AIRCUITY
Safe, Smart & Efficient Airside Solutions

Laboratory Ventilation ACH Rates Standards and Guidelines

White Paper Series

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1.0 Introduction

This document provides an overview of current US and European design practices, standards, and regulations regarding laboratory air change rate minimums for dilution ventilation.

2.0 Executive Summary

In the US and Europe there are no prescriptive requirements for air change rates in labs other than the ASHRAE 62.1-2010 fresh air requirements for university/college laboratories that corresponds to about 1.2 ACH (.18 cfm/sq. ft or 0.9l/s/m^2). In terms of recommended levels, standards are also significantly moving away from the prescribed values of the past to a more performance based approach based on the specific requirements of a given lab space.

3.0 Survey of Applicable Existing Standards and Guidelines

The following codes and standards have existing or past sections relating to laboratory air change rates.

1. US NFPA (National Fire Protection Association) Standard 45

The NFPA 45 standard is the US Standard on *Fire Protection for Laboratories Using Chemicals*. The previous version of this standard, NFPA 45-2004, had no actual requirements on Lab ACHs, although in the non-binding appendix of the standard there were some recommendations relating to lab ACHs that in the past had been sometimes used as a design practice. The text of these recommendations was as follows:

> *A.8.2.2: A minimum ventilation rate for unoccupied laboratories (e.g., nights and weekends) is four room air changes per hour. Occupied laboratories typically operate at rates of greater than eight room air changes per hour, consistent with the conditions of use for the laboratory. It is not the intent of the standard to require emergency or standby power for laboratory ventilation systems.*

However, this text and any mention of specifying lab ACHs was eliminated in the current NFPA 45 – 2011 standard that just recently issued:

> *A.8.2.2: It is not the intent of this standard to require emergency or standby power for laboratory ventilation systems.*

The only remaining reference to lab ventilation is as follows which did not change between the 2004 and 2011 versions and does not provide any prescriptive rates:

> *8.2.2* Laboratory units and laboratory hoods in which chemicals are present shall be continuously ventilated under normal operating conditions*.

As such with the 2011 version, NFPA is now silent on prescribing any lab air change rates other than to require continuous ventilation.

2. US OSHA (Occupational Safety and Health Administration) Regulations

OSHA in the US provides little guidance on air change rates for labs. The only reference OSHA has to laboratory air change rates is quite old and is from a document published on January 31, 1990 titled *"Occupational Exposures to Hazardous Chemicals in Laboratories; Final Rule"* and was published in the Federal Register as 29 CFR Part 1910.

This document does not provide any prescriptive rates for minimum air change rates and mainly required the creation of a Chemical Hygiene Plan by employers to document procedures, policies, and work practices to ensure workers would be protected from hazardous substances. The definition of what specifically should be in the plan was left to the employers. A representative example of a Chemical Hygiene Plan that could be used as guidance for an employer to create their own Plan was provided in this document but was specifically marked as being non-mandatory. This non-mandatory plan was extracted from a 1981 book entitled *"Prudent Practices for* Handling Hazardous Chemicals in Laboratories".

Under *"Section C. The Laboratory Facility"* the following sections 4(a) and 4(f) are the only sections potentially relevant to lab air change rates:

4. Ventilation

(a) General laboratory ventilation. This system should: Provide a source of air for breathing and for input to local ventilation devices (199); it should not be relied on for protection from toxic substances released into the laboratory (198); ensure that laboratory air is continually replaced, preventing increase of air concentrations of toxic substances during the working day (194); direct air flow into the laboratory from non-laboratory areas and out to the exterior of the building (194).

(f) Performance. Rate: 4-12 room air changes/hour is normally adequate general ventilation if local exhaust systems such as hoods are used as the primary method of control [194]."

The only reference to air change rates as noted above are not mandatory nor are they even recommendations but rather indications of what is ***normally adequate general ventilation*** if hoods are used. Additionally, the range is quite broad being 4 to 12 ACH and as written does not really preclude the use of lower rates.

3. ANSI/AIHA Z9.5 Laboratory Ventilation Standard

The 2003 version of this standard is the latest published version of this standard. With respect to laboratory air change rates and ventilation the standard does not take a prescriptive approach. The format of this standard is that it has both a requirements section as expressed by the use of "shall", and a recommended section that provides description and explanation of the requirements plus suggested good practices as expressed by the use of "should." The text of the relevant sections is as follows:

Section 2.1.2 - Volume Flow Rates/Room Ventilation Rate (2003):

Requirements:

The specific room ventilation rate shall be established or agreed upon by the owner or his/her designee.

Recommendations:

Since a ventilation system designer cannot know all possible laboratory operations, chemicals to be utilized, and their potential for release of fumes and other toxic agents, one air exchange rate (air changes per hour) cannot be specified that will meet all conditions. Furthermore, air changes per hour is not the appropriate concept for designing contaminant control systems. Contaminants should be controlled at the source.

Section 2.1.4 - Dilution Ventilation (2003)

Requirements:

Dilution ventilation shall be provided to control the buildup of fugitive emissions and odors in the laboratory.

Recommendations:

Control of hazardous chemicals by dilution alone, in the absence of adequate laboratory chemical hoods, seldom is effective in protecting laboratory users. Because the exhaust from that type of system must be discharged to the outside or treated intensively before being used as return air, these systems usually are not economical for controlling exposure to hazardous materials compared with use of local exhaust hoods.

The latest version and content of the ANSI/AIHA Z9.5 standard has been completed, voted on and was approved. It is now in the process of being properly formatted to ANSI requirements and should be published in the first quarter of 2012.The new language of what should be named the Z9.5-2012 standard is similar to the 2003 standard but provides some additional clarification language beyond what the 2003 standard stated as noted below:

Section 2.1.2 - Laboratory (Room) Ventilation Rate (2012)

Requirements:

The specific room ventilation rate shall be established or agreed upon by the owner or his or her designee.

Recommendations:

Ventilation is a tool for controlling exposure. Contaminants should be controlled at the source. Potential sources should be identified and exposure control devices should be specified as appropriate to control emissions at the source. (See sections 3 and 4) All sources and assumptions should be clearly defined and documented.

An air exchange rate (air changes per hour) cannot be specified that will meet all conditions. Furthermore, air changes per hour is not the appropriate concept for designing contaminant control systems.

Excessive airflow with no demonstrable safety benefit other than meeting an arbitrary air change rate can waste considerable energy.

Section 2.1.3 - Dilution Ventilation

Requirements:

Dilution ventilation shall be provided to control the buildup of fugitive emissions and odors in the laboratory. The dilution rate shall be expressed in terms of exhaust flow in negatively pressurized laboratories and supply flow in positively pressurized laboratories.

Recommendations:

Control of hazardous chemicals by dilution alone, in the absence of adequate laboratory fume hoods, is seldom effective in protecting laboratory users. It is almost always preferable to capture contaminants at the source, than attempt to displace or dilute them by room ventilation. Nevertheless, dilution or displacement may remove contaminants not captured by a specifically applied device.

The quantity of dilution (or displacement) ventilation required is a subject of controversy. Typical dilution ventilation rates can range from 4 to 10 air changes per hour depending on heating, cooling, and comfort needs and the number and size of exposure control devices.

As noted above in this recommendations section, like with the old OSHA regulations, the new 2012 ANSI standard is giving a range of what is typically used in the industry vs. providing any strict guidance as to what should be used as a minimum or recommended lab ACH level. In fact, in both versions of the standard the recommendations clearly state that setting a fixed ACH rate for a laboratory for all conditions is not the appropriate design approach.

4. *ACGIH Industrial Ventilation Manual*

A well known and frequently published handbook of the American Conference of Governmental Industrial Hygienists (ACGIH) is entitled, *"Industrial Ventilation, A Manual of Recommended Practice."* The current revision is the 27th edition. A representative quote from the manual's 22nd edition published in 1995 states on page 7-5 that:

"'Air changes per hour' or 'air changes per minute' is a poor basis for ventilation criteria where environmental control of hazards, heat, and/or odors is required. The required ventilation depends on the problem, not on the size of the room in which it occurs."

5. *ASHRAE 62.1 Standard on Ventilation for Acceptable Indoor Air Quality*

This is the definitive standard in the US as well as many parts of the world on ventilation rates for buildings. Many codes and other standards reference the information and tables in this standard. The standard itself has gone through considerable revisions over the last 10 years with versions published in 2001, 2004, 2007 and most recently in 2010. There was a major change moving from 2001 to 2004 which changed the basis of the recommendations from strictly a flow per person requirement to a combination of a flow per person requirement plus a flow per unit area requirement.

Regarding laboratory ventilation, there was confusion introduced in 2004 when the occupancy category *"Science Laboratory"* which was under the *"Educational"* spaces section was introduced. This category had a fresh air minimum requirement of 0.18 cfm/sq. ft (0.9 l/s/m²) or about 1.2 ACH for a room with a 9 foot ceiling. There was also a higher exhaust requirement stated of 1 cfm/sq. ft or about 6 ACH that was listed for a different category labeled as *"Science Lab Classrooms" in the* Minimum Exhaust Rates table (6-4). The latter was intended to refer to non-college/university science classrooms with only moderate contaminant concentrations that might be mildly irritating or mildly offensive, most typically for high school (grades 9-12) or technical training schools. However, the terminology and lack of other lab categories was confusing and ambiguous. In 2006 this was corrected by an addendum to 62.1-2004 that was included in the 62.1-2007 version and is unchanged in the 62.1-2010 version.

This 2006 revision clarified the distinction between university/college laboratories and lower level educational facilities such as high school or technical training schools by creating a new occupancy category in the educational spaces section entitled *"University/college laboratories"*. This category had the same 0.18 cfm/sq. ft minimum space ventilation level as the educational science laboratory category as shown below:

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/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1

Additionally, the "Science lab classrooms" terminology in the Minimum Exhaust Rates table, 6-4 was changed to *"Educational science laboratories"* to match the non-university category in Table 6-1, Minimum Ventilation Rates in Breathing Zone. Importantly, the new university/college laboratory category was specifically excluded from the Minimum Exhaust Rates requirements table as well as any reference to research or non-educational laboratories. This is all shown in Table 6-4, Minimum Exhaust Rates flow requirements from the 2007 and 2010 standards.

TABLE 6-4 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft^2	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, L/s·m^2	Air Class
Arenas	–	0.50	B	–	–	1
Art classrooms	–	0.70		–	3.5	2
Auto repair rooms	–	1.50	A	–	7.5	2
Barber shops	–	0.50		–	2.5	2
Beauty and nail salons	–	0.60		–	3.0	2
Cells with toilet	–	1.00		–	5.0	2
Copy, printing rooms	–	0.50		–	2.5	2
Darkrooms	–	1.00		–	5.0	2
Educational science laboratories	–	1.00		–	5.0	2
Janitor closets, trash rooms, recycling	–	1.00		–	5.0	3
Kitchenettes	–	0.30		–	1.5	2
Kitchens—commercial	–	0.70		–	3.5	2
Locker/dressing rooms	–	0.25		–	1.25	2
Locker rooms	–	0.50		–	2.5	2
Paint spray booths	–	–	F	–	–	4
Parking garages	–	0.75	C	–	3.7	2
Pet shops (animal areas)	–	0.90		–	4.5	2
Refrigerating machinery rooms	–	–	F	–	–	3
Residential kitchens	50/100	–	G	25/50	–	2
Soiled laundry storage rooms	–	1.00	F	–	5.0	3
Storage rooms, chemical	–	1.50	F	–	7.5	4
Toilets—private	25/50	–	E	12.5/25	–	2
Toilets—public	50/70	–	D	25/35	–	2
Woodwork shop/classrooms	–	0.50		–	2.5	2

In summary, the current status of this is that except for non-university educational laboratories such as high schools or technical training schools, there is no minimum exhaust requirement stated for laboratories in ASHRAE 62.1. At most for educational spaces there is a fresh outdoor air requirement related to the floor area of these labs of 0.18 cfm/sq. ft or about 1.2 ACH for spaces with a 9 foot ceiling.

6. *International Mechanical Code (IMC 2009)*

The current version of the International Mechanical Code is IMC 2009. With regard to ventilation, the IMC traditionally tracks the ASHRAE 62.1 standard, although due to timing reasons of when the standards are revised, the IMC typically lags a revision or even two behind the current version of ASHRAE 62.1 or about 5 years behind. As a result, IMC 2009 tracks the language of ASHRAE

62.1-2004 (IMC 2006 tracked the language of ASHRAE 62.1-2001) and even includes tables 6-1 & 6-4 which are reprinted together as Table 403.3.

This table includes the above mentioned 2004 version reference to educational science laboratories with its rate of 0.18 cfm/sq. ft. or again about 1.2 ACH for spaces with a 9 foot ceiling along with the 1 cfm/sq. ft. exhaust reference. Again, as noted above, this designation is directly out of ASHRAE 62.1-2004 and was meant to refer to high schools or technical training schools and was later revised in the ASHRAE 62.1-2007 standard. The next version of the IMC which will be IMC 2012 will no doubt pick up the new language of ASHRAE 62.1-2007.

In the meantime, it is also important to note that even if there were ambiguity as to what the term, educational science laboratories refers to, there are means within the IMC 2009 to cover exceptions to Table 403.3 values. IMC 2009 states in section 403.2, as noted below, that if a registered design professional can demonstrate that their design will prevent the maximum contaminant concentration from exceeding that obtainable with the table values (1cfm/sq. ft. or about 6 ACH) then the minimum airflow rate can be reduced to a lower ventilation rate in accordance with this design. As a result demand based control, which will typically provide at least 8 ACH or more of fresh air and exhaust ventilation when contaminants are sensed in the lab area, provides another accepted means of compliance.

> ***403.2 Outdoor air required:*** *The minimum outdoor airflow rate shall be determined in accordance with Section 403.3. Ventilation supply systems shall be designed to deliver the required rate of outdoor airflow to the breathing zone within each occupiable space.*
>
> ***Exception:*** *Where the registered design professional demonstrates that an engineered ventilation system design will prevent the maximum concentration of contaminants from exceeding that obtainable by the rate of outdoor air ventilation determined in accordance with Section 403.3, the minimum required rate of outdoor air shall be reduced in accordance with such engineered system design.*

7. ASHRAE HVAC Applications Handbook, Chapter 14/16: Laboratories

ASHRAE publishes a set of four handbooks that embody good design practices and information of assistance to HVAC engineers. Laboratory design practices are covered in the HVAC Applications Handbook. The previously current version was 2007 (laboratories were in Chapter 14) with a new revision that was published and released in June of 2011 (laboratories are now in Chapter 16). Substantial changes were made in the 2011 version covering laboratory ventilation recommendations and control approaches relative to ventilation.

In the prior (2007) version of the lab chapter, the discussion concerning lab and animal facility ventilation was more prescriptive but still open to allow the use of different ACH rates as appropriate for the situation as shown below:

> *2007 ASHRAE HVAC Applications, Chapter 14 on lab and animal ventilation rates:*
>
> *Minimum airflow rates are generally in the range of 6 to 10 air changes per hour when the space is occupied; however, some spaces (e.g., animal holding areas) may have minimum airflow rates established by specific standards or by internal facility policies. For example, the National Institutes of Health (NIH 1999a, 1999b) recommend a minimum of 6 air changes per hour for occupied laboratories but a minimum of 15 air changes per*

> *hour for animal housing and treatment areas. The maximum airflow rate for the laboratory should be reviewed to ensure that appropriate supply air delivery methods are chosen such that supply airflows do not impede the performance of the exhaust devices.*

Specifically with respect to animal facilities the language was as follows that recognized that prescriptive language had flaws:

2007 ASHRAE HVAC Applications, Chapter 14 specific to animal ventilation rates:

> *A guideline of 10 to 15 outside air changes per hour (ach) has been used for secondary enclosures for many years. Although it is effective in many settings, the guideline does not consider the range of possible heat loads; the species, size, and number of animals involved; the type of bedding or frequency of cage changing; the room dimensions; or the efficiency of air distribution from the secondary to the primary enclosure. In some situations, such a flow rate might overventilate a secondary enclosure that contains few animals and waste energy or underventilate a secondary enclosure that contains many animals and allow heat and odor to accumulate.*

With respect to energy efficiency, the 2007 lab chapter did not provide much guidance in the area of ventilation rates and referred to the general use of variable air volume (VAV) fume hoods as well as night setback control of lab room ventilation flows to reduce minimum air change rates when the lab was unoccupied. With respect to occ/unocc strategy there was a general reference to the need to consider the safety and function of the laboratory but these concerns were not detailed in any meaningful way:

2007 ASHRAE HVAC Applications, Chapter 14 on energy efficiency:

> *Energy can be used more efficiently in laboratories by reducing exhaust air requirements. One way to achieve this is to use variable volume control of exhaust air through the fume hoods to reduce exhaust airflow when the fume hood sash is not fully open. Any airflow control must be integrated with the laboratory control system, described in the section on Control, and must not jeopardize the safety and function of the laboratory.*
>
> *Another energy-efficiency method uses night setback controls when the laboratory is unoccupied to reduce exhaust volume to one quarter to one-half the minimum required when the laboratory is occupied. Timing devices, sensors, manual override, or a combination of these can be used to set back the controls at night. If this strategy is a possibility, the safety and function of the laboratory must be considered, and appropriate safety officers should be consulted.*

The current 2011 version of the ASHRAE HVAC Applications Handbook Chapter on Laboratories makes some significant changes to the language on lab ventilation rates and practices for energy efficiency. With respect to minimum laboratory ventilation rates, the first paragraph reviewing Chapter 16 follows the new performance based language of AIHA/ANSI Z9.5. The second paragraph gives some guidance on how rates might be selected and references both some Computational Fluid Dynamics (CFD) research as well as empirical university research performed at Yale University on lab spills and the impact of different air change rates. The final paragraph describes an alternate recommended approach to dilution ventilation that is referred to as active sensing of lab air quality (also known as Demand Based Control).

2011 ASHRAE HVAC Applications, Chapter 16 on lab ventilation rates:

Minimum ventilation rates should be established that provide a safe and healthy environment under normal and expected operating conditions. The dilution ventilation provided by this airflow is no substitute for the containment performance of a laboratory fume hood or other primary containment device regardless of the room ventilation rate. The appropriate ventilation rate for clearing a room of fugitive emissions or spills varies significantly based on the amount of release, the chemical's evaporation rate and hazard level, and ventilation system effectiveness.

Fixed minimum airflow rates in the range of 6 to 12 air changes per hour (ach) when the space is occupied have been used in the past. However, recent university research (Klein et al. 2009) showed a significant increase in dilution and clearing performance by increasing the air change rate from 6 to 8 ach with diminishing returns above 12 ach. Similarly, CFD research (Schuyler 2009) showed that increasing the lab's dilution ventilation rate from 4 to 8 ach reduced the background contaminant level by greater than a factor of 10. This indicates that minimum ventilation rates at the lower end of the 6 to 12 ach range may not be appropriate for all laboratories. Minimum ventilation rates should be established on a room-by-room basis considering the hazard level of materials expected to be used in the room and the operation and procedures to be performed. As the operation, materials, and hazard level of a room change, an increase or decrease in the minimum ventilation rate should be evaluated.

Active sensing of air quality in individual laboratories (Sharp 2010) is an alternative approach for dealing with the variability of appropriate ventilation rates, particularly when energy efficiency is important or when less may be known about the hazard level. With this approach, the minimum airflow rate is varied based on sensing the laboratory's actual air quality level or "air cleanliness." Sensors used to determine air quality should be evaluated for their ability to detect chemicals being used in the space. When air contaminants are sensed in the laboratory above a given threshold, the minimum air change rate is increased proportionally to an appropriate level to purge the room. When the air is "clean" and contaminants are below the previously mentioned threshold, lower minimum airflow rates may be appropriate. Extensive studies of lab room environmental conditions (Sharp 2010) have shown that the air in labs is typically "clean" over 98% of the time.

With respect to animal facility ventilation the new language of the 2011 version has some additional text so that it now more closely tracks the language of the Institute for Laboratory Animal Research (ILAR) Guidelines as stated in the 7th edition of "*The Guide for the Care and Use of Laboratory Animals*".

2011 ASHRAE HVAC Applications, Chapter 16 on animal ventilation rates:

A guideline of 10 to 15 outdoor air changes per hour (ach) has been used for secondary enclosures (animal holding rooms) for many years. Although it is effective in many settings, the guideline does not consider the range of possible heat loads; the species, size, and number of animals involved; the type of bedding or frequency of cage changing; the room dimensions; or the efficiency of air distribution from the secondary to the primary enclosure. In some situations, such a flow rate might overventilate a secondary enclosure *that contains few animals and waste energy or underventilate a secondary enclosure that contains many animals and allow heat and odor to accumulate. As such, lower ventilation rates might be appropriate in the secondary enclosure or room, provided that they do not result in harmful or unacceptable concentrations of toxic gases, odors or particles. Active sensing of contaminants in the secondary enclosure and varying the air change rates based on the room environmental conditions is one approach that can be considered to meet these requirements in a more energy efficient manner.*

With respect to the section on lab energy efficiency some major changes were made in the 2011 chapter with respect to control practices for ventilation rates, specifically the real time sensing of contaminants in the lab room environment (Demand Based Control). Additionally, the new fume hood minimum flow rate recommendations for variable air volume fume hoods (AIHA/ANSI Z9.5) are mentioned:

2011 ASHRAE HVAC Applications, Chapter 16 on FH min flows & ventilation rate control:

Energy can be used more efficiently in laboratories by reducing exhaust air requirements. One way to achieve this is to use variable volume control of exhaust air through the fume hoods to reduce exhaust airflow when the fume hood sash is not fully open. Recent changes in NFPA Standard 45 and ANSI/AIHA Standard Z9.5 allow the use of a much lower fume hood minimum flow rate with variable-volume hoods (as low as about 100 cfm for a traditional 6 ft hood when the sash is closed), depending on the system design and aspects of laboratory operations. Any airflow control must be integrated with the laboratory control system, described in the section on Control, and its setting and operation must not jeopardize the safety and function of the laboratory.

Reducing ventilation requirements in laboratories and vivariums based on real-time sensing of contaminants in the room environment offers opportunities for energy conservation. This approach can potentially safely reduce lab air change rates to as low as 2 ach when the lab air is "clean" and the fume hood exhaust or room cooling load requirements do not require higher airflow rates. Research by Sharp (2010) showed that lab rooms are on average "clean" of contaminants in excess of about 98% of the time.

Additionally, new more specific language with respect to occ/unocc control of lab air change rates was included to cover safety concerns with this approach relating to the time it takes to flush out a space when air changes are being varied without an active sensing approach:

2011 ASHRAE HVAC Applications, Chapter 16 on Occupied/Unocc ventilation rate control:

Setback controls that reduce ventilation rates when the laboratory is unoccupied can also reduce energy consumption. Timing devices, sensors, manual override, or a combination of these can be used to set back the controls at night. There should be no entry into the laboratory during unoccupied setback times and occupied ventilation rates should be engaged possibly 1 h or more in advance of occupancy to properly dilute any contaminants. If this strategy is used, the safety and function of the laboratory must be considered, and appropriate safety officers should be consulted.

8. European Ventilation Code Information

Europe has no specific recommendations regarding laboratory air change rates other than a German DIN standard that is generally followed by central Europe. This standard is DIN 1946-7 *"Ventilation and air conditioning - Part 7: Ventilation systems in laboratories".* This standard includes a recommendation but not a requirement for minimum lab ventilation of 25 m^3/hr./m^2. This minimum ventilation flow recommendation corresponds to about 9.1 ACH for a 9 foot ceiling or an 8.2 ACH rate for a 10 foot ceiling space. The common interpretation of this standard is that lower air flow rates can be used if there is appropriate engineering justification for another technique or approach that can also maintain good lab air quality conditions. A rough translation of the appropriate section of this German language standard is as follows:

> *The air conditioning system must be designed based on this standard for an exhaust gas volume flow results of 25 m^3/hr./m^2, based on the laboratory floor space. Depending on the exhaust needs of the technical facilities and other special requirements, this basis can be significantly higher.*
>
> *This flow value for a given laboratory space may be reduced from a design or operating basis, if a risk assessment indicates that the reduced exhaust air flow rate will be adequate and effective for the long term planned activities of the laboratory space. Such reduction of exhaust gas volume flow or use restrictions must be documented and marked at the entrance to the laboratory.*

For those who know German, the exact text of this section of the standard is as follows:

5.3.3 Abluftvolumenstrom für Laborräume

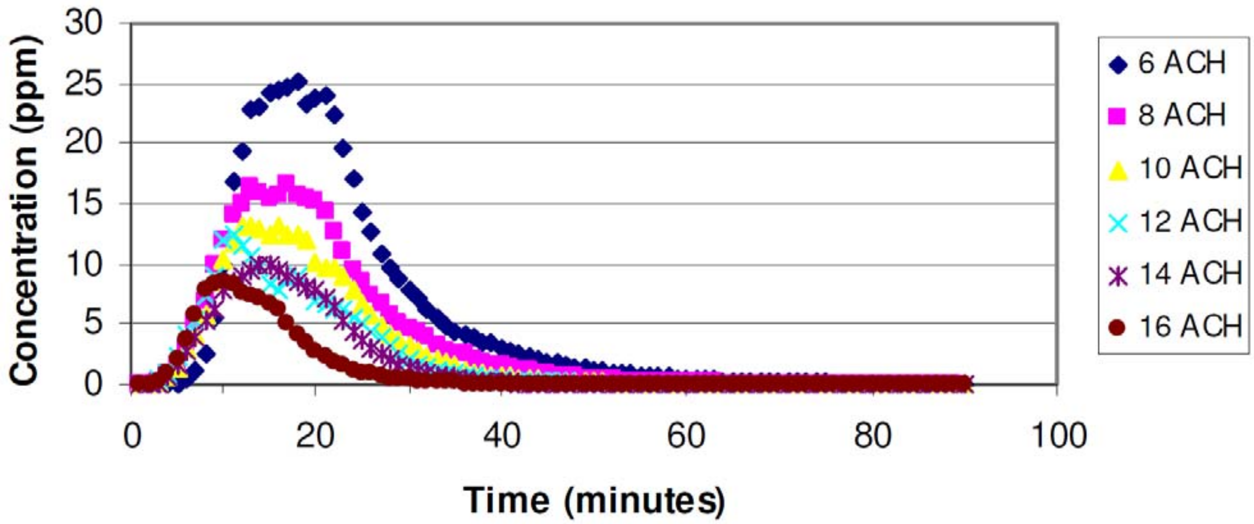
> *Als Planungsgrundlage für die Auslegung muss die RLT-Anlage so bemessen sein, dass sich ein Abluftvolumenstrom von 25 m3/(m2 .h) ergibt, bezogen auf die Labornutzfläche (siehe 3.2). Abhängig vom Bedarf ablufttechnischer Einrichtungen und besonderer Anforderungen kann diese Auslegungsgrundlage deutlich höher sein.*
>
> *Dieser Wert darf nutzungsspezifisch in Planung oder Betrieb niedriger gewählt werden, wenn eine Gefährdungsbeurteilung ergibt, dass der niedrigere Abluftvolumenstrom für die vorgesehenen Tätigkeiten im Labor dauerhaft ausreichend und wirksam ist. Solche Absenkungen des Abluftvolumenstroms oder Nutzungseinschränkungen müssen dokumentiert und am Eingang zum Labor gekennzeichnet sein (siehe Abschnitt 9).*
>
> *ANMERKUNG Bei nicht absehbaren Nutzungsänderungen, z. B. in Forschungslaboratorien, ist von niedrigeren Abluftvolumenströmen als Planungsgrundlage abzuraten. Dies bedeutet keine Festlegung für den späteren Betrieb.*
>
> *Bei der Ermittlung des Abluftvolumenstroms für den Laborraum müssen alle Teilabluftvolumenströme, z. B. von Abzügen oder Sicherheitsschränken, berücksichtigt werden.*

4.0 Laboratory Spill Test Performance and Conclusions

In terms of actual scientific evidence that provides some basis for the effectiveness of air change rates, there has been empirical research performed by Yale University on ACH effectiveness from actual lab spill testing.

1. *Yale Article Published in the Journal of Chemical Health and Safety*

A Chemical Health and Safety Journal article: *Klein, R.,C. King, A. Kosior. 2009. "Laboratory air quality and room ventilations rates." Journal of Chemical Health & Safety (9/10)* presents some interesting data and conclusions regarding the efficacy of lab air change rates. Testing was done using actual lab spill tests with different air change rates. The figure below provides an example of some of their test results, specifically, the chemical concentrations generated from small spills of diethyl ether at floor level under varying ACH rates, as measured by photoionization detection from the exhaust duct centerline:



Based on their testing, the Yale group's relevant conclusions were as follows:

> *This work reinforces the recognition that no single ACH rate is appropriate for all rooms, contaminants, or operations. It also reminds practitioners that ACH rates cannot simply be lowered below original design specifications without consideration of the engineering and safety implications of the change. Of the ACH rates evaluated, the greatest relative improvement in chemical concentration and clearance time from the room, whether under spill or continuous bench-top emission conditions, occurred between 6 and 8 ACH, with diminishing returns for rates greater than 12 ACH. This suggests that ACH rates much above 12 are generally unnecessary while those below about 8 warrant careful consideration, with lower levels suitable for low hazard operations and during periods of inactive non-occupancy*.

2. Demand Based Control Study Article Published in the ASHRAE Journal

An article was published in 2010 in the ASHRAE Journal on the frequency of the presence of lab air contaminants and the efficacy of active sensing and control of lab air contaminants: *Sharp, G.P. 2010 "Demand-Based Control of Lab air Change Rates" ASHRAE Journal 52(2):30-41.* This peer reviewed article presented the results of analyzing over 1.5 million hours of lab operation from 18 different sites and over 300 lab spaces. The results showed that the number of actionable chemical and particulate contaminant events that required more than the minimum dilution airflow was in the range of only 1 to 2 % of the time.

An example of the data is as follows that shows the percentage of total time that each of the different sites (represented by different colored lines) exceeded certain threshold levels of TVOCs (Total Volatile Organic Compounds) as read by a photoionization detector in the lab space's exhaust duct. The teal colored region represents the threshold values over which the ACH rate would be varied from the minimum flow rate (the left edge of the box) to the max ACH rate (the right edge of the box):