July 13th, 2006 Workshop Report Non-Residential Ventilation Requirements

***Prepared by: Steve Taylor, PE Principal
of Taylor Engineering, LLC, Alameda CA***

http://www.taylor-engineering.com

Non-Residential Ventilation Requirements

2008 California Building Energy Efficiency Standards

July 3, 2006

CONTENTS

Overview

Description	This proposal would remove the ventilation requirements in SECTION 121 – REQUIREMENTS FOR VENTILATION. Ventilation requirements would instead be determined by the model codes, in this case the 2006 Uniform Mechanical Code which includes a ventilation section that was updated to reflect the requirements in the latest version of AHRAE Standard 62.1-2004. The current Section 121 requirements conflict with those in the UMC, so some change must be made: either Section 121 requirements must be eliminated or the ventilation section of the UMC must not be adopted.
Type of Change	The proposed change would eliminate ventilation rate calculations and tables from the Mandatory Section of the Standards, and instead rely on the model mechanical code for these requirements.
Energy Benefits	The ventilation rates required by the UMC (and Standard 62.1-2004) are generally lower than the rates in Section 121 for most occupancy types (see comparison below), substantially lower in densely occupied spaces. For a few occupancy types, such as school classrooms, the rates are higher. Weighted by area for all occupancies, the UMC rates would be slightly lower. This will result in lower energy usage.
Non-Energy Benefits	Indoor air quality may be improved in occupancy types where the UMC rates are higher, such as schools. However indoor air quality may be reduced in other occupancies where rates are reduced. Those spaces for where rates are substantially reduced are generally spaces that are not occupied for long periods, such as assembly spaces, so indoor air quality is less of an issue due to the short exposure time.
Environmental Impact	No negative environmental impacts are anticipated.

Technology Measures	No new technologies are required.
Performance Verification	Performance (outdoor air rates) must be verified as per the current Standards.
Cost Effectiveness	Not applicable.
Analysis Tools	Not applicable.
Relationship to Other Measures	No anticipated impacts on other measures.

Background

In 1990, the CEC was directed to include ventilation and indoor air quality issues in the Energy Standards to address concerns that energy conservation efforts properly balanced the need to maintain acceptable indoor air quality. ASHRAE had recently updated their indoor air quality Standard, Standard 62-1989, with outdoor air rates that at least tripled those from prior versions of the Standard and from those in the model codes at the time. The model codes used in California, the ICBO Uniform Codes, had not yet been updated to reflect the new ASHRAE rates, and in fact they would not do so until the 1994 version of these codes. The CEC put together a panel of indoor air quality experts, engineers, and other affected parties to develop a balanced indoor air quality section in the Standards. After much debate and public hearings, the result was the promulgation of SECTION 121 – REQUIREMENTS FOR VENTILATION, first published in the 1991 version of the Energy Standards. This section has remained largely unchanged since its publication.

At about the same time, ASHRAE began the process of updating Standard 62. Some of the same individuals who developed the California ventilation standard (e.g. Steve Taylor and Hal Levin) were also members of the committee charged with upgrading Standard 62. Again after many public review cycles and hearings, consensus was reached and the new ventilation rate calculation procedure was published first as Addendum 62n in 2003 then as part of a complete reissue of Standard 62.1 in 2004.

The ventilation rate procedure (VRP) in Standard 62.1-2004 was developed through the ANSI consensus procedure and represents the current state-of-the art in ventilation. The VRP was expressly developed to serve in building codes so it was targeted to produce minimum ventilation rates that balanced indoor air quality concerns with first cost and energy cost concerns.

To assist in gaining confidence in the Standard 62.1 rates, it is useful to discuss how they were developed and the differences between this new procedure and those in previous versions of Standard 62, model codes, and Title 24.

<u>Two Component Approach and Additivity</u>

The contaminants in indoor spaces that ventilation is intended to dilute are generated primarily by two types of sources:

- Occupants (bioeffluents) and their activities (e.g. use of office machinery such as copy machines); and
- Off-gassing from building materials and furnishings.

There is little doubt or controversy about the existence of these two sources; the difficulty is how to determine the magnitude of the ventilation rate required to dilute each source and how the contaminants generated by various sources interact with each other. For a space of a given occupancy type experiencing typical occupant activities and constructed with typical materials and furnishings, the strength of sources associated with occupants and their activities is approximately proportional to the number of occupants. This has been widely confirmed by research (discussed in subsequent paragraphs). Less fully supported by research is the premise that for each space type, the source strength of building materials and furnishings is approximately proportional to the room floor area. How the individual contaminants emanating from these sources interact with each other and with the sensation and irritation of occupants is even less understood and more controversial. The impact of contaminants on people can be:

- Additive (1+2=3);
- Independent, strongest source dominates (1+2=2);
- Synergistic (1+2=4); or
- Antagonistic (1+2=1).

While all four effects occur in buildings, the majority of research suggests that the predominant form of interaction (impact on people) is additivity. This means that while the chemical nature of the various contaminants in indoor air may differ, they tend to behave in an additive fashion with respect to their impact on occupant perception of odor and irritation. Therefore the ventilation rate required to control both people-related sources (V_p) and building-related or area-based sources (V_a) is the sum of the ventilation required to control each of them alone at the breathing zone (V_{bz}):

$$V_{bz} = V_p + V_a$$

If we assume that the occupant component is proportional to the number of people and the building area component is proportional to the building area, the additivity concept for the ventilation required in the breathing zone of a space can be expressed by the following equation:

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

The concept of additivity has been demonstrated in both laboratory[1] and field settings.[2] In these studies, the researchers measured the level of perceived indoor air quality from humans and different types of building materials and furnishings alone and in combination. They then compared the total source strength when the sources were combined with the sum of the source strengths of the individual sources. In general, the agreement was good, though of course not perfect.

The results of other studies have questioned the appropriateness of additivity;[3] these particular studies are also the subject of debate and conclude that additivity needs to be studied more, not discarded. While one can debate this research, additivity is more productively considered as simply a calculation method to deal with two types of sources, those that depend primarily on the number of people

1 Iwashita, G. and K. Kimura "Addition of Olfs from Common Air Pollution Sources Measured with Japanese Subjects" CIB Working Group WG77: *Indoor Climate* (1995). Lauridsen, J. et al. "Addition of Olfs for Common Indoor Pollution Sources" *Healthy Buildings* 3 (1988): 189–195.

2 Wargocki, P. et al. "Field Study of Addition of Indoor Air Sensory Pollution Sources" *Indoor Air* 4 (1996): 307–312.

3 Bluyssen, P.M. and H.J.M. Cornelissen "Addition of Sensory Pollutant Loads—Simple or Not, That is the Question" ASHRAE *Design, Construction, and Operation of Healthy Buildings* (1998) 161–168

(contaminants from occupant activities and occupants themselves) and those that depend primarily on building floor area (contaminants from building materials and furnishings).

Note that the current Title 24 ventilation standards also have the same two components (people and building area), but the larger of the two is used, not the sum of the two. This assumes independent impacts on perception (1+2=2) of the two pollutant sources which is not supported by the majority of current research.

Determining Component Ventilation Rates

Once the form of the equation was selected, the next step was to determine the values of each component (R_p and R_a) for each occupancy category. The rates were based largely on research, experience, and judgment as described below:

- *Research On the Occupant Component*: There have been a number of laboratory and field studies of the amount of ventilation air required to dilute occupant-generated odors and irritants.[4] These studies have fairly consistently shown that about 15 cfm (7.5 L/s) will satisfy a substantial majority (about 80%) of unadapted persons (visitors) in the space. Later studies showed that a significant adaptation occurs for bioeffluents,[5] but less to building materials.[6] While the data for adapted occupants are less extensive, a 1983 study[7] shows that about 5 cfm (2.5 L/s) will satisfy a substantial majority of adapted occupants.
- *Research on the Building Component*: There have been several studies of the source strengths associated with sensory pollutants from the building itself, rather than from the occupants. The results of these studies indicate a fairly wide range of building source strengths. This is not too surprising given the breadth of building designs and usages. When these source strengths are converted to ventilation requirements required to satisfy about 80% of unadapted visitors to a space, the mean value for offices and classrooms is about 0.39 cfm/ft^2 (2.0 L/s-m^2), 0.53 cfm/ft^2 (2.7 L/s-m^2) for kindergartens and 0.66 cfm/ft^2 (3.3 L/s-m^2) for assembly halls.[8] More recent research supports these values.[9]
- *Research on Overall Rates in Office Buildings*: By far the most common subject of field studies was office buildings. Several field studies indicate that an outdoor air supply of 20 cfm (10 L/s) per person is very likely to be associated with lower rates of sick building

4 Berg-Munch, B. et al. "Ventilation Requirements For The Control Of Body Odor In Spaces Occupied By Women" *Environ. Int.* 12 (1986): 195–200. Cain, W.S., et al. "Ventilation Requirements In Buildings" *Atmospheric Environment* 17 no. 6 (1983): 1183–1197. Fanger, P.O. and B. Berg-Munch "Ventilation And Body Odor" *Proceedings of An Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces* (ASHRAE 1983): 45–50. Iwashita, G. et al. "Indoor Air Quality Assessment Based on Human Olfactory Sensation" *Journal of Architectural Planning and Environmental Engineering* 410 (1990): 9–19.

5 Berg-Munch, B. et al. "Ventilation Requirements For The Control Of Body Odor In Spaces Occupied By Women" *Environ. Int.* 12 (1986): 195–200.

6 Gunnarsen, L. and P. O. Fanger "Adaptation to Indoor Air Pollution" *Healthy Buildings* 3 (Stockholm, Sweden 1988): 157–167. Gunnarsen, L. "Adaptation and Ventilation Requirements" *Fifth International Conference on Indoor Air Quality and Climate* 1 (Toronto, Canada 1990): 599–604.

7 Cain, W.S., et al. "Ventilation Requirements In Buildings" *Atmospheric Environment* 17 no. 6 (1983): 1183–1197. Fanger, P.O. and B. Berg-Munch "Ventilation And Body Odor" *Proceedings of An Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces* (ASHRAE: 1983): 45–50

8 Fanger, P.O. et al. "Air Pollution Sources in Offices and Assembly Halls" *Energy and Buildings* 12 (1988): 7–19. Pejtersen, J. et al. "A Simple Method to determine the Olf Load in a Building" The Fifth International Conference on Indoor Air Quality and Climate, *Indoor Air* 1 (1990): 537–542. Pejtersen, J. et al. "Air Pollution Sources in Kindergartens" IAQ 91 *Healthy Buildings* (1991): 221–224. Thorstensen, E. et al. "Air Pollution Sources and Indoor Air Quality in Schools" The Fifth International Conference on Indoor Air Quality and Climate *Indoor Air* 1 (1990): 531–536.

9 Wargocki, P. et al. "Perceived Air Quality and Sensory Pollution Loads in Six Danish Office Buildings" *Indoor Air* (2002)

syndrome symptoms (and presumably more acceptable perceived indoor air quality) in office spaces.[10] These measured ventilation rates include the combined impacts of occupant and building sources as well as some degree of ventilation system efficiency.

- *Experience*: Experience with successful existing buildings was considered, including buildings built under the 1981 Standard when outdoor air rates were a third or less of the rates required after 1989. However, this experience, already largely anecdotal, must be tempered by the fact that actual ventilation rates in buildings are unlikely to be equal to the values required by the Standard at the time they were built. Research indicates that actual ventilation rates measured in buildings typically do not correspond to rates required by the version of Standard 62.1 effective at the time, the building code under which the building was designed, or even to the design values indicated on construction drawings.[11] One study encompassing about 3000 individual ventilation rate measurements in more than a dozen office buildings found that about half the measured outdoor air ventilation rates were below the design values.[12] The European Audit Project study of 56 office buildings in nine countries found that ventilation rates varied by a factor of two above or below the designed ventilation rates.[13] Nevertheless, anecdotal experience provides a useful reality test to limit proposed ventilation rates so that they are neither overly high nor low.
- *Judgement*: Because of the limited breadth of available research (most focus only on offices, for instance) and the imprecise nature of research results and anecdotal experience in existing buildings, to a very large extent ventilation rates were determined based on the experience and judgment of the committee members who developed the Standard over the last 10 years. It should be noted that prior versions of the Standard, and the Title 24 ventilation standards, were even more reliant on committee judgment since even less research was available at the time.

The development of the VRP rate table began first with offices since they were the subject of the most research.

Starting with the occupant ventilation component (R_p), the fact that the Standard was targeted for use in building codes as a minimum standard led to the decision to use 5 cfm (2.5 L/s) per person as the base rate, since research has shown that this rate will satisfy a substantial majority of adapted occupants. This value is based on occupant-related contaminants from adults at a sedentary activity level consistent with office spaces, and therefore must be adjusted upwards for some other occupancy categories where the occupants are more active. It also must be adjusted upwards in some occupancy categories to account for contaminants generated by occupant activities, such as art and science classrooms.

---

10 Mendell, M.J. "Non-Specific Symptoms in Office Workers" *Indoor Air* 3 no. 4 (1993): 227–236. Seppanen, O.A. et al. "Association of Ventilation Rates and CO_2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings" *Indoor Air* 9 no. 4 (1999): 226–252. Apte, M.G. et al. "Associations Between Indoor CO_2 Concentrations and Sick Building Syndrome Symptoms in US Office Buildings" *Indoor Air* 10 no. 4 (2000): 246–257

11 Persily, A.K. and Gorfain, J. *Analysis of Ventilation Data from the U.S. Environmental Protection Agency Building Assessment Survey and Evaluation (BASE) Study*, NISTIR 7145 (NIST December 2004)

12 Persily, A.K. "Ventilation Rates in Office Buildings" (ASHRAE IAQ 1989) *The Human Equation: Health and Comfort* 128–136

13 Bluyssen, P.M. et al. *European Audit Project to Optimize Indoor Air Quality and Energy Consumption in Office Buildings* (1995)

Occupant Component		
CATEGORY	R_p	DISCUSSION
0	0 cfm (0 L/s) per person	Applies to spaces where the ventilation requirements are assumed to be so dominated by building related sources, due to the typically very low and transient nature of the occupancy, that the occupant component may be ignored. Examples include storage rooms and warehouses.
1	5 cfm (2.5 L/s) per person	Applies to spaces where primarily adults are involved in fairly passive activities similar to sedentary office work.
2	7.5 cfm (3.5 L/s) per person	Applies to spaces where occupants are involved in higher levels of activity (though not strenuous), thereby producing higher levels of bioeffluents, or are involved in activities associated with increased contaminant generation. Examples include lobbies and retail stores.
3	10 cfm (5 L/s) per person	Applies to spaces where occupants are involved in more strenuous levels of activity (though not at an exercise-like level), or are involved in activities associated with even higher contaminant generation. Examples include most classrooms and other school occupancies.
4	20 cfm (10 L/s) per person	Applies to spaces where occupants are involved in very high levels of activity, or are involved in activities associated with very high contaminant generation. Examples include beauty salons, dance floors, and exercise rooms. Hair sprays, shampoos, etc., are considered occupant-related rather than building-related.

To determine the building component (R_a), the committee reviewed the available research on occupant perception of odors from non-occupant sources in offices, schools and other building types. The mean ventilation rate noted in the studies of office buildings to achieve 80% satisfaction by adapted occupants was 0.4 cfm/ft^2 (2 L/s-m^2), and the lowest value was about 0.03 cfm/ft^2 (0.15 L/s-m^2).[14]

Based on these data, and again in the context of establishing code minimum requirements, the value of 0.06 cfm/ft^2 (0.30 L/s-m^2) was identified as the base rate to handle building sources for offices. When combined with the base occupant rate of 5 cfm (2.5 L/s) per person, typical occupant densities, and ventilation system efficiencies (more on ventilation efficiency below), this building component rate results in an overall ventilation rate of about 20 cfm (10 L/s) per person for office spaces, consistent with engineering experience and the office building research referenced above.

Building Component		
CATEGORY	R_a	DISCUSSION
1	0.06 cfm/ft^2 (0.3 L/s-m^2)	Applies to spaces where building related contaminants are generated at rates similar to office spaces. Examples include conference rooms and lobbies.
2	0.12 cfm/ft^2 (0.6 L/s-m^2)	Applies to spaces where building related contaminants are generated at rates significantly higher than those for offices. Examples include typical classrooms and museums.
3	0.18 cfm/ft^2 (0.9 L/s-m^2)	Applies to spaces where building related contaminants are assumed to be generated at an even higher rate. Examples include laboratories and art classrooms.
4	0.30 cfm/ft^2 (1.5 L/s-m^2)	These last two categories apply to three unusual spaces, all in the Sports and Entertainment category, for which there is no people-based ventilation requirement (R_p = 0). For that reason, and because of their unique natures, the building ventilation requirements are elevated to five to eight times the base rate.
5	0.48 cfm/ft^2 (2.4 L/s-m^2)	

The next step was to determine occupant and building rates for the other occupancy categories listed in the VRP table. As noted above, there are insufficient hard research results to identify specific

[14] Fanger, P.O. et al. "Air Pollution Sources in Offices and Assembly Halls, Quantified by the Olf Unit." *Energy and Buildings* 12 (1988): 7–19. Pejtersen, J.L. et al. "A Simple Method to determine the Olf Load in a Building." The Fifth International Conference on Indoor Air Quality and Climate, *Indoor Air* 1 (1990): 537-542

values of R_p and R_a for each space type. Therefore, most of the rates are based on professional judgment, engineering experience, and a subjective assessment of the relative contaminant source strength from materials within the space relative to the base office occupancy.

To reflect the inherently approximate nature of ventilation rates determined in this fashion, the values of R_p and R_a for each occupancy type are based on simple multiples of the base rates.

Title 24 ventilation rate components can be summarized as:

- The occupant component is 15 cfm/person. This is the rate associated with the satisfaction of "visitors" to a space, not to the adapted occupants within the space. It can be argued that it is not appropriate for a code minimum rate to focus on visitors' first impressions but rather on occupant perception, as the Standard 62 occupant rate does.
- The building component varies by occupancy type but for most occupancy types is 0.15 cfm/ft^2. At the times these rates were developed, there was almost no research to support the values; they were developed almost entirely from the judgment of the committee who developed them.

<u>Ventilation Efficiency</u>

The breathing zone is that region within an occupied space between three planes: 3 and 72 inches above the floor and more than 2 feet from the walls or fixed air-conditioning equipment. The breathing zone is the region within an occupied space to which ventilation air must be supplied. This concept is defined to clarify the difference between moving air through the ventilation system ductwork and actually getting it to where the occupants breathe.

The ability of the ventilation system to deliver outdoor air to the breathing zone of the space can be described by two factors: zone air distribution effectiveness, and system ventilation efficiency as applied to multiple space recirculating systems.

- *Zone Air Distribution Effectiveness*: Concerns have long been expressed about inefficiencies in the mixing of ventilation air within rooms and the possibility that ventilation air was not getting to the breathing zone of the space. Several terms have been used to describe this performance, including Zone Air Distribution Effectiveness (used in the current Standard), Ventilation Effectiveness (used in Standard 62-2001), and Air Change Effectiveness (used in ASHRAE Standard 129 and most research projects). These terms have slightly different definitions but essentially measure the same effect: the ability of the system to deliver air from the supply air outlet to the breathing zone of the space. There has been a significant amount of research on ventilation effectiveness in the lab and in the field.[15] In addition, ASHRAE has issued a standard test method (ASHRAE Standard 129-1997) for measuring air change effectiveness. The table of default values for Zone Air Distribution Effectiveness in Standard 62.1 is based on this research as well as engineering judgment for applications where research

[15] Faulkner, D. et al. "Ventilation Efficiencies of Desk-Mounted Task/Ambient Conditioning Systems" *Indoor Air* 9 no. 4 (1999): 273–281. Faulkner D. et al. "Indoor Airflow and Pollutant Removal in a Room with Floor-Based Task Ventilation" *Building and Environment* 30 no. 3 (1995): 323–332. Fisk, W.J. et al. "Air Change Effectiveness and Pollutant Removal Efficiency During Adverse Conditions" *Indoor Air* 7 no. 1 (1997): 55–63. Fisk, W.J. et al. "Air Exchange Effectiveness in Office Buildings" *International Symposium on Room Air Convection and Ventilation Effectiveness* (1992): 213–223. Fisk, W.J. et al. "Air Change Effectiveness of Conventional and Task Ventilation for Offices" ASHRAE *IAQ Healthy Buildings, Postconference Proceedings* (1991): 30–34. Offerman, F.J. "Ventilation Effectiveness and ADPI Measurements of a Forced Air Heating System" ASHRAE *Transactions* 94 (1988): 694–704. Persily et al. "Air Change Effectiveness Measurements in Two Modern Office Buildings" *Indoor Air* 4 no. 1 (1994): 40–55. Persily et al. "Field Measurements of Ventilation and Ventilation Effectiveness in an Office/Library Building" *Indoor Air* 3 (1991): 229–246. Sandberg, M. "Ventilation Efficiency as a Guide to Design" ASHRAE *Transactions* 89 no. 2B (1983): 455–477

is less complete. The research has shown without exception that spaces supplied with air cooler than the room air have an air change effectiveness near one (E_z~1) regardless of the design of the air distribution system. This includes overhead supply and return systems even when serving spaces partitioned into cubicles. The reason is that the cool air is denser than the room air and naturally falls while heat sources in the room (people, PCs) cause plumes of warm air that rise up toward the ceiling. The combination causes air to naturally mix. Poor zone air distribution effectiveness (E_z) results mostly from warm air supply systems.

- *System Ventilation Efficiency for Multiple Zone Recirculating Systems*: Systems that serve multiple spaces and that recirculate air from one or more of these spaces have an inherent inefficiency if the percentage of outdoor air required is not the same for each space. This is because the percentage of outdoor air in the supply air is the same for all spaces, so spaces that require a high ratio of outdoor air to supply air will be under-ventilated if outdoor air rates at the air handling unit are not increased. Adjustment for this effect was first introduced in the 1989 version of the Standard. Equation 6-1 (sometimes called the "Multiple Spaces Equation") in that Standard was derived for single path supply air systems, such as central variable air volume or constant volume systems with terminal reheat. The current Standard uses the same approach for single path systems, but the equation has been rearranged to use the term System Ventilation Efficiency. Because many designers considered the Multiple Spaces Equation too complex, it has been simplified into a default table of System Ventilation Efficiency values. The concept has also been expanded[16] in Appendix A of the current Standard to allow multiple recirculation paths to be taken into account, improving the System Ventilation Efficiency of systems such as dual fan/dual duct systems and systems with fan-powered terminal units.

Title 24 ventilation requirements completely ignore ventilation efficiency issues. In fact, they indirectly state that all systems have a ventilation efficiency of 1.0 by allowing transfer air to meet ventilation requirements (Exception to Section 121 (b) 2). This makes Title 24 easier to use, but it ignores the fundamental science: these inefficiencies do exist and should be accounted for.

The ASHRAE Standard 62.1-2004 VRP has been adapted into the 2006 IAPMO Uniform Mechanical Code. A copy of UMC Chapter 4 is included in an Appendix. The UMC is the model code used in California as the basis of the California Mechanical Code. Hence, unless Chapter 4 is not adopted by the State Building Standards Commission, the ASHRAE/UMC ventilation rate procedure will be a code requirement in California.

A proposal is also before the International Code Council to adopt the ASHRAE Standard 62.1-2004 VRP into the International Mechanical Code. The hearings on this proposal are scheduled for September.

Analysis and Results

The ventilation rate calculation procedures for Title 24 and Standard 62.1/UMC Chapter 4 have significant fundamental construction differences that do not allow direct comparison including:

[16] Warden, D. "Outdoor Air: Calculation and Delivery" *ASHRAE Journal* 37 no. 6 (1995): 54–63

1. Change from "independent" approach to "additive" approach of the people and building components.
2. Exclusion of air distribution effectiveness and ventilation efficiency in Title 24.
3. Different default occupant densities. Title 24 uses half of the occupant density used for exiting purposes in the Uniform Building Code as the lowest assumption designers can use in determining occupant count. Standard 62.1/UMC specifies a default occupant density that must be used if there is not a more definitive determination of occupant count. The ASHRAE Standard 62.1/UMC minimum occupant densities tend to be higher (more conservative) than the Title 24 minimum densities.

To get a sense of the impact, the table below was developed for various common occupancy types, summarized as:

- Column (1) compares the two codes assuming the minimum number of people is used as allowed by the two codes respectively.
- Column (2) compares the two codes assuming the number of people is equal to the minimum allowed by Title 24.
- Column (3) compares the two codes assuming the number of people is equal to the minimum allowed by ASHRAE Standard 62.1/UMC.
- In all three columns, the ventilation system efficiency is assumed to be typical values for the occupancy type as listed in the table. Comparative rates will of course vary if different ventilation efficiency values are assumed.
- Shaded cells are where ASHRAE/UMC rates are higher than Title 24 rates.

Occupancy Type	Ventilation Efficiency Ev	% Difference in Ventilation Rate From ASHRAE to Title 24		
		Minimum occupancy from		
		(1) Each Code	(2) Title 24	(3) ASHRAE
Auditoriums	1.0	-64%	-64%	-64%
Financial Institutions	1.0	-32%	-32%	-32%
Grocery Stores	1.0	-7%	-2%	3%
Hotels	0.8	-8%	-40%	-8%
Office Buildings	0.8	-29%	-29%	-29%
Religious facilities	0.8	-23%	-51%	-54%
Restaurants	0.8	76%	7%	-16%
Retail and Wholesale Stores	1.0	-7%	-2%	3%
Schools	0.8	57%	23%	12%
Barber shops	1.0	-38%	-76%	-38%
Bars	1.0	36%	-24%	-38%
Coin operated laundries	0.8	-13%	-59%	-13%

Conclusions from this comparison are:

- ASHRAE/UMC rates are lower than Title 24 for almost all occupancies, particularly when occupancy assumptions the same. In particular, rates for densely occupied spaces (e.g. assembly) are significantly lower.
- ASHRAE/UMC rates for schools are higher than Title 24 regardless of occupant density assumptions. This may be appropriate because students are a sensitive population and early results of an ASHRAE study have shown significant benefits to increased ventilation rates on students' ability to concentrate and perform typical school activities[17].
- Rates for restaurants and bars may be higher for ASHRAE/UMC than Title depending on occupancy density assumptions. For restaurants, the practical effect is minimal since outdoor air rates are typically determined by kitchen exhaust rates which typically far exceed occupant based ventilation rates.
- Variations between the two procedures are largely due to differences in the "floor" assumptions in the number of people. Title 24 minimum occupancy densities are tied to UBC exiting densities. ASHRAE/UMC occupancy densities are based on more typical applications and are therefore more realistic.

One other consideration in changing to the ASHRAE/UMC approach is the difficulty in using and enforcing the new procedures. Because ASHRAE/UMC requires that air distribution effectiveness and ventilation efficiency be accounted for, it is somewhat more difficult to determine rates both by designers and enforcement officials. However, this is the price of including real and significant physical effects in the calculation procedure. We cannot ignore these effects for the sake of simplicity.

Recommendations

Current Standard

SECTION 121 – REQUIREMENTS FOR VENTILATION

(a) **General Requirements.**

1. All enclosed spaces in a building that are normally used by humans shall be ventilated in accordance with the requirements of this section and the CBC.
2. The outdoor air-ventilation rate and air-distribution assumptions made in the design of the ventilating system shall be clearly identified on the plans required by Section 10-103 of Title 24, Part 1.

(b) **Design Requirements for Minimum Quantities of Outdoor Air**. Every space in a building shall be designed to have outdoor air ventilation according to Item 1 or 2 below:

1. **Natural ventilation**.

   A. Naturally ventilated spaces shall be permanently open to and within 20 feet of operable wall or roof openings to the outdoors, the openable area of which is not less than 5% of the conditioned floor area of the naturally ventilated space. Where openings are covered with louvers or otherwise obstructed, openable area shall be based on the free unobstructed area through the opening.

   EXCEPTION to Section 121 (b) 1. A: Naturally ventilated spaces in high-rise residential dwelling units and hotel/motel guest rooms shall be open to and within 25 feet of operable wall or roof openings to the outdoors.

   B. The means to open required operable openings shall be readily accessible to building occupants whenever

[17] 1257-TRP "Indoor Environmental Effects on the Performance of School Work by Children"; Wyon, et al; preliminary progress report to ASHRAE TC 2.5/4.3, June 2006.

the space is occupied.

2. **Mechanical ventilation**. Each space that is not naturally ventilated under Item 1 above shall be ventilated with a mechanical system capable of providing an outdoor air rate no less than the larger of:

A. The conditioned floor area of the space times the applicable ventilation rate from TABLE 121-A; or

B. 15 cfm per person times the expected number of occupants.

For meeting the requirement in Section 121 (b) 2 B for spaces without fixed seating, the expected number of occupants shall be either the expected number specified by the building designer or one half the maximum occupant load assumed for egress purposes in the CBC, whichever is greater. For spaces with fixed seating, the expected number of occupants shall be determined in accordance with the CBC.

EXCEPTION to Section 121 (b) 2: Transfer air. The rate of outdoor air required by Section 121 (b) 2 may be provided with air transferred from other ventilated spaces if:

A. None of the spaces from which air is transferred have any unusual sources of indoor air contaminants; and

B. Enough outdoor air is supplied to all spaces combined to meet the requirements of Section 121 (b) 2 for each space individually.

Proposed Standard with underline and strikeout:

SECTION 121 – REQUIREMENTS FOR VENTILATION

(a) **General Requirements.**

1. All enclosed spaces in a building that are normally used by humans shall be ventilated in accordance with the requirements of this section and the CBC.

2. The outdoor air-ventilation rate and air-distribution assumptions made in the design of the ventilating system shall be clearly identified on the plans required by Section 10-103 of Title 24, Part 1.

(b) **Design Requirements for Minimum Quantities of Outdoor Air**. Comply with Chapter 4 of the California Mechanical Code. ~~Every space in a building shall be designed to have outdoor air ventilation according to Item 1 or 2 below:~~

~~1. **Natural ventilation**.~~

~~A. Naturally ventilated spaces shall be permanently open to and within 20 feet of operable wall or roof openings to the outdoors, the openable area of which is not less than 5% of the conditioned floor area of the naturally ventilated space. Where openings are covered with louvers or otherwise obstructed, openable area shall be based on the free unobstructed area through the opening.~~

~~**EXCEPTION to Section 121 (b) 1. A:** Naturally ventilated spaces in high-rise residential dwelling units and hotel/motel guest rooms shall be open to and within 25 feet of operable wall or roof openings to the outdoors.~~

~~B. The means to open required operable openings shall be readily accessible to building occupants whenever the space is occupied.~~

~~2. **Mechanical ventilation**. Each space that is not naturally ventilated under Item 1 above shall be ventilated with a mechanical system capable of providing an outdoor air rate no less than the larger of:~~

~~A. The conditioned floor area of the space times the applicable ventilation rate from TABLE 121-A; or~~

~~B. 15 cfm per person times the expected number of occupants.~~

~~For meeting the requirement in Section 121 (b) 2 B for spaces without fixed seating, the expected number of occupants shall be either the expected number specified by the building designer or one half the maximum occupant load assumed for egress purposes in the CBC, whichever is greater. For spaces with fixed seating, the expected number of occupants shall be determined in accordance with the CBC.~~

~~**EXCEPTION to Section 121 (b) 2:** Transfer air. The rate of outdoor air required by Section 121 (b) 2 may be provided with air transferred from other ventilated spaces if:~~

~~A. None of the spaces from which air is transferred have any unusual sources of indoor air contaminants; and~~

~~B. Enough outdoor air is supplied to all spaces combined to meet the requirements of Section 121 (b) 2 for each space individually.~~

Rationale

Because of the significant differences between the ventilation rate calculation procedures in Title 24 Section 121 and those in the 2006 UMC, the State must choose to eliminate one or the other. Otherwise designers and code enforcement officials would have to calculate rates using both codes and determined which is the most stringent, which would be a burden on both groups and not serve the interest of California.

We recommend that the State eliminate the Title 24 Section 121 ventilation requirements and instead adopt the 2006 UMC Chapter 4 into the CMC for the following reasons:

- The Section 121 procedure was developed in 1990 and is out of date with the latest science and consensus on ventilation and indoor air quality.
- The State's ventilation requirements would be in step with those of other States adopting the UMC, and (if the IMC code change proposal is successful) with most other States in the U.S.
- Minimum ventilation rates would decrease for most occupancy types, reducing energy costs.
- Minimum ventilation rates for schools would increase, improving indoor air quality for this sensitive group of people.

We do not propose to change any of the operational and control requirements currently in Section 121, such as CO_2 based demand controlled ventilation. The ASHRAE/UMC procedure allows, but does require, demand controlled ventilation.

Material for Compliance Manuals

ASHRAE has developed a Standard 62.1 User's Manual that can be used by designers applying the UMC whose procedure is almost identical to the Standard 62.1 VRP. Alternatively, the CEC can adapt the VRP section of the ASHRAE manual into the Title 24 User's Manual for ease of use and to focus the manual on the VRP alone. (Standard 62 has many requirements that go beyond simply ventilation.)

Bibliography and Other Research

ASHRAE Standard 62.1-2004 "Ventilation for Acceptable Indoor Air Quality"

See footnotes above for other references.

Appendix A. 2006 UMC Chapter 4

CHAPTER 4

VENTILATION AIR SUPPLY

401.0 General.
This chapter contains requirements for ventilation air supply and exhaust, evaporative cooling systems and makeup-air requirements for direct-gas-fired heaters, industrial air heaters, and miscellaneous heaters. ~~Ventilation (outdoor) air for occupants shall be designed in accordance with ANSI/ASHRAE 62-2001. Ventilation-air supply requirements for specific occupancies are found in the Building Code.~~

~~**Part I – Ventilation Air**~~

402.0 ~~Makeup~~ Ventilation Air.

402.1 General Requirements. All rooms and occupied spaces listed in Table 4-1 shall be designed to have ventilation (outdoor) air for occupants in accordance with this chapter.

402.1.1 Construction Documents. The outdoor air ventilation rate and air distribution assumptions made in the design of the ventilation system shall be clearly identified on the construction documents.

402.2 Natural Ventilation. Use of natural ventilation systems designed in accordance with this section shall be permitted in lieu of or in conjunction with mechanical ventilation systems. [ASHRAE 62.1:5.1]

> Exception: An engineered natural ventilation system when approved by the authority having jurisdiction need not meet the requirements of 402.2.1 and 402.2.2. [ASHRAE 62.1:5.1]

402.2.1 Location and Size of Openings. Naturally ventilated spaces shall be permanently open to and within 25 ft (8 m) of operable wall or roof openings to the outdoors, the openable area of which is a minimum of 4% of the net occupiable floor area. Where openings are covered with louvers or otherwise obstructed, openable area shall be based on the free unobstructed area through the opening. Where interior spaces without direct openings to the outdoors are ventilated through adjoining rooms, the opening between rooms shall be permanently unobstructed and have a free area of not less than 8% of the area of the interior room nor less than 25 ft^2 (2.3 m^2). [ASHRAE 62.1:5.1.1]

402.2.2 Control and Accessibility. The means to open required operable openings shall be readily accessible to building occupants whenever the space is occupied. [ASHRAE 62.1:5.1.2]

402.3 Mechanical Ventilation. Where natural ventilation is not permitted by this section or the building code, mechanical ventilation systems shall be designed, constructed and installed to provide a method of supply air and exhaust air. The system shall operate so that all rooms and spaces are continuously provided with the required ventilation rate while occupied.

403.0 Ventilation Rates. The design outdoor air intake flow rate for a ventilation system shall be determined in accordance with sections 403.1 through 403.6.

403.1 Zone Calculations. Zone parameters shall be determined in accordance with Sections 403.1.1 through 403.1.3. [ASHRAE 62.1:6.2.2]

403.1.1 Breathing Zone Outdoor Airflow. The design outdoor airflow required in the breathing zone of the occupiable space or spaces in a zone, i.e., the *breathing zone outdoor airflow (Vbz)*, shall be determined in accordance with Equation 4-1. [ASHRAE 62.1:6.2.2.1]

$Vbz = RpPz + RaAz$ (4-1) where:

Az = zone floor area: the net occupiable floor area of the zone ft^2 (m^2).

Pz = zone population: the largest number of people expected to occupy the zone during typical usage. If the number of people expected to occupy the zone fluctuates, *Pz* shall be permitted to be estimated based on averaging approaches described in Section 403.4 . If *Pz* cannot be accurately predicted during design, it shall be estimated based on the zone floor area and the default occupant density listed in Table 4-1.

Rp = outdoor airflow rate required per person as determined from Table 4-1.

Ra = outdoor airflow rate required per unit area as determined from Table 4-1. [ASHRAE 62.1:6.2.2.1]

403.1.2 Zone Air Distribution Effectiveness. The *zone air distribution effectiveness (Ez)* shall be determined using Table 4-2. [ASHRAE 62.1:6.2.2.2]

403.1.3 Zone Outdoor Airflow. The design *zone outdoor airflow (Voz)*, i.e., the outdoor airflow that must be provided to the zone by the supply air distribution system, shall be determined in accordance with Equation 4-2. [ASHRAE 62.1:6.2.2.3]

Voz = Vbz/Ez (4-2)

403.2 Single-Zone Systems. When one air handler supplies a mixture of outdoor air and recirculated air to only one zone, the *outdoor air intake flow (Vot)* shall be determined in accordance with Equation 4-3. [ASHRAE 62.1:6.3]

Vot = Voz (4-3)

403.3 100% Outdoor Air Systems. When one air handler supplies only outdoor air to one or more zones, the *outdoor air intake flow (Vot)* shall be determined in accordance with Equation 4-4. [ASHRAE 62.1:6.2.4]

Vot = all zonesVoz (4-4)

403.4 Multiple-Zone Recirculating Systems. When one air handler supplies a mixture of outdoor air and recirculated return air to more than one zone, the *outdoor air intake flow (Vot)* shall be determined in accordance with Sections 403.4.1 through 403.4.4. [ASHRAE 62.1:6.2.5]

403.4.1 Primary Outdoor Air Fraction. When Table 4-3 is used to determine system ventilation efficiency, the *zone primary outdoor air fraction (Zp)* shall be determined in accordance with Equation 4-5. [ASHRAE 62.1:6.2.5.1]

Zp = Voz/Vpz (4-5)

Vpz is the primary airflow to the zone from the air handler including outdoor air and recirculated return air. [ASHRAE 62.1:6.2.5.1]

403.4.2 System Ventilation Efficiency. The *system ventilation efficiency (Ev)* shall be determined using Table 4-3 or Appendix A of ASHRAE 62.1. [ASHRAE 62.1:6.2.5.2]

403.4.3 Uncorrected Outdoor Air Intake. The design *uncorrected outdoor air intake (Vou)* shall be determined in accordance with Equation 4-6. [ASHRAE 62.1:6.2.5.3]

Vou = D all zones RpPz + all zones RaAz (4-6)

The *occupant diversity, D,* shall be permitted to be used to account for variations in occupancy within the zones served by the system. [ASHRAE 62.1:6.2.5.3]

The *occupancy diversity* is defined as
D = Ps/ all zones Pz (4-7)

where the *system population (Ps)* is the total population in the area served by the system. Alternative methods shall be permitted to be used to account for population diversity when calculating Vou, provided that the resulting value is no less than that determined by Equation 4-6. [ASHRAE 62.1:6.2.5.3]

403.4.4 Outdoor Air Intake. The design *outdoor air intake flow (Vot)* shall be determined in accordance with Equation 4-8. [ASHRAE 62.1:6.2.5.4]

Vot = Vou/Ev (4-8)

403.5 Design for Varying Operating Conditions.

403.5.1 Variable Load Conditions. Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full and part-load condition. [ASHRAE 62.1:6.2.6.1]

403.5.2 Short-Term Conditions. If it is known that peak occupancy will be of short duration or the ventilation rate will be varied or interrupted for a short period of time, the design shall be permitted to be based on the average conditions over a time period *T* determined by Equation 4-9 [ASHRAE 62: Section 6.2.6.2]:

T = 3 v / Vbz (4-9) IP

where:
T = averaging time period, (min)
v = the volume of the zone for which averaging is being applied, ft^3 (m^3).

Vbz = the breathing zone outdoor airflow calculated using Equation 6-1 and the design value of the *zone population Pz*, cfm (L/s).

403.6 Dynamic Reset. The system shall be permitted to be designed to vary the design *outdoor air intake flow (Vot)*, or the space or zone airflow as operating conditions change.

403.7 Exhaust Ventilation. Exhaust airflow shall be provided in accordance with the requirements in Table 4-4. Exhaust makeup air shall be permitted to be any combination of outdoor air, recirculated air, and transfer air.

TABLE 4-1 MINIMUM VENTILATION RATES IN BREATHING ZONE [2,3]
[ASHRAE 62.1:Table 6-1]

Occupancy Category[6]	People Outdoor Air Rate R_P (cfm/person)	Area Outdoor Air rate R_A (cfm/ft^2)	Default Occupant Density[4] (people/1000 ft^2)
Correctional Facilities			
Cell	5	0.12	25
Day room	5	0.06	30
Guard stations	5	0.06	15
Booking/waiting	7.5	0.06	50
Educational Facilities			
Daycare (through age 4)	10	0.18	25
Classrooms (ages 5-8)	10	0.12	25
Classrooms (age 9 plus)	10	0.12	35
Lecture classroom	7.5	0.06	65
Lecture hall (fixed seats)	7.5	0.06	150
Art classroom	10	0.18	20
Science laboratories [E]	10	0.18	25
Wood/metal shop	10	0.18	20
Computer lab	10	0.12	25
Media center [A]	10	0.12	25
Music/theater/dance	10	0.06	35
Multi-use assembly	7.5	0.06	100
University/College Laboratories			
Food and Beverage Service			
Restaurant dining rooms	7.5	0.18	70
Cafeteria/fast food dining	7.5	0.18	100
Bars, cocktail lounges	7.5	0.18	100
General			
Conference/meeting	5	0.06	50
Corridors	-	0.06	-
Storage rooms B	-	0.12	-
Hotels, Motels, Resorts, Dormitories			
Bedroom/living Room	5	0.06	10
Barracks sleeping areas	5	0.06	20
Lobbies/pre-function	7.5	0.06	30
Multi-purpose assembly	5	0.06	120
Office Buildings			
Office space	5	0.06	5
Reception areas	5	0.06	30
Telephone/data entry	5	0.06	60
Main entry lobbies	5	0.06	10
Miscellaneous spaces			
Bank vaults/safe deposit	5	0.06	5
Computer (not printing)	5	0.06	4
Pharmacy (prep. area)	5	0.18	10
Photo studios	5	0.12	10
Shipping/receiving [B]	-	0.12	-

TABLE 4-1 MINIMUM VENTILATION RATES IN BREATHING ZONE [2,3] (continued)
[ASHRAE 62.1:Table 6-1]

Transportation waiting	7.5	0.06	100
Warehouses [B]	-	0.06	-
Public Assembly Spaces			
Auditorium seating area	5	0.06	150
Places of religious worship	5	0.06	120
Courtrooms	5	0.06	70
Legislative chambers	5	0.06	50
Libraries	5	0.12	10
Lobbies	5	0.06	150
Museums (children's)	7.5	0.12	40
Museums/galleries	7.5	0.06	40
Retail			
Sales (except as below)	7.5	0.12	15
Mall common areas	7.5	0.06	40
Barber shop	7.5	0.06	25
Beauty and nail salons	20	0.12	25
Pet shops (animal areas)	7.5	0.18	10
Supermarket	7.5	0.06	8
Coin-operated laundries	7.5	0.06	20
Sports and Entertainment			
Sports arena (play area)	-	0.30	-
Gym, stadium (play area)	-	0.30	30
Spectator areas	7.5	0.06	150
Swimming (pool & deck) [C]	-	0.48	-
Disco/dance floors	20	0.06	100
Health club/aerobics room	20	0.06	40
Health club/weight rooms	20	0.06	10
Bowling alley (seating)	10	0.12	40
Gambling casinos	7.5	0.18	120
Game arcades	7.5	0.18	20
Stages, studios [D]	10	0.06	70

GENERAL NOTES FOR TABLE 4.1

2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods.

3 **Air Density:** Volumetric airflow rates are based on an air density of 1.2 kgda/m^3 (0.075 lbda/ft^3), which corresponds to dry air at a barometric pressure of 101.3 kPa (1 atm) and an air temperature of 21 °C (70 °F). Rates shall be permitted to be adjusted for actual density but such adjustment is not required for compliance with this chapter.

4 **Default Occupant Density:** The default occupant density shall be used when actual occupant density is not known.

6 **Unlisted Occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

ITEM-SPECIFIC NOTES FOR TABLE 4.1

A For high school and college libraries, use values shown for Public Spaces – Library.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E No class of air has been established for this occupancy category.

TABLE 4-2
Zone Air Distribution Effectiveness
[ASHRAE 62.1:Table 6-2]

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air at least 15°F (8°C) above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches at least 4.5 ft (1.4 m) above the floor.	1.0
Floor supply of cool air and ceiling return, provided low- velocity displacement ventilation achieves unidirectional flow and thermal stratification	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust or return	0.8
Makeup supply drawn in near to the exhaust or return location	0.5

Notes for Table 4-2
1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the breathing zone.
4. "Floor" includes any point below the breathing zone.
5. As an alternative to using the above values, determine *Ez* in accordance with ASHRAE Standard 129 for all air distribution configurations except unidirectional flow.

TABLE 4-3
System Ventilation Efficiency
[ASHRAE 62.1:Table 6-3]

Max (Z_p)	E_v
≤ 0.15	1.0
≤ 0.25	0.9
≤ 0.35	0.8
≤ 0.45	0.7
≤ 0.55	0.6
≥ 0.55	Use ASHRAE 62.1, Appendix A

Notes for Table 4-3.
1. "Max *Zp*" refers to the largest value of *Zp*, calculated using Equation 4-5, among all the zones served by the system.
2. Interpolating between table values is permitted.

TABLE 4-4 Minimum Exhaust Rates
[ASHRAE 62.1:Table 6-4]

Occupancy Category	Exhaust Rate cfm/unit	Exhaust Rate cfm/ft^2	Exhaust Rate L/s-unit	Exhaust Rate L/s-m^2
Art classrooms	-	0.70	-	3.5
Auto repair rooms [1]	-	1.50	-	7.5
Barber shop	-	0.50	-	2.5
Beauty and nail salons	-	0.60	-	3.0
Cell with toilet	-	1.00	-	5.0
Darkrooms	-	1.00	-	5.0
Arena [2]	-	0.50	-	2.5
Kitchen – commercial	-	0.70	-	3.5
Kitchenettes	-	0.30	-	1.5
Locker rooms	-	0.50	-	2.5
Locker/dressing rooms	-	0.25	-	1.25
Parking garages [3]	-	0.75	-	3.7
Janitor, trash, recycle	-	1.00	-	5.0
Pet shops (animal areas)	-	0.90	-	4.5
Copy, printing rooms	-	0.50	-	2.5
Science lab classrooms	-	1.00	-	5.0
Toilets – public [4]	50/70	-	25/35	-
Toilet – private [5]	25/50	-	12.5/25	-
Woodwork shop/classroom	-	0.50	-	2.5

Notes For Table 4-4
1 Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
2 The rates do not include exhaust from vehicles or equipment with internal combustion engines.
3 Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.
4 Rate is per water closet or urinal. Provide the higher rate where periods of heavy use are expected to occur, e.g., toilets in theatres, schools, and sports facilities.
5 Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.

404.0 Makeup Air.
Makeup-air requirements for direct gas-fired heaters, industrial air heaters, and miscellaneous heaters are found in Chapters 5 and 9.

~~Part II – Evaporative Cooling Systems~~

40~~3~~5.0 ~~General~~ Evaporative Cooling Systems.

Evaporative cooling systems shall comply with this chapter.

Evaporative cooling systems shall be provided with outside air as specified for cooling systems in this code.

Air ducts and fire dampers that are a portion of an evaporative cooling system shall comply with this code.

40~~4.0~~5.1 Location.
Evaporative cooling systems shall be installed so as to minimize the probability of damage from an external source.

405.~~0~~2 Access, Inspection, and Repair.
Evaporative coolers shall be accessible for inspection, service, and replacement without removing permanent construction.

~~406.0~~5.3 Installation.
An evaporative cooler supported by the building structure shall be installed on a substantial level base and shall be secured directly or indirectly to the building structure by suitable means to prevent displacement of the cooler.

Modifications made to the supporting framework of buildings as a result of the installation shall be in accordance with the requirements of the Building Code. Openings in exterior walls shall be flashed in an approved manner in accordance with the requirements of the Building Code.

An evaporative cooler supported directly by the ground shall be isolated from the ground by a level