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Technical White Paper

Indoor Air Quality Procedure Under ASHRAE Standard 62.1-2019 and -2022



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Executive Overview

Executing energy efficient building designs is a never-ending challenge. Gains were made over prior decades via advances in control, LED lighting, and variable speed systems. The pressure mounts again for efficient and sustainable systems.

A sizable energy saving opportunity remains within HVAC system designs. This paper demonstrates that addressing indoor air quality through a standards-based air cleaning approach may reduce initial equipment costs and deliver lower power consumption in many commercial buildings. This approach, called the Indoor Air Quality Procedure (IAQP), allows outdoor airflow to be reduced if indoor air quality can be assured through other means: combining air cleaning with contaminant control.

Reduction of outdoor air, paired with an air cleaning system, is guided by the IAQP as defined in ASHRAE Standard 62.1. This direct approach can provide measurably better indoor air with lower operating and initial equipment cost.

“The IAQP may allow for a more cost-effective solution to providing good air quality.”

ASHRAE 62.1-2019 User’s Manual

Ventilation Procedures

Ventilation is necessary for healthy indoor spaces as human and building generated contaminants would eventually render a space toxic if unmanaged. Building codes across the U.S. and Canada, with few exceptions, reference ASHRAE Standard 62.1 Ventilation and Acceptable Indoor Air Quality for code-compliant ventilation designs.

The foreword in 62.1 defines the duality of the role 62.1 plays for air quality and system design:

Ventilation Procedures (Continued)

ASHRAE Standard 62.1 specifies minimum ventilation rates and other measures intended to provide indoor air quality (IAQ) that is acceptable to human occupants and that minimizes adverse health effects...To signify that indoor air quality goes beyond minimum ventilation requirements—and in recognition of those aspects of building systems (equipment, filtration, controls, and more) that contribute to acceptable IAQ—the title of the standard has been updated to “Ventilation and Acceptable Indoor Air Quality.” -Standard 62.1 Foreword

Standard 62.1 offers three approaches to space ventilation. Mechanical ventilation in most buildings will follow either the Ventilation Rate Procedure (VRP) or the Indoor Air Quality Procedure (IAQP).

Ventilation Rate Procedure. *The prescriptive design procedure presented in Section 6.2, in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area, shall be permitted to be used for any zone or system.*

Indoor Air Quality Procedure. *The IAQP is an alternative to the VRP used to determine the design rate of outdoor airflow to maintain concentrations of design compounds (DCs) and PM_{2.5} in the indoor environment to be less than design limits (DLs), based on indoor and outdoor sources, air cleaning, and other variables. These outdoor air requirements shall be calculated with mass-balance equations. Verification of occupant satisfaction and indoor DC concentrations shall be performed after the building is completed.*

-ASHRAE 62.1 Section 6.1.1 and 6.1.2

The conventional design approach is the prescriptive Ventilation Rate Procedure, in which a mechanical system is sized to include sufficient outdoor air for contaminant dilution. The approach increases HVAC capacity for heating and cooling and is generally the most energy intensive approach with outdoor air capacity sized for worst-case utilization. Controls may be added to regulate outdoor airflow based on population (or other logic) to achieve some energy savings; however, HVAC equipment capacity is selected for the maximum conditions.

Ventilation Procedures (Continued)

“The VPR is an indirect solution to achieving acceptable IAQ. The IAQP is a more direct approach to the goal.”

ASHRAE 62.1-2019 User’s Manual

ASHRAE established the indoor air quality procedure (IAQP) in 1981 as a direct, engineered approach for a more efficient and cost-effective design. The procedure has evolved to become a well-researched and defined alternative to the ventilation rate procedure (VRP). In some cases, the IAQP is the preferred approach. Under the IAQP, HVAC systems can be simplified and right-sized as the outdoor air load is 30 – 75% lower. With reduced load, the system will have lower operating costs compared to a VRP design. Due to these benefits, IAQP is gaining favor for the efficiency, sustainability, and savings it delivers. Example capacity and energy saving scenarios are in Appendix One.

Indoor Air Quality Procedure (IAQP)

The IAQP is an engineered approach to acceptable indoor air quality. Engineers apply contaminant source control (air cleaners & filters) in concert with lower outdoor air ventilation to deliver a compliant design. In the past the standard required designers to identify contaminant sources, generation rates, steady state concentrations, and air cleaner removal efficiencies. Now the standard is prescriptive and offers designers the options to supplement or modify contaminants and thresholds.

Successful IAQP designs ensure steady state concentrations as calculated in the mass balance equations are below the maximum levels defined in the standard (or by the engineer). The pivotal decisions are the selection of an outdoor air rate and air cleaner. Air cleaner selection is guided by ASHRAE standards and position documents. Automation for this iterative approach is available in ASHRAE’s calculator or calculators from various manufacturers.[2] A comparison between a VRP design and IAQP design for an elementary school classroom is presented in Appendix Two.

IAQP Design Compounds

As a more direct approach, the IAQP is specific in its intent: maintain the listed design compounds below thresholds recognized by authorities as detrimental to human health. The 15 design compounds (contaminants), including PM2.5, are connected to three pollutant categories: people, building, and outdoor air. People generated contaminants are generally TVOC's like acetone, acetaldehyde, and phenol. The primary building generated contaminant is formaldehyde. Outdoor air is the primary source for contaminants like ozone and PM2.5. ASHRAE's calculator defines generation rates for the contaminants by space type, space use, and outdoor airflow based on scientific peer-reviewed research.

The mass balance process determines compound concentrations at steady state. These levels are compared to the design limits. A ratio of each contaminant concentration to its design limit is calculated. Even if standalone no compound exceeds the design limit, a mixture test is required. That test confirms that human organ system susceptibility to higher concentrations, in combination, do not exceed a healthy limit.

The calculated ratios are added based on the mixtures shown below (found in Section 6.3.3.1). The sum must be less than one. So said differently, under eye irritation, all of the ratios of the design compounds to their limits must be less than one.

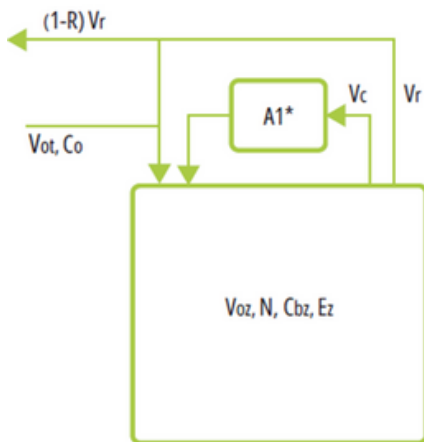
Upper Respiratory Tract Irritation	Eye Irritation	Central Nervous System
Acetaldehyde	Acetaldehyde	Acetone
Acetone	Acetone	Dichloromethane
Xylene	Xylene	Xylene
Ozone	Formaldehyde	1,1,1 - trichloroethane
	Ozone	Toluene

IAQP Mass Balance Equation

Effective air cleaners will capture or mitigate contaminant risk in concert with outdoor air dilution, resulting in steady state concentration levels. The magnitude of outdoor air reduction can be substantial (75%) based on system design and space type. This is determined through the mass balance equation where each contaminant steady-state concentration is determined then compared against the concentration design limits defined by ASHRAE (or others). Selecting equipment and dilution rates to keep concentrations within limits is solved iteratively in that calculation.

A variety of mass balance equations exist because the equation needs to match the system designed, whether single or multi-zone, VAV or constant volume. An example mass balance for the system shown follows.

Calculate the concentration of each contaminant (one at a time) in the Breathing Zone (C_{bz}).



$$C_{bz} = \frac{N_i + E_z V_{oz} C_{oi}}{E_z (V_{oz} + V_c E_{fi})}$$

where:

N_i = contaminant generation rate for contaminant i ($\mu\text{g}/\text{m}^3$)

E_z = ventilation effectiveness from Table 6-4 (unitless)

V_{oz} = outdoor airflow rate (cfm)

C_{oi} = concentration of contaminant i in outdoor air ($\mu\text{g}/\text{m}^3$)

V_c = volume of air cleaning capacity for the air cleaner (cfm)

E_{fi} = filter effectiveness (removal value) for contaminant i (%)

Converting the equation into words; the concentration is the quotient of all the contamination sources and their generation rates divided by the cleaning capacity of the system.

$$\text{Contam. Concen. (i) in the Breathing Zone} = \frac{\text{Contaminant Generation } \left(\frac{\mu\text{g}}{\text{h}}\right)}{\text{Contaminant Cleaning } \left(\frac{\text{m}^3}{\text{h}}\right)}$$

Find a selection of mass balance equations from ASHRAE Standard 62.1 in Appendix Three.

IAQP and Energy

The industry, particularly ASHRAE, is increasing support for IAQP because it is a more energy efficient and effective approach. Lowering outdoor air delivers two potential economic benefits:

1. Equipment savings through reduced size and complexity
2. Lower operating costs with reduced conditioning demands as demonstrated in Appendix One.

Regarding equipment savings, or initial cost offsets, there are both the direct and indirect benefits of the IAQP to be considered. Initial equipment capacity under the VRP includes the conditioning load for all air in the system, which includes recirculated and outdoor air. It stands to reason that a 50%+ reduction of outdoor air can have a substantial impact on system sizing, particularly considering the summer and/or winter design day. Furthermore, by reducing equipment capacity you reduce equipment size and power draw. In some locations, by reducing outdoor air load on the system, it is possible to avoid energy recovery systems, local code depending.

Projects with higher sustainability goals benefit by reducing conditioning load through the multiplicative benefit of reducing geothermal, solar, wind or other sustainable capacity as it will be less required. Said differently, one Watt-dollar saved on the HVAC via IAQP might be worth tens of Watt-dollars of generation capacity and associated costs.

Multiple calculators, including one from the US Department of Energy may help determine the potential energy savings.[6] This tool was used to determine the kWh/cfm used in Appendix One calculations.

Outdoor air ventilation is the primary means of regulating CO₂ concentration. While CO₂ is not a design compound under 62.1, designers are cognizant of potential CO₂ level rise from human respiration. While outdoor CO₂ levels have increased since the industrial revolution to over 420ppm around the world, it still represents 0.04% of outdoor air. Such low outdoor concentration means indoor concentrations are diluted with a small amount of outdoor air. The definition of “unhealthy” levels of CO₂ is difficult to assess as direction from ASHRAE, third parties, international agencies, National Institute of Occupational Safety and Health (NIOSH) approach the topic differently. ASHRAE does not have an explicit position and does not consider CO₂ a design compound for that reason. [7]

- *Indoor CO₂ concentrations do not provide an overall indication of IAQ, but they can be a useful tool in IAQ assessments if users understand the limitations in these applications*
- *Existing evidence for direct impacts of CO₂ on health, well-being, learning outcomes, and work performance at commonly observed indoor concentrations is inconsistent, and therefore does not currently justify changes in ventilation and IAQ standards, regulations or guidelines.*
-ASHRAE Position Document on Indoor Carbon Dioxide

ASHRAE does recommend specific CO₂ thresholds over ambient for activating demand control ventilation [8]. The following points may be helpful, while the industry monitors ASHRAE’s guidance on this topic.

- 1,000 ppm, commonly referenced, for CO₂ was determined by perceived indoor air quality without any controls for TVOC, PM, etc.
- NIOSH CO₂ limit is 5,000 ppm
- Demand control ventilation limits are referenced in 62.1-2022 Addendum AB and have CO₂ increases above ambient of between 600 and 2,100 ppm, or 1,000 to 2,500 ppm steady state.

Conclusion

Mechanical ventilation design is critical for a healthy building. Design choices have meaningful implications for energy, sustainability, and first cost. As designers consider the traditional choice of VRP versus the emerging preference for the IAQP it is helpful to consider how ASHRAE continues to evolve the standard, as documented in Appendix Four.

Advances in technology and standardization support a refreshed evaluation of the IAQP. Owners seek to unlock capital and reduce operating costs through construction and maintenance intervals. In the end, cost effective, code compliant and acceptable indoor air quality is the priority, and the IAQP remains a direct approach to that achieving the goal.

Appendix One

In the example below, three different scenarios are modeled for outdoor airflow demands while applying the VRP in Atlanta, GA.

Equipment Savings Model

Using the VRP on the classroom example below, an engineer would have to size the unit to accommodate OA under summer design day conditions in that region, which has an enthalpy of 40. The table shows that by applying the IAQP instead of the VRP, using a 500cfm capacity Air Cleaner in the space with a removal value averaging 50% (validated by 145.2 and 52.2 testing), the engineer can reduce the capacity of the HVAC unit substantially since the IAQP allows for a more targeted approach to OA levels. Considering the estimated cost per ton is \$2,000 in that market, the total capacity reduction, by applying the IAQP, results in \$6,000 savings per classroom.

Equipment Savings

Project Data			Outdoor Airflow (cfm)			Capacity & Equipment Savings		
Space Type	Area (ft ²)	Pop	VRP	IAQP	Savings	Tons	\$2k/ton	\$5k/ton
Classroom	950	25	462	125	337	3	\$6,000	\$15,000
Lecture Hall	2,000	300	2,370	1,200	1,170	14	\$28,000	\$70,000
Office	5,000	50	688	200	488	4	\$8,000	\$20,000

Operating Cost Savings Model

The preceding scenarios were extended to consider the ongoing energy savings available through reduced outdoor air flow. The annual modeled energy per cfm of outdoor air conditioning for Atlanta is 10kWh per cfm.

Annual Operating Benefit

Project Data			Outdoor Airflow (cfm)			Capacity & Equipment Savings		
Space Type	Area (ft ²)	Pop	VRP	IAQP	Savings	Energy (kWh/cfm)	@\$0.10/kWh	@\$0.15/kWh
Classroom	950	25	462	125	337	10	\$337	\$506
Lecture Hall	2,000	300	2,370	1,200	1,170	10	\$1,170	\$1,755
Office	5,000	50	688	200	488	10	\$488	\$732

Appendix Two

Example 1: Ventilation Rate Procedure

The summary is 18cfm/person for a direct application of the VRP in the classroom with 25 people and 1,000 ft² with a ventilation effectiveness of 0.8. Table 6-1 in Standard 62.1-2022 states the rate per person is 10cfm and the area rate is 0.12cfm/ ft².

The outdoor air intake flow (V_{ot}) shall be:

Where V_{bz} is determined by calculating using values in Table 6-1:

$$V_{bz} = R_p \times P_z + R_a \times A_z \quad (6-1)$$

$$V_{bz} = 10 \text{ cfm/person} \times 25 \text{ persons} + 0.12 \text{ cfm/ft}^2 \times 1,000 \text{ ft}^2$$

$$V_{bz} = 250 + 120 = 370 \text{ cfm}$$

$$V_{oz} = V_{bz} / E_z \quad (6-2)$$

$$V_{oz} = 370 \text{ cfm} / 0.8 \text{ (high supply high return)}$$

$$V_{oz} = 462.5 \text{ cfm}$$

$$V_{ot} = V_{oz} \quad (6-3)$$

$$V_{ot} = 462.5 \text{ cfm}$$

Delivers approximately 18.6 cfm/person

Example 2: IAQP Applied (Instead of VRP) to Example 1 Above

Using the same criteria from the classroom in Example 1, and applying the IAQP using the ASHRAE provided mass balance calculator, the new OA rate can be reduced from 18.6 cfm per person (VRP) to 5cfm per person (IAQP). As you can see below, the IAQP design passes the design limit and mixture tests for all design compounds.

System Selection			
System Type	Single Zone		Choose selection from dropdown.
Filter Location	A1		Choose selection from dropdown. (Refer to INTRO tab for more information on filter location.)
System Efficiency Calculation Method	Simplified Method		Choose method from dropdown. (Simplified Method should only be selected for Multiple Zone)
DATA ENTRY INSTRUCTIONS:			
1. Enter data in row 42 for a single zone only.			
2. Enter data for the Clean Air Rate in cell D16.			
3. Data for Primary Zone Airflow (column J) is optional.			
System Inputs			
Design System Population (optional)	750	occupants	Ps System population, maximum simultaneous # of occupants of space served by system
System Design Airflow (optional)		cfm	Vps System primary airflow from air handler. This may differ from the sum of primary airflow to zones. REQUIRED ENTRY for Filter Locations A2 and B
Cleaned Air Rate (Location A1)	500	CFM	Vc Rated airflow through the installed air cleaning device for filter location A1
Calculation Results			
Occupant Diversity	-		D Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/Pz
	750	CFM	Voz Zone outdoor airflow (Single Zone Systems)
	-	CFM	Vou Uncorrected outdoor air intake (Multiple Zone Systems)
	-		Xs Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps
	-		Ev System ventilation efficiency, based on method chosen above
Outside Air Intake	125	CFM	Vot Minimum outside air intake, Vot/Voz Calculated Vot satisfies IAQP requirements
Critical Zone	-		This zone has the highest calculated ventilation efficiency
Mixtures Check			
Outside Air Intake Override	750	CFM	Voz Increase Voz if doesn't pass mixtures check
Mixed Exposure Sum	0.35		Em Upper Respiratory Tract Irritation
Mixed Exposure Sum	0.53		Em Eye Irritation
Mixed Exposure Sum	0.04		Em Central Nervous System
Pass Mixtures Check?	Yes		Em < 1 Yes/No

Appendix Three

Table F-1 Required Zone Outdoor Airflow or Space Breathing Zone Contaminant Concentration with Recirculation and Filtration for Single-Zone Systems

Required Recirculation Rate			Required Zone Outdoor Airflow (V_{oz} in Section 6)	Space Breathing Zone Contaminant Concentration
Filter Location	Flow	Outdoor Airflow		
None	VAV	100%	$V_{oz} = \frac{N}{E_z F_r (C_{bz} - C_o)}$	$C_{bz} = C_o + \frac{N}{E_z F_r V_{oz}}$
A	Constant	Constant	$V_{oz} = \frac{N - E_z R V_r E_f C_{bz}}{E_z (C_{bz} - C_o)}$	$C_{bz} = \frac{N + E_z V_{oz} C_o}{E_z (V_{oz} + R V_r E_f)}$
A	VAV	Constant	$V_{oz} = \frac{N - E_z F_r R V_r E_f C_{bz}}{E_z (C_{bz} - C_o)}$	$C_{bz} = \frac{N + E_z V_{oz} C_o}{E_z (V_{oz} + F_r R V_r E_f)}$
B	Constant	Constant	$V_{oz} = \frac{N - E_z R V_r E_f C_{bz}}{E_z [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z V_{oz} (1 - E_f) C_o}{E_z (V_{oz} + R V_r E_f)}$
B	VAV	100%	$V_{oz} = \frac{N}{E_z F_r [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z F_r V_{oz} (1 - E_f) C_o}{E_z F_r V_{oz}}$
B	VAV	Constant	$V_{oz} = \frac{N - E_z F_r R V_r E_f C_{bz}}{E_z [C_{bz} - (1 - E_f)(C_o)]}$	$C_{bz} = \frac{N + E_z V_{oz} (1 - E_f) C_o}{E_z (V_{oz} + F_r R V_r E_f)}$

Table F-1 Required Zone Outdoor Airflow or Space Breathing Zone Contaminant Concentration with Recirculation and Filtration for Single-Zone Systems (Continued)

Symbol or Subscript	Definition
A, B	filter location
V	volumetric flow
C	contaminant concentration
E_z	zone air distribution effectiveness
E_f	filter efficiency
F_r	design flow reduction fraction factor
N	contaminant generation rate
R	recirculation flow factor
Subscript: o	outdoor
Subscript: r	return
Subscript: b	breathing
Subscript: z	zone

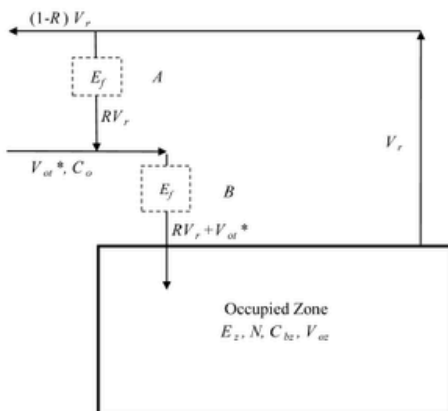


Figure F-1 Ventilation system schematic—constant-volume system with no infiltration/exfiltration. ($V_{ot} = V_{oz}$ for single-zone systems.)

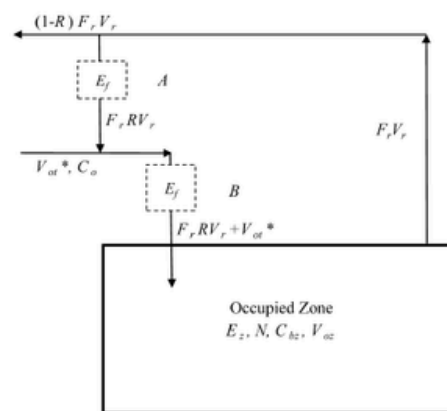


Figure F-2 Ventilation system schematic—variable-air-volume system with no infiltration/exfiltration. ($V_{ot} = V_{oz}$ for single-zone systems.)

Appendix Four

From-2016 To-2019 and -2022 for ASHRAE Standard 62.1

ASHRAE 62.1 §6.3

IAQP Requirements	-2016 and earlier	-2019 and later
Outdoor Air Quality Evaluation	STANDARD resource list	STANDARD via EPA website* + CALCULATOR
Design Compounds	Undefined	STANDARD Table 6-5 + CALCULATOR
Design Compound Limits	Undefined	STANDARD Table 6-5 + CALCULATOR
Define Generation Rates by Sources	Undefined	STANDARD + CALCULATOR
Mixtures of Compounds	Undefined	STANDARD Table 6-6 + CALCULATOR
Determine & Air Cleaner Efficiency	Manufacturer Claims	STANDARD Tests ASHRAE 145.2 and 52.2
Perform Mass Balance Calculation for O.A.	STANDARD Formula	STANDARD + CALCULATOR
Document Design	STANDARD §6.3.6	STANDARD §6.6
Evaluate Air Quality	Subjective Evaluation	STANDARD approach §7.3

* unique site conditions must be evaluated

References

- [1] ASHRAE Standard 62.1-2022 Section 6.1.4.3
- [2] ASHRAE Standard 62.1-2022 Indoor Air Quality Procedure (IAQP) Calculator ASHRAE-D-86925
- [3] ASHRAE Standard 62.1-2022 Addendum N © September 30, 2022
- [4] Filtration and Air Cleaning
- [5] Filtration and Air Cleaning
- [6] EnergyPlus™ open source software by the U.S. Department of Energy (DOE) Building Technologies Office (BTO) and managed by National Renewable Energy Laboratory (NREL)
- [7] ASHRAE Position Document on Indoor Carbon Dioxide: Approved by ASHRAE board of Directors February 2, 2022, © 2022 ASHRAE
- [8] ASHRAE 62.1-2022 Ventilation and Acceptable Indoor Air Quality Addendum AB Approved by ASHRAE and the American National Standards Institute on October 31, 2023