zone primary airflow (V_{pz}) for Zone 2 must now be calculated.



Solving for V_{pz} :

$$V_{pz} = 300 \text{ cfm} / 0.60 = 500 \text{ cfm}$$

The resulting zone primary airflow is increased from an initial value of 300 cfm—the required airflow to meet the load in the space—to 500 cfm, the required airflow to meet the outdoor air requirement of the space.

The remaining calculations for determining the outdoor air intake flow (V_{ot}) are unchanged by the limited ventilation ratio.

For this example, it is assumed that all of the VAV boxes are shutoff boxes. As a result, $V_{dz} = V_{pz}$ and $Z_d = Z_p$ for all of the zones.

It is also assumed that the uncorrected outdoor air intake flow (V_{ou}) for the system is the sum of the design outdoor airflows required in each zone:

$$V_{ou} = \Sigma V_{oz} = 700 \text{ cfm}$$

In TRACE 700:

$$V_{pz} = V_{pz - min} / (\text{VAV Minimum Rate})$$

For this example, the default **VAV Minimum Rate** of 30% is applied to all three zones to determine the primary zone airflows:

- Zone 1 $V_{pz} = 1350 / 0.3 = 4500 \text{ cfm}$
- Zone 2 $V_{pz} = 500 / 0.3 = 1667 \text{ cfm}$
- Zone 3 $V_{pz} = 1000 / 0.3 = 3333 \text{ cfm}$

The average outdoor air fraction (X_s) is calculated by dividing the uncorrected outdoor air intake by the system primary airflow (V_{ps}).

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

In TRACE 700, V_{ps} is reported as "Vfan" on the **ASHRAE Standard 62.1** report and is equal to the "Main Fan" airflow found on the **System Checksums** report.

$$V_{ps} = \Sigma V_{pz} = 9500 \text{ cfm}$$

$$X_s = 700 \text{ cfm} / 9500 \text{ cfm} = 0.0737$$

The system ventilation efficiency may now be calculated for each zone using Equation A-2:

- Zone 1: $E_{vz} = 1 + 0.0737 - 0.1481 = 0.9256$
- Zone 2: $E_{vz} = 1 + 0.0737 - 0.6 = 0.4737$
- Zone 3: $E_{vz} = 1 + 0.0737 - 0.2 = 0.8737$

After the ventilation efficiency (E_{vz}) has been calculated for all of the zones, the system ventilation efficiency (E_v) is determined to be the smallest zone ventilation efficiency per Equation A-3:

$$E_v = \text{minimum } (E_{vz})$$

For this example, $E_v = 0.4737$.

Because the maximum ventilation ratio Z_p (0.60) is greater than 0.55, Table 6-3 cannot be used to determine the system ventilation efficiency for this example so: $E_v = 0.4737$.

The final step is to calculate the outdoor air intake flow (V_{ot}) by dividing the uncorrected outdoor air intake (V_{ou}) by the highest system ventilation efficiency (E_v):

$$V_{ot} = 700 \text{ cfm} / 0.4737 = 1478 \text{ cfm}$$

For this example, **1478 cfm** of unconditioned outdoor air is required to adequately ventilate all spaces.

Limiting the primary ventilation fraction significantly reduced the amount of unconditioned outdoor air required to adequately ventilate these spaces from 9500 cfm (100% outdoor air) to 1478 cfm.

What is the “right” value for the Maximum Vent (Z) Ratio Allowed field?

It is left to your discretion to define the **Max Vent (Z) Ratio Allowed** value. While reducing the ventilation fraction decreases the outdoor air intake flow, it increases the fan energy because of the higher system airflow. It also increases the amount of VAV reheat required (if present) to temper the air delivered to the affected zones, or it may lead to overcooling in the affected zones without reheat.