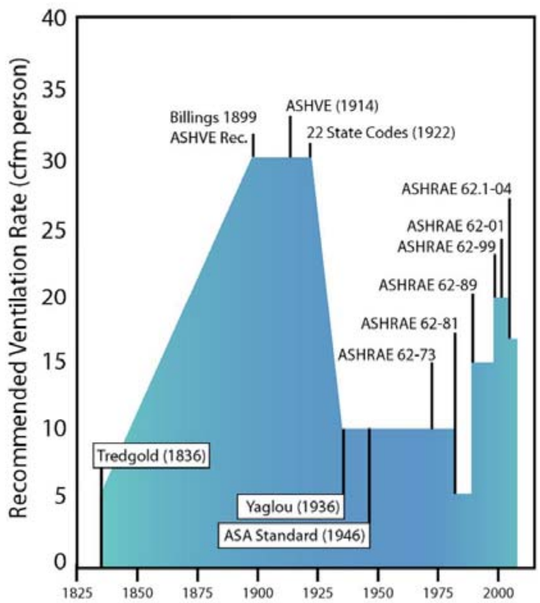
ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

This HAP e-Help will explain how ASHRAE 62.1-2004 ventilation requirements are determined in HAP 4.3. Differences between Standard 62.1-2004 and Standard 62-2001 will be examined with respect to space usage and outdoor air requirements. We will examine how HAP determines the minimum system ventilation (outdoor air) requirement per 62.1-2004 at the space level and then at the system level which is the outdoor air (OA) intake of the HVAC unit. Finally, we will review the Ventilation Sizing Summary report for a VAV system using ASHRAE Standard 62.1- 2004 ventilation air preference.

HAP e-Help # 006 titled "Ventilation" dated November 2, 2005 is prerequisite reading to this discussion. It examines ASHRAE Standard 62-2001, and "user defined" ventilation sizing method. It explains the hierarchy employed by the software to determine the ventilation air requirements of the HVAC system. Ventilation airflow control methods are also explained including constant, proportional, scheduled and DCV (demand controlled ventilation).

Background on ASHRAE Standard 62

Since its introduction, Standard 62 from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has been the primary design reference affecting the ventilation aspects of HVAC systems. ASHRAE Standard 62.1-2004, is the most recent ventilation standard. As shown below, the standards for ventilation air have evolved over the years to accommodate the changing design trends in the industry.



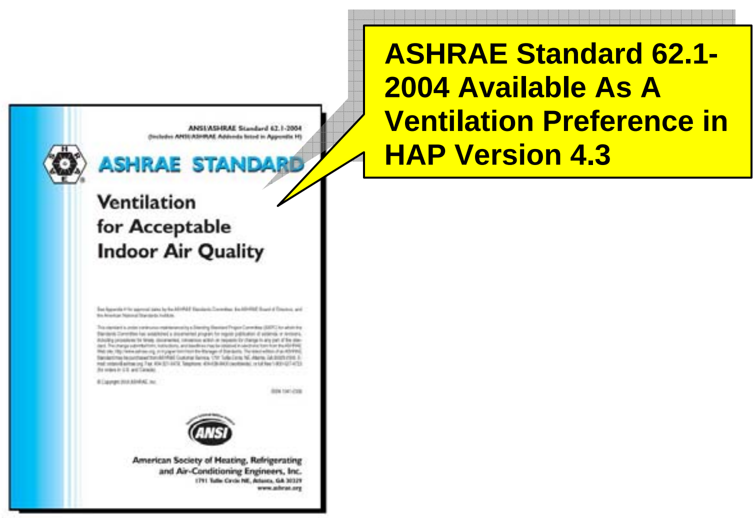


Figure 1 - Evolution of ASHRAE Ventilation Standards

The purpose of ASHRAE 62.1-2004 is to specify minimum ventilation rates to help achieve acceptable indoor air quality. Since contaminants in indoor air can be diluted by supplying the space with uncontaminated outdoor air, ASHRAE established ventilation rates in Standard 62.1-2004 based on achieving this dilution. Constant dilution to ASHRAE 62.1-2004 minimums is considered good design practice in order to achieve acceptable indoor air quality.

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Setting Up an ASHRAE Standard 62.1-2004 Project in HAP 4.3

The “Preferences…” option on the “View” menu is used to specify the preferences affecting the entire project including the ventilation calculation method. See Figure 2 below. HAP version 4.3 and later includes the choice for ASHRAE Standard 62.1-2004 in addition to the "User-Defined", and Standard 62-2001 method.

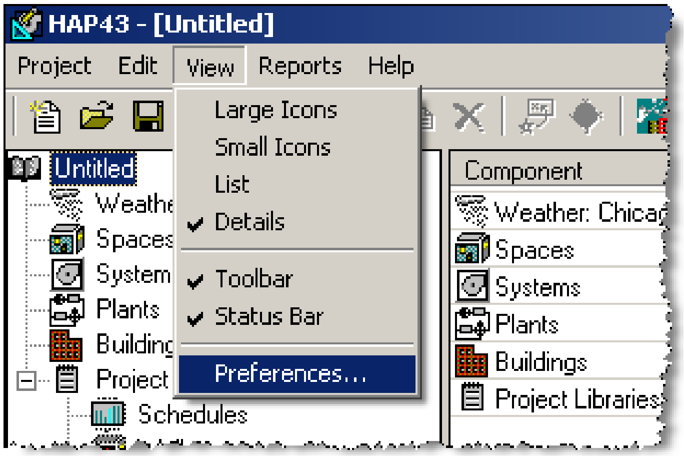

Figure 2 - View Preferences

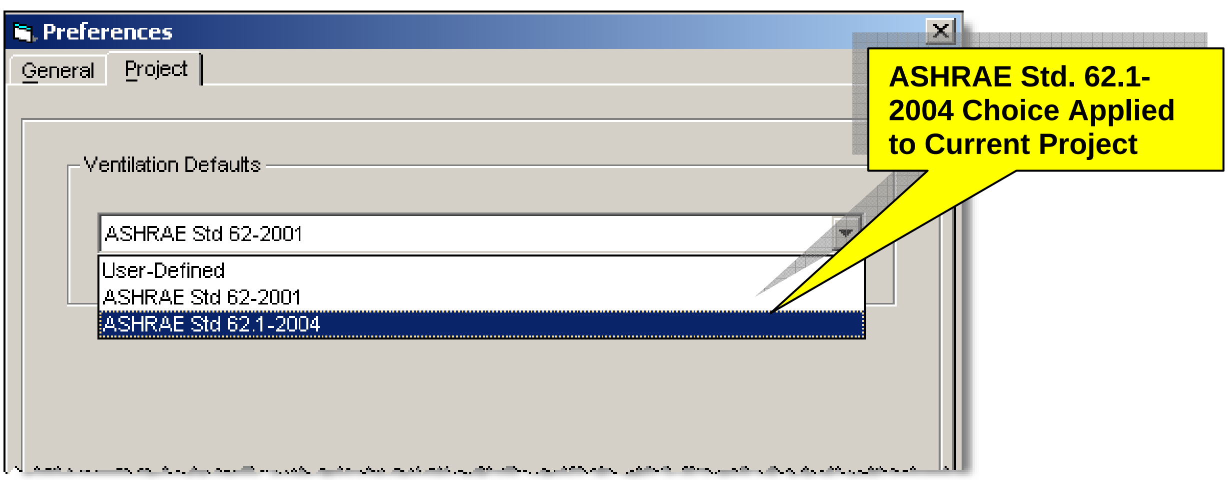

Figure 3 - ASHRAE 62.1-2004 Choice in HAP 4.3

When a new project is started in HAP, the user decides on which ventilation method to use. If ASHRAE 62.1-2004 is desired, it must be selected for each new project. At the time this e-Help was written, HAP defaults to the earlier ASHRAE Standard 62-2001 since many building codes still reference 2001. The ventilation setting is project-specific. It is not a global HAP setting. If a user decides to standardize on the newer 62.1-2004 method, it must be selected for each project in HAP 4.3.

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Defining the Space Ventilation Requirements using ASHRAE 62.1-2004

If one of the two ASHRAE ventilation methods is chosen, HAP will use the specific Space Usage options and the OA requirements that comply with that Standard. For example in Figure 4, the Space Usage options displayed by HAP in the Space Properties input screen reflect specific values from ASHRAE Standard 62.1-2004 previously selected under View “Preferences”. Notice there is a note at the bottom of the Space Properties window that serves as a reminder which source of defaults has been selected.

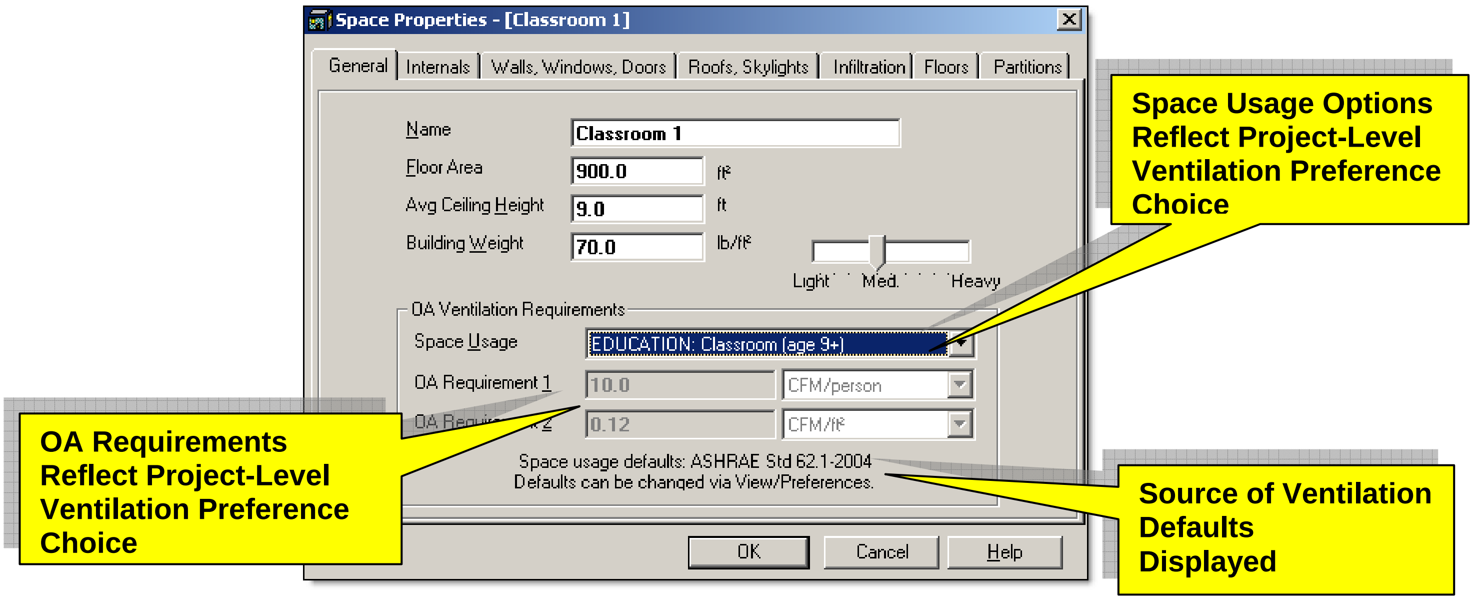


Figure 4 - HAP Space Properties Input Screen

ASHRAE Standard 62.1-2004 revised the outdoor air requirements for various types of space usages. The Standard also completely overhauled the methods for determining minimum airflow rates of outdoor air. A portion of a key ASHRAE table of minimum ventilation rates is shown in Figure 5. We will now discuss these changes in detail and how they are applied in HAP.

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s • person	cfm/ft²	L/s • m²		#/1000 ft² Or #/100 m²	cfm/person	L/s • person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Day room	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	[illegible]	0.06	0.3		15	9	[illegible]	[illegible]

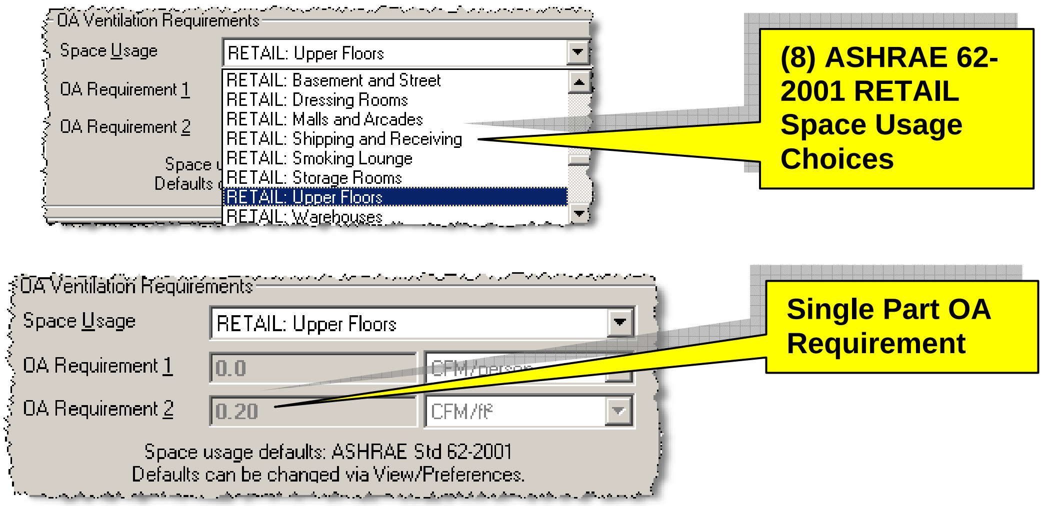
Figure 5 - Minimum Ventilation Rates ASHRAE 62.1-2004
(Reproduced with permission from ASHRAE)

ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

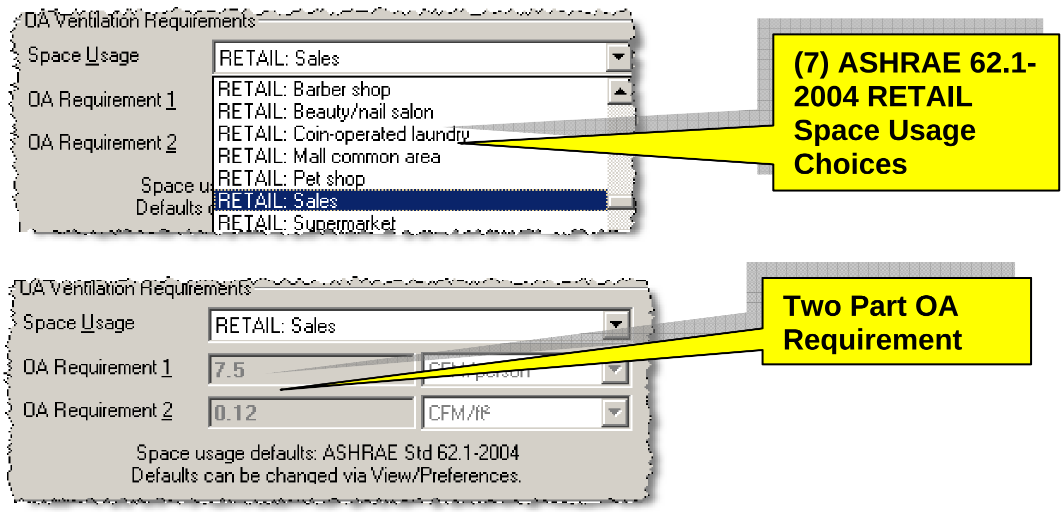
Differences between ASHRAE 62-2001 and ASHRAE 62.1-2004

ASHRAE 62.1-2004 determines the total outdoor airflow rate for the system using the Ventilation Rate Procedure from Section 6.2 and Appendix A in the Standard. This procedure involves a two-part OA requirement unlike the previous standard ASHRAE 62-2001. The first part uses per-person criteria and addresses CO_2 and people-generated pollutants or odors. The second part uses a per-floor area to address pollutants generated by materials in the space such as carpeting and furnishings. In contrast, Standard 62-2001 requires just a one-part OA requirement as shown below.

Differences exist in the space usage choices between the two Standards. Figures 6 and 7 allow visual comparisons between Standard 62-2001 and 62.1-2004 in the Retail and Education category.



ASHRAE 62-2001

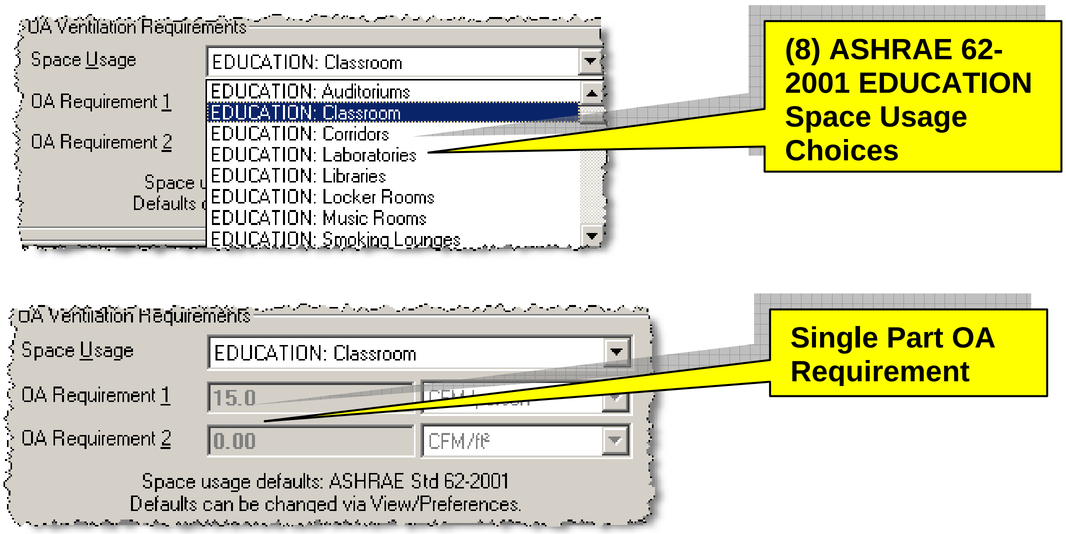


ASHRAE 62.1-2004

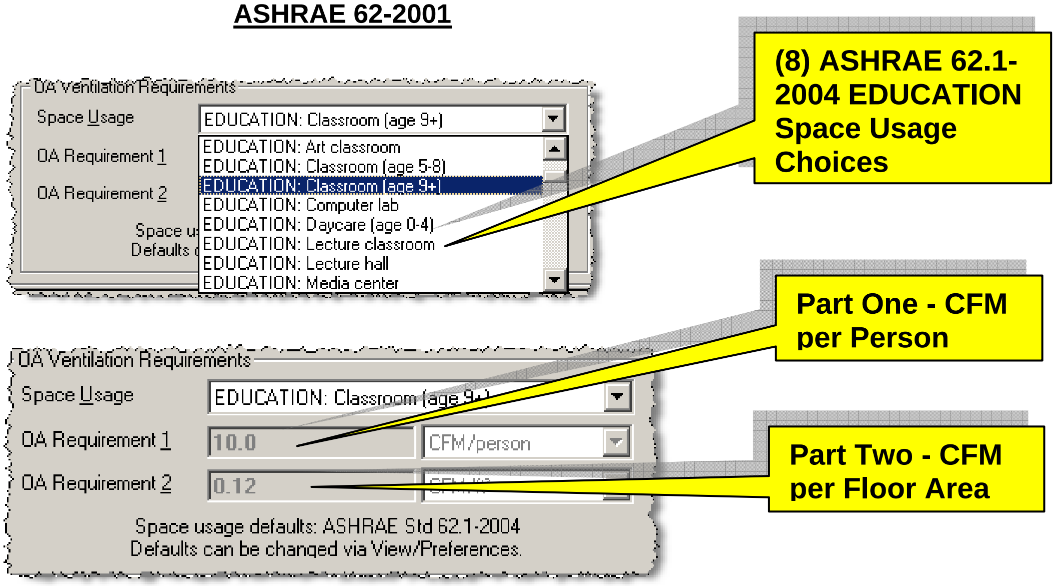
Figure 6 - RETAIL Space Usage Comparison

ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

Shown below are the space usage comparisons in the **EDUCATION** category. Notice the quantity of space usage choices has remained the same, but the space usage names have been revised in Standard 62.1-2004.



ASHRAE 62-2001



ASHRAE 62.1-2004

Figure 7 - EDUCATION Space Usage Comparison

ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

Standard 62.1-2004 Ventilation Air Sizing Calculations in HAP

The procedure to calculate the ventilation airflow in Standard 62.1-2004 involves 2 major steps. The first step determines the ***space*** ventilation airflow. The second determines the total ***system*** ventilation airflow.

It is important to note that the second step determines how much ventilation airflow is required at the central system intake to ensure that each space receives its required ventilation. As we will see, the ventilation airflow required at the intake can be larger than the sum of the uncorrected space airflows. A term called system ventilation efficiency is calculated in this second step in order to determine the final ventilation amount at the unit intake. These terms and associated calculation methods are described below.

Before we continue, we should clarify some terminology between HAP and ASHRAE. The term "zone" is used in ASHRAE Standard 62.1-2004 to refer to what HAP identifies as a "space". To avoid confusion, this E-Help will adopt the HAP terminology. For example, later when we discuss what the Standard refers to as "zone ventilation efficiency" will be referred to in this e-Help as "space ventilation efficiency" for clarity.

Step 1: Space Ventilation Airflow

The space ventilation airflow calculation involves 3 separate considerations which collectively yield the required *space* ventilation airflow.

1. Calculate the time averaged occupancy for short-term conditions
2. Add the CFM/person and CFM/sq ft requirements for each space
3. Assign the space air distribution effectiveness

Calculation of Space Ventilation Requirements

1. Calculate the Time Averaged Occupancy

If the number of people in the space fluctuates over time, Standard 62.1-2004 allows the space population to be estimated using a time averaging procedure. HAP applies the user's fractional people schedule along with the equations in paragraph 6.2.6.2 of ASHRAE Standard 62.1-2004 to produce an "averaging time period". The interval length is a function of the ventilation air change for the space. Average occupant schedule values are calculated for this interval and the largest average value is used to determine the time averaging factor. This factor is then used to correct the OA ventilation amount (CFM/person) described in item 2 below.

As an example, suppose a 2000 sq ft space with floor to ceiling height of 9 ft has 10 occupants and uses the occupant schedule shown in Figure 8. The requirements for this space are 5 CFM/person and 0.06 CFM/sq ft. Without considering time averaging, the uncorrected outdoor airflow would be 170 CFM. To consider time averaging, the averaging interval must first be determined. The time averaging interval equation from the Standard is 3 x Space Volume / Uncorrected Outdoor Airflow or 3 x 18000 / 170 which equals 318 minutes or 5.3 hours. This is rounded to 5 hours. Next, the program calculates an average schedule factor for each group of 5 consecutive hours in the people design day schedule. First, hours 0000 thru 0400 are used, then 0100 thru 0500, then 0200 thru 0600, etc. The average schedule factor for the interval 1200-1600 in Figure 8 would use the five consecutive schedule values of 50%, 100%, 100%, 100% and 40% to determine an average of 390/5 or 78%. Once averages are calculated for all 5-hour blocks in the day, the largest average is used as the Time Averaging Factor. In the case of Figure 8, the largest average occurs during the interval of 0800-1200 and is 90%. That means the people count is 0.90 x 10 occupants = 9 occupants. If we take 5 CFM/person X 9 people we now have 45 CFM versus 50 CFM initially resulting in a reduction of 5 CFM for the space. So the sum of the two part OA requirement is 165 CFM instead of 170 CFM.

If the people schedule uses 100% for all hours the Time Averaging Factor would be 100%.

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The time averaging factor does not always result in a downward correction to the people occupancy and an associated decrease in ventilation airflow. It depends on the space volume, people occupancy, and profile. For example, suppose a 900 sq ft classroom has 30 occupants, requires 10 CFM/person and 0.12 CFM/sq ft and uses the occupant schedule in Figure 8. The uncorrected outdoor airflow is 408 CFM. The time averaging interval from the ASHRAE equation is 3 x Space Volume / 408 CFM which equals 60 minutes or 1 hour. In this example the program calculates an average schedule factor for each one consecutive hour. The largest one hour "average" in this case is 100%, so for this classroom there is no change to the original uncorrected ventilation airflow based on the time averaging factor.

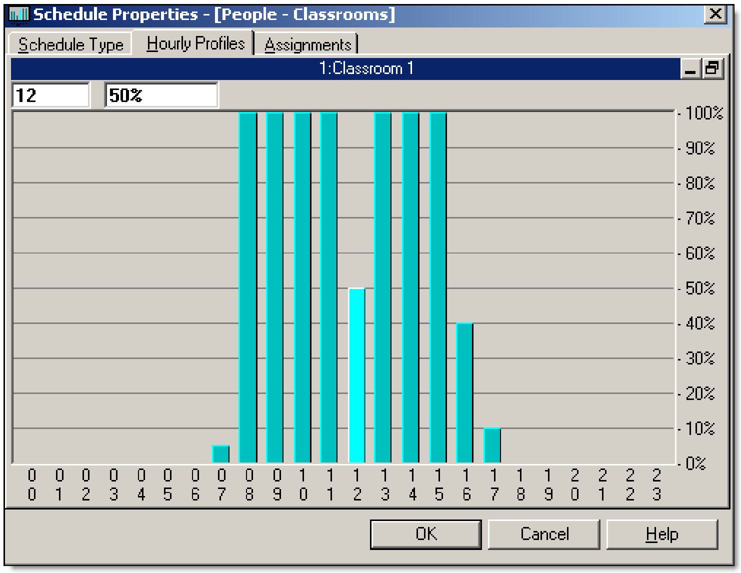

Figure 8 - People Profile for Classroom

2. Add the OA Requirements for Each Space

During sizing calculations for Standard 62.1-2004, HAP will first correct the occupancy based on the Time Averaged Occupancy method described above. Then HAP will sum the per person and per sq ft OA requirements to obtain the total OA requirement for each space. This is called the "uncorrected outdoor air" for the space.

3. Assign the Space Air Distribution Effectiveness

The next consideration that affects the required space outdoor airflow amount involves the air delivery from the diffusers. The Air Distribution Effectiveness is a new concept in ASHRAE 62.1-2004. It is not enough to simply deliver ventilation air to a space. The air must effectively reach the breathing zone of the occupants. Standard 62.1-2004 says a system that is effective at delivering air to the breathing zone would require less outdoor airflow than a less effective system for the same space.

The breathing zone is defined as the space between 3 and 72 inches above the floor as shown in Figure 9. When supply air is delivered anywhere above the breathing zone, it is considered to be the same as ceiling delivery. Since different types of systems and air terminals are more or less effective at delivering ventilation air to this breathing zone, the effectiveness of the air distribution system is considered by HAP in calculating ventilation requirements.

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Cooling applications that deliver the air through ceiling diffusers will have an effectiveness value of 1.0. If sidewall supply registers are higher than 72 inches above the floor, then they are considered "ceiling supply" and the effectiveness value of 1.0 still applies.

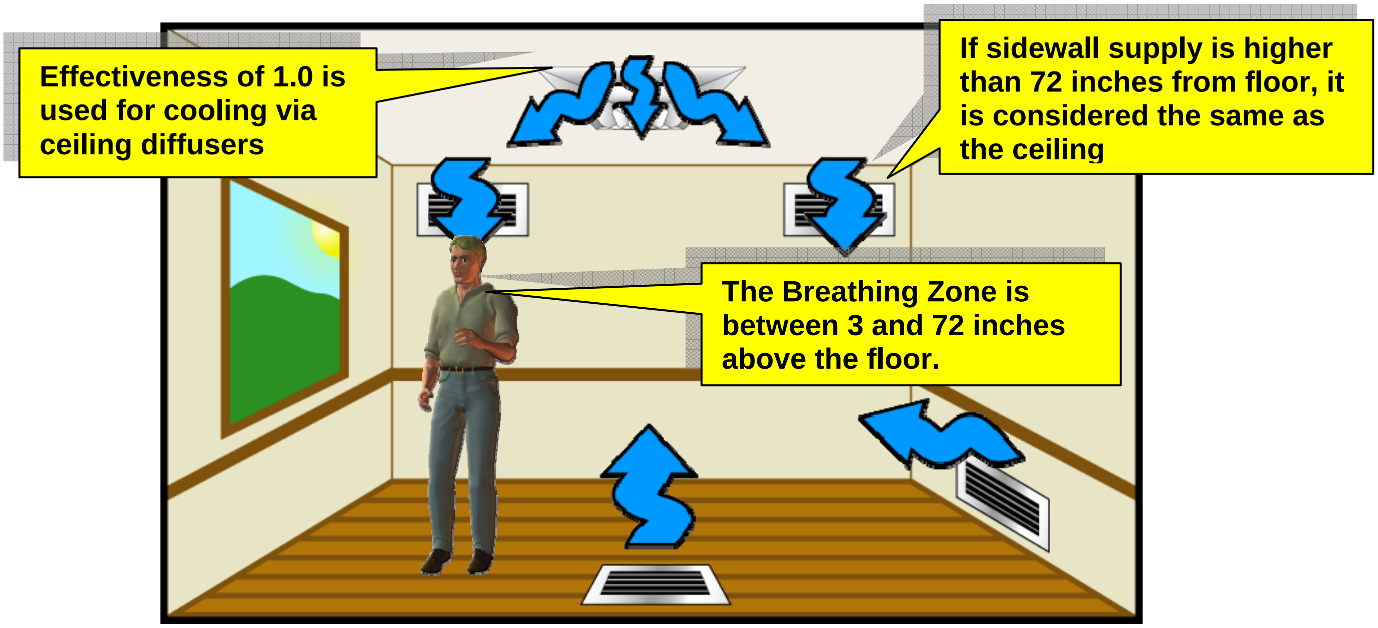

Figure 9 - Space Air Distribution Effectiveness

Per ASHRAE 62.1-2004, systems that deliver warm air from a ceiling supply diffuser, and have supply air 15°F or more above room air temperature, have an effectiveness of 0.8. Systems with warm air supplied from a ceiling diffuser, with a temperature less than 5°F warmer than the room air, have an effectiveness of 1.0.

The required outdoor air for a space is then calculated as the uncorrected outdoor air (from Step 1, part 2 above) divided by the Space Air Distribution Effectiveness. For example, if the uncorrected outdoor air is 408 CFM and the Distribution Effectiveness is 0.8, the required outdoor air for the space is 408 / 0.8 or 510 CFM. Standard 62.1-2004 refers to this result as the “Zone Outdoor Airflow”. HAP lists this result as “Required Outdoor Air” on its reports.

Step 2: System Ventilation Requirements

Step 2 determines how much ventilation air is required at the common OA intake to ensure that each space receives its required ventilation. As we will see, the ventilation airflow required at the intake can be larger than the sum of the required outdoor air for the spaces due to issues related to the “critical space”. Determination of the OA amount at the unit intake also involves calculation of a space and system “ventilation efficiency” value per formulation in ASHRAE 62.1-2004 Appendix A. This section discusses the procedures for system level ventilation calculations, but there will still be considerable discussion involving spaces.

“Critical Space” involves a concept that meeting the ventilation requirements of one space may require over ventilating other spaces. The outdoor air fraction, which is space ventilation CFM divided by supply air CFM, is important in understanding critical

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space concepts. As an example, consider Figure 10. Suppose the rooftop serves only two spaces and suppose space A requires supply airflow of 800 CFM and outdoor ventilation air of 200 CFM, for an outdoor air fraction of 25%. Also suppose space B requires 600 CFM of supply air and 300 CFM of outdoor ventilation air for an outdoor air fraction of 50%. Both spaces receive supply air from the same rooftop unit. If that supply air contains 25% ventilation air, the ventilation requirement of Space A will be met, but the ventilation requirement of Space B will not be met.

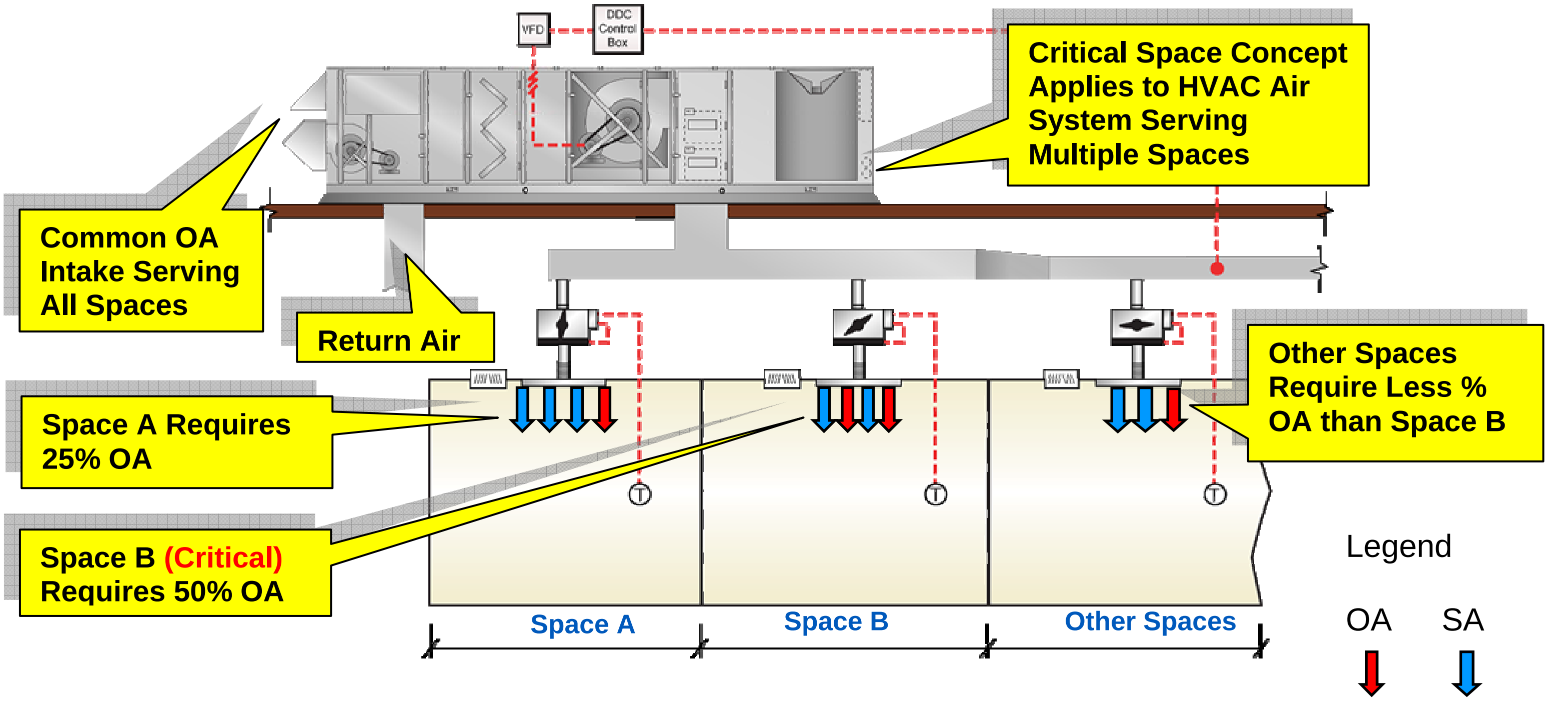

Figure 10 - Typical VAV System and Critical Space

So, the common supply air must contain more than 25% outdoor air in order meet Space B requirements. Suppose the common supply air is increased to contain 50% outdoor air. This will over ventilate Space A. However, once Space A is over ventilated, there is unused or "unvitiated" ventilation air that recirculates from Space A and that moderates the need to increase supply air all the way to 50% ventilation. If we perform the ventilation efficiency calculation described in Appendix A of Standard 62.1-2004, we find that supply air must be 41.7% outdoor air in order to satisfy both Space A and Space B ventilation requirements. 41.7% is less than the 50% outdoor air required by Space B so it appears Space B is under ventilated. But Space A is over ventilated and recirculation of the unused ventilation air from Space A makes up the difference required for Space B so its ventilation requirement is met.

In this example, the space ventilation efficiency for Space A was 1.107 while for Space B it was 0.857. Space B is the critical space because it has the smaller ventilation efficiency value. The system ventilation efficiency is equal to the critical space's ventilation efficiency, so the system efficiency is 0.857. Then, the required outdoor airflow for the system is the uncorrected airflow divided by the system ventilation efficiency, or 500 / 0.857 = 583.4 CFM. With 1400 CFM supply air in this example and 583.4 CFM of outdoor ventilation air, ventilation is 41.7% of supply.

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The Critical Space concept existed in ASHRAE 62-2001. However, the mathematics for handling it is different in Standard 62.1-2004 and a new term called "ventilation efficiency" is used. The Standard defines a complex calculation procedure which HAP follows to determine the ventilation efficiency for each space. This calculation procedure is different depending if the system is a single duct type (like constant volume single zone versus a dual duct) or recirculation system (such as a fan powered VAV system). The recirculation systems require a more involved calculation.

HAP performs the entire Standard 62.1-2004 calculation twice for each system if the system provides cooling and heating. It performs it once assuming cooling operation. Then it does it again for heating operation. The larger system ventilation CFM is used as the final result. If heating duty results in the larger ventilation airflow requirement, then HAP uses a space air distribution effectiveness of 0.8 (reflecting warm air supply typically 15°F or more above room temperature) for all spaces in the system.

Note: For dedicated ventilation systems providing 100% outdoor air to all spaces as shown below, the total system ventilation airflow is simply the sum of the ventilation values for all spaces in the system. The required air for each space is set at the diffuser and the 100% OA unit is sized for the sum. There is no "critical space" calculation required.

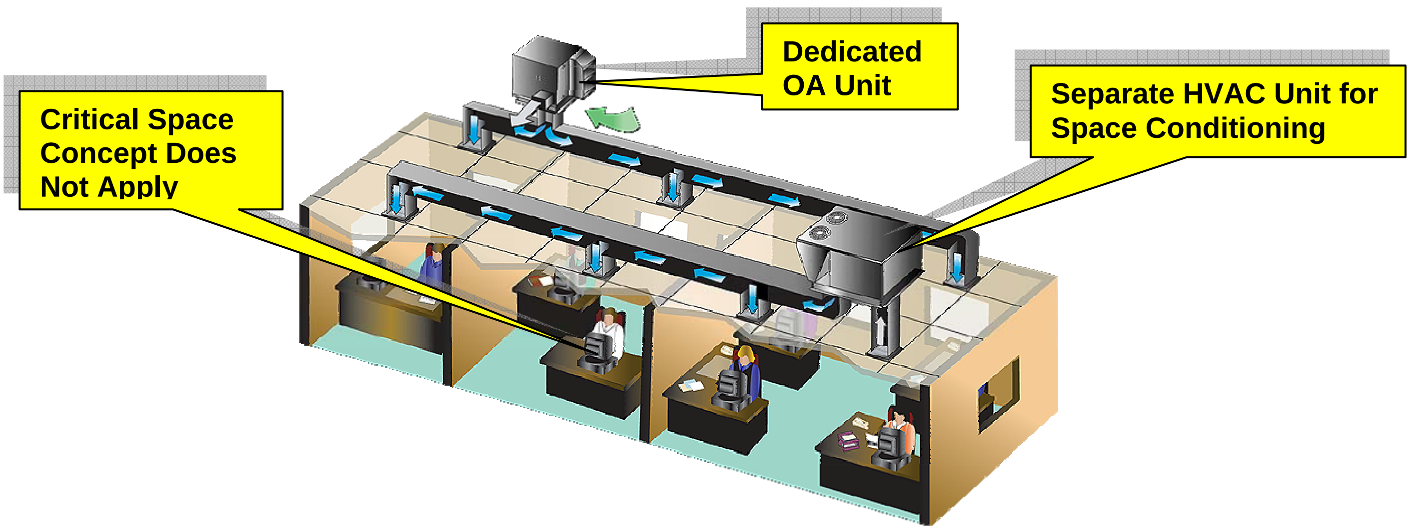

Figure 11 - No Critical Space Issues with Dedicated OA Unit

ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

Understanding the Ventilation Sizing Summary Report

The last section of this HAP e-Help will use the information from our discussion so far to interpret the output data from the Ventilation Sizing Summary. The example system is a 7-zone VAV system supplying multiple classroom spaces similar to the one used previously in this e-Help. Also included in the system are a small computer lab, corridor, and vestibule. ASHRAE 62.1-2004 ventilation air preference has been chosen at the project level.

The total cooling coil for this 7 zone system is 26.4 tons at August 1500 as shown below. This reflects a Design Ventilation Airflow Rate calculated by HAP based on ASHRAE 62.1-2004 requirements of 2547 CFM. Notice the Design Condition for ventilation air is at the "minimum flow (heating)". As discussed previously, because this is a cooling and heating system, HAP does the Standard 62.1-2004 ventilation air calculation once for cooling and once for heating and uses the higher of the two values. In this example, heating duty was higher because the heating duty air distribution effectiveness was lower (0.80) than cooling duty (1.0) which results in 25% more ventilation air requirement to each space during the heating cycle.

Total VAV Coil Load

Central Cooling Coil Sizing Data

Total coil load .... 26.4 Tons Load occurs at .... Aug 1500

1. Summary

Ventilation Sizing Method .... ASHRAE Std 62.1-2004
Design Condition .... Minimum flow (heating)
Occupant Diversity 1.000
Uncorrected Ventilation AirflowRate .... 1760 CFM
System Ventilation Efficiency 0.691
Design Ventilation AirflowRate .... 2547 CFM

Design Ventilation Airflow Rate = Uncorrected CFM / Ventilation Efficiency = 1760/.691 = 2547 CFM

Critical Space Ventilation Efficiency = .691

2. Space Ventilation Analysis Table

Zone Name / Space Name	Mult.	Minimum Supply Air (CFM)	Floor Area (ft²)	Required Outdoor Air (CFM/ft²)	Time Averaged Occupancy	Required Outdoor Air (CFM/person)	Air Distribution Effectiveness	Required Outdoor Air (CFM)	Uncorrected Outdoor Air (CFM)	Space Ventilation Efficiency
D100-Computer Closet										
Lab	1	215	90.0	0.18	4.0	10.00	0.80	70	56	1.177
D101-Classroom										
D101-Classroom	1	627	900.0	0.12	30.0	10.00	0.80	510	408	0.691
D102-Classroom										
D102-Classroom	1	627	900.0	0.12	30.0	10.00	0.80	510	408	0.691
D103-Classroom										
D103-Classroom	1	627	900.0	0.12	30.0	10.00	0.80	510	408	0.691
D104-Classroom										
D104-Classroom	1	772	900.0	0.12	30.0	10.00	0.80	510	408	0.844
D105-South Vestibule										
D105-South Vestibule	1	165	88.0	0.06	2.0	5.00	0.80	19	15	1.388
D114-Corridor										
D114-Corridor	1	458	950.0	0.06	8.0	0.00	0.80	71	57	1.349
Totals (incl. Space Multipliers)		**3492**							**1760**	**0.691**

Figure 12 - Ventilation Report for VAV System

ASHRAE 62.1-2004 Ventilation Air Sizing in HAP

The following explains the column headings in the Ventilation Report for a VAV system. Refer to Figure 12.

Minimum Supply Air (CFM)
This value represents the minimum supply airflow (not just the outdoor airflow) for the VAV terminal service each zone. The minimum supply airflow for each zone in this example system was entered as 50% of the supply terminal airflow under Zone Components/ Supply Terminals/ Minimum Airflow. Notice in this example the Design Ventilation Airflow is less than the Minimum Supply Air CFM. HAP automatically adjusts (overrides) the minimum box supply air CFM upward as required if the user's input value for minimum box airflow does not accomplish required minimum ventilation.

As an added note, this column heading only appears for VAV systems. For a CAV system the heading would say "Maximum Supply Air (CFM). That is because a CAV system diffuser has no minimum airflow setpoint like a VAV terminal.

Floor Area (sq ft)
This is the space floor area used in the uncorrected ventilation airflow calculation that is based on CFM/Sq Ft.

Required Outdoor Air (CFM/Sq Ft)
This represents the part two value for the OA requirement based on Space Usage in ASHRAE 62.1-2004.

Time Averaged Occupancy
This value represents the number of occupants used in the final calculations for ventilation air. Any headcount reductions have been taken into account based on the time averaging factor calculations discussed earlier in this HAP e-Help.

Required Outdoor Air (CFM/Person)
This represents the part one value for the OA requirement based on Space Usage in ASHRAE 62.1-2004.

Air Distribution Effectiveness
This value takes into consideration the ability of the supply air from the diffusers or registers to effectively reach the breathing zone of its occupants. In our case a value of .8 was used because heating duty ventilation airflow (0.80 effectiveness) exceeded cooling duty ventilation airflow (1.0 effectiveness).

Required Outdoor Air (CFM)
This column contains the calculated outdoor air quantities after taking into account the air distribution effectiveness. The uncorrected outdoor air CFM divided by the air distribution effectiveness is the required outdoor air CFM for each space. This is not the final airflow for the common OA intake for the system.

Uncorrected Outdoor Air (CFM)
This column contains the part one and two outdoor air quantities before taking into account the air distribution effectiveness and critical space issues. The time averaging factor for occupancy determination has been applied to this value however.

Space Ventilation Efficiency
Space ventilation efficiency is used to identify the critical space in the system. The space with the lowest ventilation efficiency is the most critical therefore it dictates the outdoor airflow for the system to ensure it receives its required airflow. The Uncorrected Outdoor Air (1760) divided by the lowest Space Ventilation Efficiency (.691) value is the final answer called Design Ventilation Airflow Rate (2547).The Space Ventilation Efficiency is calculated by HAP using the procedures in Appendix A of the Standard, as opposed to using the more simplified method in table 6-2.of the Standard. This results in the highest level of accuracy.

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Conclusion

ASHRAE Standard 62.1-2004 requires HVAC systems to introduce outdoor air at specified minimum ventilation rates to minimize the potential for adverse health effects while remaining acceptable to the human occupants.

Determining the ventilation airflow for each space involves summing a two part OA requirement then applying a time averaging factor that adjusts for occupant fluctuations in the space. Differences exist in the space usage choices between the older Standard 62-2001 and Standard 62.1-2004.

Next, HAP considers the ability of the cooling/heating system to deliver air to the breathing zone according to Standard 62.1-2004. This is represented in terms of an effectiveness value that will increase the required space ventilation airflow to compensate for a less effective air delivery.

Then, HAP uses ASHRAE 62.1-2004 formulas to determine how much ventilation air is required at the central system intake to ensure that each space receives the required ventilation. This process involves finding the critical space. The critical space exhibits the lowest ventilation efficiency and dictates the overall outdoor airflow for the system.

The purpose of ASHRAE 62.1-2004, is to specify minimum ventilation rates to help achieve acceptable indoor air quality through constant dilution with outdoor air. These minimums are considered good design practice in order to achieve acceptable indoor air quality. HAP version 4.3 and later incorporates the ability to satisfy the requirements of Standard 62.1-2004 for the project ventilation preference.