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Input Data for Multizone Airflow and IAQ Analysis

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ABSTRACT

The use of multizone airflow and contaminant dispersal models requires a range of input data. In terms of airflow analysis, these data include leakage characteristics of airflow elements, wind pressure coefficients, ventilation system characteristics such as duct losses and fan curves, and schedules for openings and ventilation systems. Contaminant dispersal analyses require contaminant source information, filter efficiencies, reaction and deposition rates, and schedules for elements such as sources and perhaps filters. Acquiring such data can be a major part of an analysis effort. In order to facilitate the use of multizone modeling techniques, a database containing many of these inputs has been developed. This database is not comprehensive relative to the requirements of any given analysis, but it does cover a range of the data that are available at this time. However, the analysis of a specific building always requires input data that are relevant to that particular situation. In addition to the data presented in this report, other sources of model input data are described.

Keywords: airflow, building technology, infiltration, modeling, multizone modeling, simulation, ventilation

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INTRODUCTION

Multizone airflow and contaminant dispersal models enable the analysis of building airflow patterns and airborne contaminants in multizone building airflow systems. These models have been used for a number of years primarily to support air quality and ventilation research efforts, but more recently their practical application has increased. For example, they have been used to design stairwell pressurization systems for smoke control, in indoor air quality forensic investigations, and to understand airflows and pressures in complex building systems. It is anticipated that these models will become increasing useful in the design of buildings and ventilation systems in response to more demanding ventilation, energy efficiency and indoor air quality requirements (Musser 2000).

Before performing such multizone airflow and contaminant analysis using these models, whether for design or some other objective, two key steps must be performed: developing the multizone idealization of the building being analyzed and acquiring the input data used to describe that idealization in the model. Idealization refers to representing the building as a series of interconnected zones. Any given building can be idealized in a number of different ways, with the idealization used in a given analysis depending on the building layout, the configuration of any ventilation systems, and, perhaps most importantly, the objective of the analysis. Once the building idealization has been established, the user acquires the input data that describe the zones of the building, the various elements relevant to the analysis, and a number of other parameters including outdoor conditions.

The input data for performing multizone airflow and IAQ analysis can come from a variety of sources including the published literature, manufacturers data, and building specific measurements. Again, the objective and nature of the analysis must be considered when acquiring input data. For example, a simulation analysis of a generic residential building can be based on envelope airtightness data from available databases, while a detailed study of ventilation in a specific building is better based on airtightness values for that building. In a study of the impact of specific contaminant sources, the building airtightness data is less critical than the source data itself.

One multizone model that can be used for performing such analyses is the CONTAMW model developed at NIST (Dols, Walton and Denton 2000). This model allows the creation and use of libraries of input data for certain elements involved in the analysis. These libraries allow one to use the same element in multiple analyses without re-entering it each time. However, other types of input data must also be entered for each analysis.

Table 1 lists the input data for airflow and contaminant dispersal analysis with CONTAMW. The table describes the elements needed to perform CONTAMW analyses in terms of the data required, the "location" of these data, and whether the element is required or optional. The location refers to whether this information is stored with the CONTAMW project (.prj) file, referred to as "local," or whether it can be stored in a CONTAMW library. This report presents a number of libraries that have been developed, but also discusses other useful resources for acquiring input data. The last column indicates whether the data are required or optional. Some of the data are optional in general, but required for contaminant analysis.

Table 1 CONTAMW Input Data

Element	Data	Data "location"	Required or Optional
Airflow Analysis			
Levels	Elevation, distance to level above	Local	Required
Zones	Temperature, floor area (volume)	Local	Required
Airflow elements			
Flow paths	Model, model parameters	Library	Required
Air handling systems	Supply and return locations and airflow rates	Local	Optional
Ducts	Configuration, locations, dimensions, loss coefficients, duct leakage, fan curves	Library	Optional
Wind pressure coefficients	Values based on façade and wind direction	Library	Required to consider wind effects
Weather	Outdoor temperature, wind speed, wind direction, barometric pressure	Weather file	Optional
Contaminant Analysis			
Contaminants	Molecular weight	Local	Optional*
Sources/sinks	Model, model parameters	Local	Optional*
Filters	Efficiency for each contaminant	Local	Optional
Occupants	Occupancy schedule, inhalation rates, contaminant generation rates	Local	Optional
Schedules			
Week and day	On/off times and levels for airflow elements, source/sinks, and filters.	Library	Optional
Occupancy	Location (zone) as a function of time.	Local	Optional

* Required for contaminant analysis.

As described in the CONTAMW Users Manual (Dols, Walton and Denton 2000), CONTAMW allows certain types of data to be stored in libraries and then to be used in different project files. When developing a project file to perform a CONTAMW analysis, the user opens the library and copies the desired elements using the CONTAMW Library Manager. The data that can be stored in library files (and the extensions of these files) include Week Schedules (.LB1), Wind Pressure Profiles (.LB2), Airflow Elements (.LB3) and Ductflow Elements (.LB4).

This report presents a number of data library files that have been developed, which are documented in the appendices to this report. These files are available at the CONTAMW website at www.bfrl.nist.gov/iMZWeb. In addition, this report also describes other relevant data that are not contained in these libraries.

LIBRARY DATA

This section describes the data that can be contained in CONTAMW library files and introduces several such libraries that have been developed for use in CONTAMW analyses. These libraries are discussed in more detailed in the appendices of this report.

Schedules (.LB1)

Schedules are used in CONTAMW to "control" a number of different elements by turning them on or off, or modulating their impact, based on time of day and day of the week. Elements that can be controlled by schedules include airflow openings, fans and contaminant sources, among others. For a given element, a schedule contains values between 0 and 1 as a function of time, with 0 corresponding to the element being "off" and 1 to the element being fully on. For example, a schedule applied to a window or other opening would allow it to be open, partially open or closed at different times of day. Since schedules can vary from day to day, this window opening schedule can be different on weekdays and weekends for instance. A schedule could also be applied to a combustion appliance such that products of combustion are released to the indoor air on a given schedule. For example, CO emissions from a gas stove can be scheduled to occur at breakfast, lunch and dinner, with different emission rates for each event. Table 2 shows an example schedule for such emissions. In addition to a schedule such as that presented in the table, the description of this source also requires a maximum value for the emission rate this is expected to occur during the simulations.

Table 2 Example Schedule for CO Emissions from a Gas Stove

Time (h)	Control Value	Comment
00:00	0	No emissions
07:00	0.25	Emissions at 25% of maximum value (for 30 min)
07:30	0	Emissions return to zero
12:30	0.33	Emissions at 33% of maximum value (for 30 min)
13:00	0	Emissions return to zero.
17:15	0.50	Emissions at 50% of maximum value.
17:45	0.75	Emissions at 75% of maximum value.
18:00	0	Emissions return to zero.
24:00	0	Control value required at midnight to match next morning.

All CONTAMW schedule files have the extension .lb1. Appendix A describes the schedule library file SCHEDULE.lb1, which contains a number of different schedules. There are several schedules to have a forced-air fan operate for a given number of minutes per hour. The library also includes schedules for cooking, bath and kitchen fan exhaust operation, and a bedroom door. While these schedules are fairly generic, they can be modified to meet the needs of a specific modeling project.

Wind Pressure Profiles (.LB2)

In order to convert wind speeds to pressures on the exterior facade of a building being analyzed, CONTAMW uses wind pressure coefficients. These coefficients, typically designated as C_p, are related to the wind pressure on the exterior facade of the building p_w by the following equation:

$$p_w = C_p \frac{\rho v^2}{2} \qquad (1)$$

where C_p is the wind pressure coefficient (dimensionless) which is a function of wind direction and location on the exterior facade, ρ is the air density (kg/m^3) and v is the wind speed (m/s) at the building height.

Within the framework of CONTAMW, wind pressure coefficients are among the data required when describing an airflow path on the exterior of a building. One option is to include no wind pressure coefficient, in which case the pressure difference across the opening is unaffected by wind speed. Another option is to specify a constant wind pressure coefficient, independent of wind direction. The most general option is to enter data that describe the wind pressure coefficient for an opening as a function of wind direction. Table 3 shows an example of such a wind pressure profile from one of the libraries presented in this report. Figure 1 is a plot of the data in Table 3. This profile can be used for all airflow paths on a given wall of a building. The more complete approach is to account for variations in wind pressure coefficient by location over a facade, but such detailed information is hard to obtain and it is more common to average wind pressure coefficients over each facade of a building.

Table 3 Example Wind Pressure Profile (S&C_2_Long from WINDPRE.lb2)

Angle (degrees)	**Wind pressure coefficient (dimensionless)**	**Angle (degrees)**	**Wind pressure coefficient (dimensionless)**
0	0.603	--	--
15	0.562	195	-0.345
30	0.480	210	-0.370
45	0.356	225	-0.494
60	0.183	240	-0.632
75	-0.052	255	-0.592
90	-0.340	270	-0.340
105	-0.592	285	-0.052
120	-0.632	300	0.183
135	-0.494	315	0.356
150	-0.370	330	0.480
165	-0.345	345	0.562
180	-0.452	360	0.603

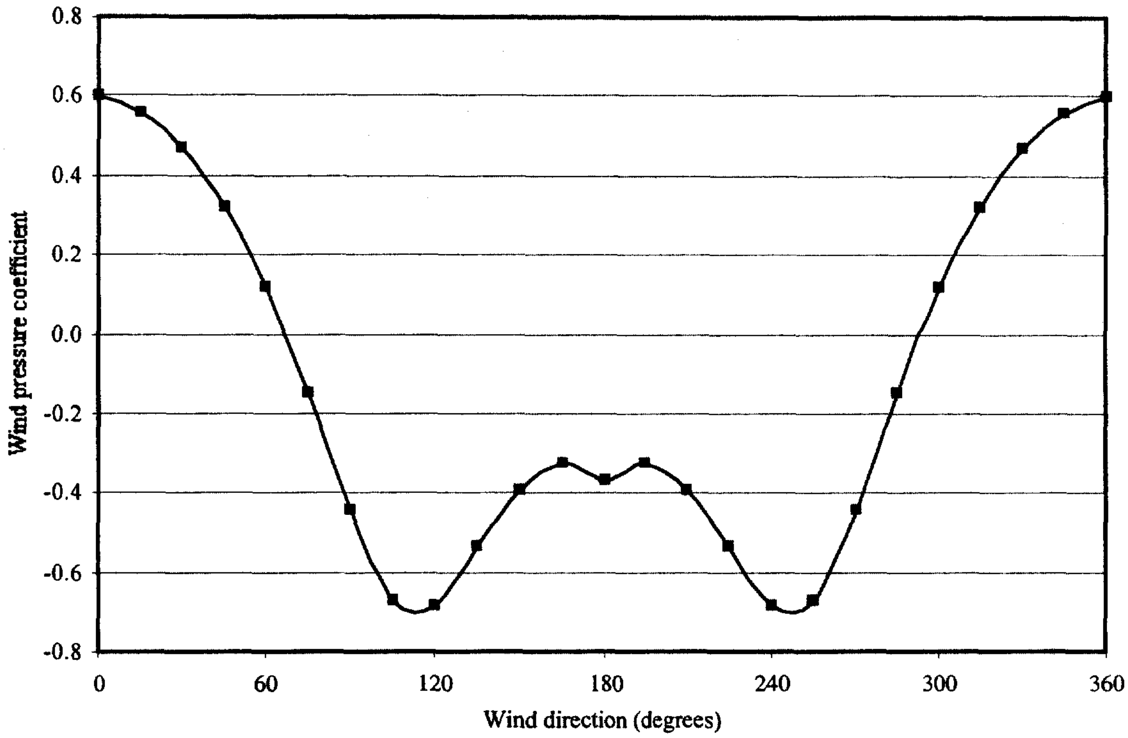

Figure 1 Plot of Wind Pressure Profile in Table 3

The most reliable means of determining the values of C_p for a given building are through on-site measurements or wind tunnel studies. However, these can be involved and expensive, and are not appropriate for studies of generic buildings. Based on a number of field and wind tunnel studies, useful data on wind pressure coefficients are available (Orme, et al. 1994; ASHRAE 1997a). In addition to providing several useful examples of wind pressure coefficients for a variety of buildings, the ASHRAE handbook chapter describes a specific correlation for low-rise, rectangular buildings that was developed by Swami and Chandra (1988) (which is the basis for the profile in Table 3 and Figure 1). This correlation is based on a number of studies and yields wind pressure coefficients averaged over a building facade as a function of wind direction. This correlation takes the following form:

$$C_p = C_{p0} \ln(1.248 - 0.703\sin(\alpha/2) - 1.175\sin^2(\alpha) - 0.131\sin^3(2\alpha G) + 0.769\cos(\alpha/2) + 0.07G^2\sin^2(\alpha/2) + 0.717\cos^2(\alpha/2) \quad (2)$$

where C_{p0} is the wind pressure coefficient on the facade towards which the wind blows in a normal direction ($\alpha = 0$), α is the wind direction measured normal to the wall, and G is the natural log of the ratio of the length of the wall to the length of the adjacent wall. To use this correlation, one needs a value for C_{p0}. Some relevant information for determining C_{p0} is given in the ASHRAE handbook chapter and other sources (Orme, et al. 1994, Swami and Chandra 1988). The correlation in equation (2) is the basis of the wind pressure profile libraries presented in Appendix B and described briefly below.

Additional information on wind pressure coefficients exists, and some examples are presented below. However, these have not been incorporated into CONTAM libraries due to the building specific nature of the information.

Swami and Chandra (1988) present a correlation of wind pressure coefficients for high-rise buildings, where the value of C_p is determined for a specific point on the building facade instead of being averaged over the entire facade. This correlation is expressed as follows:

$$C_p = 0.068 - 0.839\alpha + 1.733\cos(2\alpha) - 1.556ZH\sin(\alpha)S^{0.169} - 0.922\cos(2\alpha)S^{0.279}$$
$$+0.344\sin(2\alpha) - 0.801ZH\cos(\alpha) + 1.118\cos(Xr) - 0.961\cos(Xr\times\alpha) + 0.691\cos(Xr\times\alpha)S^{0.245} \quad (3)$$
$$+2.515ZH\sin(\alpha) + 0.399Xr\sin(\alpha) - 0.431XL + 0.046\cos(Xr)S^{0.85}$$

where α is the wind direction (radians), S is the ratio of the width of the wall under consideration to the width of the adjacent wall, XL is the ratio of the horizontal distance to the point from the edge of the wall to the length of the wall, ZH is the ratio of the vertical distance to the point from the ground level to the height of the wall, and Xr = 2 * (XL – 0.5). ZH equals zero at ground level and XL equals zero at the wall edge closest to the direction from which the wind is coming as shown in Figure 2.

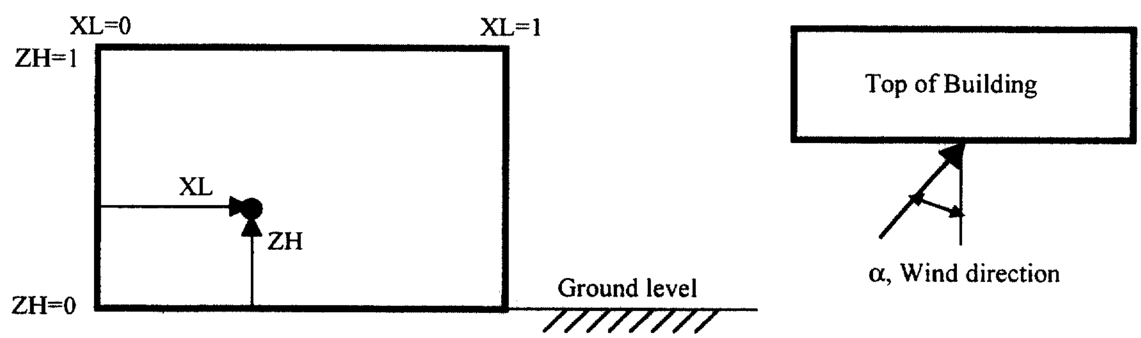

Figure 2 Determination of Tall Building Wind Pressure Coefficients

Wind pressure coefficients for roofs depend on the pitch of the roof, the aspect ratio of the building (length/width), and the wind direction. Some information is available in the ASHRAE handbook chapter and elsewhere (Orme et al. 1994). The latter source is incorporated into the wind pressure library file described in Appendix B. The ASHRAE handbook chapter presents surface averaged coefficients for the roofs of tall buildings in graphical form as a function of wind direction for three values of building length-to-width ratio. Orme et al. also contains wind pressure coefficients for building elements that protrude above roof level, e.g., stacks or chimneys. This information is presented as a function of roof pitch and height of the opening.

All CONTAMW wind pressure files have the extension .lb2. Appendix B describes the wind pressure library file WINDPRS.lb2, which contains wind pressure coefficients for low-rise building walls based on the correlation in Equation 2. These particular profiles cover buildings with length-to-width ratios of one, two and three, and are based on a value of C_{p0} of 0.6. The library also contains wind pressure profiles for roofs of low-rise buildings as a function of roof pitch and wind direction (Orme et al. 1994).

Flow Elements (.LB3)

CONTAMW uses flow elements to describe the airflow characteristics of openings between zones and the outdoors, and between interior zones. There are several different ways to describe these airflow characteristics; the libraries presented in this report use effective leakage areas (ELA) at 4 Pa (ASHRAE 1997a). Other options for describing airflow paths include power law models, orifice models, quadratic models, stairwell and shaft models, and two-way flow models. Each model requires specific data to describe the airflow characteristics of the opening.

The effective leakage area of an opening is defined by the expression for airflow through an orifice

$$Q(\Delta p) = C_D A \sqrt{\frac{2\Delta p}{\rho}} \qquad (4)$$

where Q is the airflow rate through the orifice (m^3/s), C_D is the discharge coefficient, A is the cross-sectional area of the opening (m^2), Δp is the pressure difference across the opening (Pa) and ρ is the air density (kg/m^3). The effective leakage area (at 4 Pa) for an opening is defined as the orifice area that will result in the same airflow rate at 4 Pa assuming a discharge coefficient of 1. This effective leakage area or ELA can be expressed as follows

$$ELA_4 = Q(4)\sqrt{\frac{\rho}{8}} \qquad (5)$$

For ρ equal to 1.2 kg/m^3, equation (5) takes the form of ELA_4 being equal to 0.387 times the airflow rate at 4 Pa. When specifying a flow element within CONTAMW in terms of an effective leakage area, one must also enter the exponent n to which the pressure difference across an opening is raised in calculating the airflow rate. In the libraries presented in this report, this exponent is set equal to 0.65 (ASHRAE 1997).

Four flow element libraries are presented in Appendix C: two for residential buildings and two for commercial/institutional buildings. The first residential library, ASHRAELA.lb3, contains selected values from the table of effective leakage areas presented in Chapter 25 of the ASHRAE Fundamentals Handbook (ASHRAE 1997a). The second residential library, RESMISC.lb3, contains a collection of residential leakage coefficients that have been used in previous modeling studies at NIST (Emmerich and Persily 1996; Persily 1998a and 2000). The two commercial flow element libraries are C&ISUM.lb3 and C&IMISC.lb3. The first contains a summary of a database of whole building envelope leakage values from the published literature (Persily 1998b). The second contains a number of measured leakage values for commercial, institutional and high-rise residential buildings.

Of the two residential libraries, the first is based on a comprehensive analysis of residential component leakage (Colliver et al. 1994) and provides more well-established leakage values. The second library is based on specific modeling studies and is therefore less appropriate for general use, but nonetheless contains a broad collection of leakage sites. In addition to the data contained in these libraries, there have also been a number of studies of residential airtightness that provide whole building leakage values that can be useful in establishing exterior wall leakage for modeling purposes (Palmiter et al. 1989 and 1999; Sherman et al. 1986 and 1998).

The libraries in Appendix C present effective leakage areas for a number of flow elements (e.g., doors and windows) as well as ELAs for whole buildings. The former are based on component leakage tests (ASTM E283 and E783), while the latter are based on whole building pressurization tests (E779). Depending on the nature of the flow element, these libraries present the data as effective leakage in cm^2 per unit area (m^2) of the element (e.g. a wall), per unit length (m) of the element (e.g. a door frame), or per element (e.g. electrical penetration). While the libraries in Appendix C are useful for creating an airflow model of a building, the particular values may or may not be relevant for a specific building. In other words, they are not a substitute for building-specific data.

In addition to the data presented in these appendices, other data are presented in the published literature (Klote and Milke 1992; Orme et al. 1994).

Duct Elements (.LB4)

CONTAMW allows the user to model ventilation duct systems, and one can create libraries to describe duct elements. Such elements could include ducts of a specific size, shape, surface roughness and leakage rate, fans associated with a fan curve relating airflow rate to pressure difference, and junctions between ducts. Such elements are generally specific to the ventilation system being represented, and therefore no duct element libraries are presented here. Information on duct losses is available from a variety of sources (ACCA 1995; ASHRAE 1994 and 1997a).

LOCAL LIBRARY DATA

In addition to the data that can be stored in libraries, CONTAMW also employs data elements in project files that cannot be shared between projects using libraries. These "local-only" data elements are associated with project specific data, including zones, contaminants and occupants, which prevents sharing them between projects. (Future releases of CONTAMW will have the ability to share some of these data via libraries.) This section discusses some of these data elements and some sources for relevant data.

Filters

CONTAMW allows the placement of filters in any airflow path or duct element to account for the removal of contaminants by filtration or gaseous air cleaning devices or by losses associated with air leakage paths. The data needed to define a filter in CONTAMW are the contaminant impacted by the filter and a value between 0 and 1 characterizing the filter efficiency for that contaminant. Some efficiency data are available from manufacturers and from the research literature, but there is no comprehensive database from which to draw efficiencies for different filter types. There is more such data for particulate filters than for gaseous air cleaners.

Some particulate filter efficiency data is available in an informative appendix to ANSI/ASHRAE Standard 52.2-1999, which is a test method for laboratory testing of particulate filters. Among other performance parameters, the standard reports a Minimum Efficiency Reporting Value or MERV for each tested device. The MERV ranges from 1 to 16, with higher values corresponding to higher particulate removal efficiencies. Appendix D to the standard contains sample efficiency data for five different types of filters. These are reproduced in Table 4.

Gaseous air cleaner efficiency data is less widely available than that for particle filters, due in part to the lack of a standardized test method for determining these efficiencies. A number of research papers have been written on this subject of gaseous air cleaning, some of which report measured efficiencies (Axley 1994a; Iwashita and Kimura 1994; Liu and Huza 1995; Muller and England 1995; Obee and Brown 1995; VanOsdell 1994; VanOsdell and Sparks 1995; Weschler et al. 1994a). However, a great deal of work remains to be done before efficiency data are widely available in a standard form.

Table 4 Sample Particulate Filter Efficiencies (ASHRAE 1999)

Filter	Average particle size efficiency, % Particle size range, μm		
	0.30 to 1.0	1.0 to 3.0	3.0 to 10
MERV14	84	98	100
MERV11	33	78	99
MERV9	11	42	94
MERV8	6	31	81
"Furnace filter" (not ratable by Standard 52.2)	2	11	7

Kinetic Reactions

Chemical reactions can act as a source of contaminants as well as a removal mechanism (Axley 1995). While some important work has been done in this area (Blondeau et al. 1998; Weschler et al. 1992 and 1994b; Weschler and Shields 2000) and there is a great deal of information on kinetic reaction rates in the chemistry literature, there is not an extensive database of the relevant reactions and rates relevant to indoor air.

Within CONTAMW, chemical reactions are modeled as first-order rate expressions, where the rate of production or destruction of contaminant α is given by

$$R_\alpha = \sum_\beta \left(K_{\alpha,\beta} C_\beta \right) \tag{6}$$

where R_α is the rate of production or destruction, $K_{\alpha,\beta}$ is the reaction rate coefficient between contaminants α and β in s^{-1}, and C_β is the concentration of reaction β. Therefore, to model chemical reactions in CONTAMW, the user must input values for $K_{\alpha,\beta}$. The form of equation (6) limits the chemical reactions that CONTAMW can address, but future versions of the program may include more complete models of chemical reaction.

Source/Sinks

Data on contaminant source strengths and loss mechanisms are critical inputs for performing contaminant dispersal analyses. Sources and losses cover a wide range of phenomena, with the associated data depending on the contaminant and the particular source or loss mechanism involved. Table 5 classifies source and sink mechanisms that may need to be addressed in contaminant analysis depending on the objective of the analyses, the contaminants of interest, and the relevant sources and sinks. Input data characterizing these mechanisms for individual contaminants is variable in its availability, and there are not yet comprehensive databases available for use in modeling. However, useful data are available and progress continues.

CONTAMW contains a number of different models of contaminant sources and sinks, each requiring input data that are specific to the model. These models include a constant contaminant generation (or loss) rate, a source that depends on pressure difference between the zone and the outdoors, a source strength that decays exponentially over time, and a reversible sink that can store contaminant when the airborne concentration is high and re-emit it when the concentration is lower. Other contaminant source models may be added to CONTAMW in the future.

Table 5 Contaminant Source and Sink Mechanisms

	Comments
Contaminant sources	
Indoor emissions from materials, furnishings, equipment, activities, and contaminated water	Examples include floor coverings, furniture painting, smoking and cooking
Outdoor air	May need to account for penetration
Chemical reaction	Discussed above
Re-emission from reversible sinks	
Contaminant loss mechanisms	
Filtration/air cleaning	Discussed above
Chemical reaction	Discussed above
Irreversible surface deposition	Relevant to particles and some gasses
Reversible surface adsorption	
Radioactive decay	

Indoor contaminant sources from materials, furnishings, equipment and activities have been studied extensively, though much work remains before comprehensive databases are available. Much of this source data has been obtained through measurements in environmental chambers (ASTM 1997; Bortoli and Colombo 1992; Matthews 1987; Tucker 1991), and some of these measurements have been used to develop source models (Guo 1993). In terms of materials and furnishings much of the attention has focused on volatile organic compounds and on office buildings (Brown 1999a; Daisey et al. 1994; Hodgson 1999; Hodgson et al. 2000; Levin 1987). Particular attention has also been given to surface coatings (Salthammer 1997; Tichenor et al. 1993), wood stains (Chang and Guo 1994), paint (Clausen 1994), adhesives (Girman et al. 1986 and Nagda et al. 1995), household cleaners and other products (Colombo et al. 1991), floor coverings (Clausen et al. 1993; Lundgren et al. 1999), contaminated water (Little 1992; Andelman et al. 1986; Keating et al. 1997; Moya et al. 1999; Howard-Reed et al. 1999; Howard and Corsi 1996 and 1998) and office equipment (Brown 1999b; Wolkoff et al. 1993). Building HVAC systems have also been investigated as contaminant sources (Batterman and Burge 1995). In addition to VOCs, some data are available for indoor sources of moisture (Christian 1993 and 1994), radon (Colle et al. 1981, ECA 1995; Gadgil 1992; Revzan and Fisk 1992), and combustion products from a range of appliances (Girman et al. 1982; Mueller 1989; Nabinger et al.1995; Traynor 1989; Traynor et al. 1989) and from cigarette smoke (Daisey et al. 1991).

Contaminant entry associated with outdoor air can be another significant source, with much attention focused on ozone (Cano-Ruiz et al. 1992) and particles (Weschler et al. 1990). The issue of ambient contaminant concentrations is addressed later in this report under Other Data. However, when modeling entry of contaminants from outdoor air, one must account for the "efficiency" of penetration of these contaminants. Less than complete penetration is mostly an issue for particles, ozone and various reactive contaminants, and some data are available in this area (Weschler et al. 1990). Contaminant loss due to surface deposition and reversible adsorption have received some attention, but again no comprehensive database is available for use in modeling. Most of the research to date has focused on model development (Axley 1994b) and experimental studies (Colombo et al. 1994; Matthews et al. 1987; Nazaroff et al. 1993; Neretnieks et al. 1993). There has been some model development in the area of water vapor storage on interior materials and furnishings (Jones 1993 and 1995; Kerestecioglu et al. 1990), but data do not exist for the generalized application of such models. Radioactive decay is almost exclusively an issue when modeling indoor radon concentrations, and the relevant information is available in most discussions of radon.

Occupancy Schedules

Occupant schedules can be used in CONTAMW to determine occupant exposure to contaminants and to account for contaminants generated by occupants, for example CO_2 and water vapor. These schedules specify the times at which a given occupant is in a given zone of the building being modeled, including the times when the occupant is not in the building. From the calculated contaminant concentration time histories calculated for the building, CONTAMW can determine a number of different exposure parameters based on the schedules for each occupant. No comprehensive dataset of occupancy schedules exists, but there have been some studies of occupant activity patterns. Information useful for developing occupancy schedules is available in the EPA Exposure Factors Handbook (EPA 1999).

OTHER DATA

CONTAMW simulations also require weather data and in some cases ambient contaminant concentration data. Some resources of each are identified in this sections that follow.

Weather

Airflow simulations with CONTAMW require the user to specify outdoor weather conditions of air temperature, wind speed and wind direction. Contaminant analyses involving water vapor also require outdoor humidity levels. Depending on the objectives of the analysis, the user may specify these parameters to represent "typically" cold, warm, hot, windy and/or calm conditions. To obtain a complete characterization of the dependence of a building's air change rate on weather conditions, some analyses involve steady-state airflow simulations over a range of weather conditions. For example, one might calculate the building air change rate for a range of outdoor air temperatures at 5 °C (for example) increments and a range of wind speeds at 2 m/s (for example) increments.

Other analyses may require actual or representative weather data for a given city, perhaps over a specific time period. Representative years of weather data for a number of U.S cities are available in the form of TMY2 (Marion and Urban 1995) and WYEC2 (ASHRAE 1997b) weather files. Historical data for a large number of U.S. cities is available from the National Climatic Data Center at www.ncdc.noaa.gov.

Ambient Contaminant Concentrations

Contaminant simulations generally require data on ambient or outdoor contaminant levels, unless the ambient concentration is very low compared to indoors. In some cases a constant outdoor value may be appropriate and in other cases the variations in outdoor levels need to be considered. General information on the EPA criteria contaminants of CO, NO_2, O_3, SO_2, Pb and PM10 are available in the EPA criteria documents (EPA 1982, 1991, 1993 and 1996). These documents contain information on typical ambient levels and concentration profiles over time. Measurements of ambient concentration data for these criteria pollutants at a number of U.S. sites are available from the EPA Aerometric Information Retrieval System (AIRS) at www.epa.gov/airs.

SUMMARY

While this report has discussed the data needed to perform multizone airflow and contaminant transport analyses using CONTAMW and similar programs, there are only limited input data available for these simulations. This report presents some such data for airflow elements and other parameters. Significant data needs still exist in the area of source strengths and contaminant transport parameters such as filtration and air cleaning efficiencies, deposition rates and sinks parameters.

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Appendix A: CONTAM Schedule Library

The table below contains information on the schedules contained in the file SCHEDULE.lb1. These generic schedules are based on schedules used in previous studies and can be modified by the user to meet the needs of a particular simulation.

NAME	DESCRIPTION
Off	Always off; can be used to turn off or close any element.
5MIN	5 min on-time per hour, everyday; can be used for forced-air fans.
10MIN	10 min on-time per hour, everyday; can be used for forced-air fans.
15MIN	15 min on-time per hour, everyday; can be used for forced-air fans.
20MIN	20 min on-time per hour, everyday; can be used for forced-air fans.
25MIN	25 min on-time per hour, everyday; can be used for forced-air fans.
Cooking	Schedule for generation of H_2O, particles, combustion products or any contaminant associated with cooking; based on 2 meals per day on weekdays and 3 meals per day on weekends.
Kitchfan	Kitchen fan schedule based on cooking; 1 h each at breakfast and dinner on weekdays; 1 h each at breakfast, lunch and dinner on weekends.
Bathfan	Bath exhaust fan schedule based on showers; 30 min per day; time differences for weekdays and weekends.
BR-door	Bedroom door schedule, open all day, closed all night; time differences for weekdays and weekends.

Appendix B: CONTAM Wind Pressure Profile Library

The table below contains information on the wind pressure profiles contained in the file WINDPRS.lb2.

NAME	DESCRIPTION
S&C_1_Both	Swami & Chandra 1987 correlation; long wall (= short); $C_p(0)$ = 0.6
S&C_2_Long	Swami & Chandra 1987 correlation; long wall (= 2x short); $C_p(0)$ = 0.6
S&C_2_Short	Swami & Chandra 1987 correlation; short wall (= 1/2 long); $C_p(0)$ = 0.6
S&C_3_Long	Swami & Chandra 1987 correlation; long wall (= 3x short); $C_p(0)$ = 0.6
S&C_3_Short	Swami & Chandra 1987 correlation; short wall (= 1/3 long); $C_p(0)$ = 0.6
LowRoof_01	Low-rise roof, L/W=1, exposed, pitch < 10 deg
LowRoof_02	Low-rise roof, L/W=1, 1/2 height obstructions, pitch < 10 deg
LowRoof_03	Low-rise roof, L/W=1, building height obstructions, pitch < 10 deg
LowRoof_04	Low-rise roof, L/W=1, exposed, pitch 11-30 deg
LowRoof_05	Low-rise roof, L/W=1, 1/2 height obstructions, pitch 11-30 deg
LowRoof_06	Low-rise roof, L/W=1, building height obstructions, pitch 11-30 deg
LowRoof_07	Low-rise roof, L/W=2, exposed, pitch < 10 deg
LowRoof_08	Low-rise roof, L/W=2, 1/2 height obstructions, pitch < 10 deg
LowRoof_09	Low-rise roof, L/W=2, building height obstructions, pitch < 10 deg
LowRoof_10	Low-rise roof, L/W=2, exposed, pitch 11-30 deg
LowRoof_11	Low-rise roof, L/W=2, 1/2 height obstructions, pitch 11-30 deg
LowRoof_12	Low-rise roof, L/W=2, building height obstructions, pitch 11-30 deg

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Appendix C: CONTAM Flow Element Libraries

This appendix presents four flow element libraries: ASHRAELA.lb3, RESMISC.lb3, C&ISUM.lb3 and C&IMISC.lb3. The first two contain flow elements relevant to residential buildings, and the other two apply to commercial, institutional and high-rise residential buildings. Within the libraries, each element name consists of four parts: component, descriptors (most names will have more than one descriptor), generic building type, and tightness value. The component and descriptor parts of the name will be separated from building type and value by an underscore "_". The following are the abbreviations used to create the flow elements names:

Components:

CE	Ceiling	FP	Fireplace	RF	Roof
CH	Chimney	FR	Frame	VE	Vent
DR	Door	IT	Interface	WH	Water heater
DW	Doorway	JT	Joint	WL	Wall
FL	Floor	PE	Penetrations	WN	Window

Descriptors:

2W	Two Way Air Flow	DY	Dryer	PA	Partition
AL	Aluminum	EC	Electrical outlet or switch	PC	Precast Concrete
AP	Apartment	EL	Elevator	PL	Plumbing
AR	Per unit area	EX	Exterior	PT	Patio
AS	Assembly	FD	Fold Down	RE	Shopping mall/Retail store
AT	Attic	FR	Frame	RL	Recessed light
BA	Bathroom	GA	Garage	RS	Restaurant
BL	Block	GL	Glass	SC	School
BR	Brick	GS	Gas	SH	Single hung
CA	Caulked, sealed or gasketed	HA	Hall	SI	Single
CASE	Casement	HC	Healthcare	SL	Slider or sliding
CC	Cast-in-place concrete	ID	Industrial	SM	Storm
CK	Crack	IN	Interior	SN	Stone
CL	Closed	IO	Inoperable	SP	Sports
CO	Concrete	IS	Insulation	SR	Stair/Stairwell
CP	Concrete panel	JA	Jalousie	ST	Steel
CR	Corner	KI	Kitchen	TI	Tile
CS	Crawl Space	MA	Masonry	UC	Uncaulked
CT	Closet	ME	Metal	UN	Per unit item
CW	Curtain wall	MN	Manufactured	WD	Wood
DA	Damper	NO	No	WE	Weatherstripped
DB	Double or double hung	NW	Not weatherstripped	WF	Whole house fan
DE	Difference	OO	Operable	YE	Yes
DW	Ductwork	OP	Open		

Generic Building Types:

C	Commercial	N	Industrial
I	Institutional	R	Residential
M	Manufactured House		

Values:

AV	Average or best estimate	+S	Mean plus one standard deviation
MN	Minimum	-S	Mean minus one standard deviation
MX	Maximum		

For example, a flow element designated as DRINCTCL_RAV would refer to a closed interior closet door in a residential building with an average tightness value.

Appendix C1: ASHRAELA.lb3

Selected items from 1997 ASHRAE Fundamentals, Chapter 25, Table 3

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
CE_RAV	Residential	Ceiling, general – best estimate	1.8 cm^2/m^2	C1
CE_RMN	Residential	Ceiling, general – minimum	0.79 cm^2/m^2	C1
CE_RMX	Residential	Ceiling, general – maximum	2.8 cm^2/m^2	C1
CERL_RAV	Residential	Ceiling penetrations, recessed lights– best estimate	10 cm^2/item	C1
CERL_RMN	Residential	Ceiling penetrations, recessed lights – minimum	1.5 cm^2/item	C1
CERL_RMX	Residential	Ceiling penetrations, recessed lights – maximum	21 cm^2/item	C1
CEWF_RAV	Residential	Ceiling penetrations, whole house fans – best estimate	20 cm^2/item	C1
CEWF_RMN	Residential	Ceiling penetrations, whole house fans – minimum	1.6 cm^2/item	C1
CEWF_RMX	Residential	Ceiling penetrations, whole house fans – maximum	21 cm^2/item	C1
CH_RAV	Residential	Chimney– best estimate	29 cm^2/item	C1
CH_RMN	Residential	Chimney – minimum	21 cm^2/item	C1
CH_RMX	Residential	Chimney – maximum	36 cm^2/item	C1
DR_RAV	Residential	Door, general, average– best estimate	0.31 cm^2/m	C1
DR_RMN	Residential	Door, general, average – minimum	0.23 cm^2/m	C1
DR_RMX	Residential	Door, general, average – maximum	0.45 cm^2/m	C1
DRATCSNW_RAV	Residential	Doors, attic/crawl space, not weatherstripped – best estimate	30 cm^2/item	C1
DRATCSNW_RMN	Residential	Doors, attic/crawl space, not weatherstripped – minimum	10 cm^2/item	C1
DRATCSNW_RMX	Residential	Doors, attic/crawl space, not weatherstripped – maximum	37 cm^2/item	C1
DRATCSWE_RAV	Residential	Doors, attic/crawl space, weatherstripped – best estimate	18 cm^2/ item	C1
DRATCSWE_RMN	Residential	Doors, attic/crawl space, weatherstripped – minimum	8 cm^2/ item	C1
DRATCSWE_RMX	Residential	Doors, attic/crawl space, weatherstripped – maximum	18.5 cm^2/ item	C1
DRATFDNW_RAV	Residential	Doors, attic fold down, not weatherstripped – best estimate	44 cm^2/ item	C1
DRATFDNW_RMN	Residential	Doors, attic fold down, not weatherstripped – minimum	23 cm^2/ item	C1
DRATFDNW_RMX	Residential	Doors, attic fold down, not weatherstripped – maximum	86 cm^2/ item	C1
DRATFDWE_RAV	Residential	Doors, attic fold down, weatherstripped – best estimate	22 cm^2/ item	C1
DRATFDWE_RMN	Residential	Doors, attic fold down, weatherstripped – minimum	14 cm^2/ item	C1
DRATFDWE_RMX	Residential	Doors, attic fold down, weatherstripped – maximum	43 cm^2/ item	C1
DRDBNW_RAV	Residential	Door, double, not weatherstripped– best estimate	11 cm^2/m^2	C1
DRDBNW_RMN	Residential	Door, double, not weatherstripped – minimum	7 cm^2/m^2	C1
DRDBNW_RMX	Residential	Door, double, not weatherstripped – maximum	22 cm^2/m^2	C1
DRDBWE_RAV	Residential	Door, double, weatherstripped– best estimate	8 cm^2/m^2	C1
DRDBWE_RMN	Residential	Door, double, weatherstripped – minimum	3 cm^2/m^2	C1
DRDBWE_RMX	Residential	Door, double, weatherstripped – maximum	23 cm^2/m^2	C1
DREL_CAV	Commercial	Doors, elevator (passenger) – best estimate	0.26 cm^2/ item	C1
DREL_CMN	Commercial	Doors, elevator (passenger) – minimum	0.14 cm^2/ item	C1
DREL_CMX	Commercial	Doors, elevator (passenger) – maximum	0.35 cm^2/ item	C1
DRMS_RAV	Residential	Door, mail slot – best estimate	4 cm^2/m	C1
DRPTSLAR_RAV	Residential	Door, sliding exterior glass patio – best estimate	5.5 cm^2/m^2	C1
DRPTSLAR_RMN	Residential	Door, sliding exterior glass patio – minimum	0.6 cm^2/m^2	C1
DRPTSLAR_RMX	Residential	Door, sliding exterior glass patio – maximum	15 cm^2/m^2	C1

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
DRPTSLUN_RAV	Residential	Door, sliding exterior glass patio – best estimate	22 cm^2/item	C1
DRPTSLUN_RMN	Residential	Door, sliding exterior glass patio – minimum	3 cm^2/item	C1
DRPTSLUN_RMX	Residential	Door, sliding exterior glass patio – maximum	60 cm^2/item	C1
DRSINW_RAV	Residential	Door, single, not weatherstripped – best estimate	21 cm^2/item	C1
DRSINW_RMN	Residential	Door, single, not weatherstripped – minimum	12 cm^2/item	C1
DRSINW_RMX	Residential	Door, single, not weatherstripped – maximum	53 cm^2/item	C1
DRSIWE_RAV	Residential	Door, single, weatherstripped – best estimate	12 cm^2/item	C1
DRSIWE_RMN	Residential	Door, single, weatherstripped – minimum	4 cm^2/item	C1
DRSIWE_RMX	Residential	Door, single, weatherstripped – maximum	27 cm^2/item	C1
DRSMDE_RAV	Residential	Door, storm (difference between with and without) – best estimate	6 cm^2/item	C1
DRSMDE_RMN	Residential	Door, storm (difference between with and without) – minimum	3 cm^2/item	C1
DRSMDE_RMX	Residential	Door, storm (difference between with and without) – maximum	6.2 cm^2/item	C1
FLCS_RAV	Residential	Floors over crawl spaces, general – best estimate	2.2 cm^2/m^2	C1
FLCS_RMN	Residential	Floors over crawl spaces, general – minimum	0.4 cm^2/m^2	C1
FLCS_RMX	Residential	Floors over crawl spaces, general – maximum	4.9 cm^2/m^2	C1
FLCSNODW_RAV	Residential	Floors over crawl spaces, without ductwork in crawl space – best estimate	1.98 cm^2/m^2	C1
FLCSYEDW_RAV	Residential	Floors over crawl spaces, with ductwork in crawl space – best estimate	2.25 cm^2/m^2	C1
FPDACL_RAV	Residential	Fireplace, with damper closed – best estimate	43 cm^2/m^2	C1
FPDACL_RMN	Residential	Fireplace, with damper closed – minimum	10 cm^2/m^2	C1
FPDACL_RMX	Residential	Fireplace, with damper closed – maximum	92 cm^2/m^2	C1
FPDAOP_RAV	Residential	Fireplace, with damper open – best estimate	350 cm^2/m^2	C1
FPDAOP_RMN	Residential	Fireplace, with damper open – minimum	145 cm^2/m^2	C1
FPDAOP_RMX	Residential	Fireplace, with damper open – maximum	380 cm^2/m^2	C1
FPGLDR_RAV	Residential	Fireplace, with glass doors – best estimate	40 cm^2/m^2	C1
FPGLDR_RMN	Residential	Fireplace, with glass doors – minimum	4 cm^2/m^2	C1
FPGLDR_RMX	Residential	Fireplace, with glass doors – maximum	40 cm^2/m^2	C1
FRDR_RAV	Residential	Door frame, general – best estimate	12 cm^2/ item	C1
FRDR_RMN	Residential	Door frame, general – minimum	2.4 cm^2/ item	C1
FRDR_RMX	Residential	Door frame, general – maximum	25 cm^2/ item	C1
FRDRMACA_RAV	Residential	Door frame, masonry, caulked – best estimate	1 cm^2/m^2	C1
FRDRMACA_RMN	Residential	Door frame, masonry, caulked – minimum	0.3 cm^2/m^2	C1
FRDRMACA_RMX	Residential	Door frame, masonry, caulked – maximum	1 cm^2/m^2	C1
FRDRMAUC_RAV	Residential	Door frame, masonry, uncaulked – best estimate	5 cm^2/m^2	C1
FRDRMAUC_RMN	Residential	Door frame, masonry, uncaulked – minimum	1.7 cm^2/m^2	C1
FRDRMAUC_RMX	Residential	Door frame, masonry, uncaulked – maximum	5 cm^2/m^2	C1
FRDRWDCA_RAV	Residential	Door frame, wood, caulked – best estimate	0.3 cm^2/m^2	C1
FRDRWDCA_RMN	Residential	Door frame, wood, caulked – minimum	0.1 cm^2/m^2	C1
FRDRWDCA_RMX	Residential	Door frame, wood, caulked – maximum	0.3 cm^2/m^2	C1
FRDRWDUC_RAV	Residential	Door frame, wood, uncaulked – best estimate	1.7 cm^2/m^2	C1
FRDRWDUC_RMN	Residential	Door frame, wood, uncaulked – minimum	0.6 cm^2/m^2	C1
FRDRWDUC_RMX	Residential	Door frame, wood, uncaulked – maximum	1.7 cm^2/m^2	C1
FRWNMACA_RAV	Residential	Window framing, masonry, caulked – best estimate	1.3 cm^2/m^2	C1
FRWNMACA_RMN	Residential	Window framing, masonry, caulked – minimum	1.1 cm^2/m^2	C1
FRWNMACA_RMX	Residential	Window framing, masonry, caulked – maximum	2.1 cm^2/m^2	C1
FRWNMAUC_RAV	Residential	Window framing, masonry, uncaulked – best estimate	6.5 cm^2/m^2	C1
FRWNMAUC_RMN	Residential	Window framing, masonry, uncaulked – minimum	5.7 cm^2/m^2	C1
FRWNMAUC_RMX	Residential	Window framing, masonry, uncaulked – maximum	10.3 cm^2/m^2	C1

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
FRWNWDCA_RAV	Residential	Window framing, wood, caulked – best estimate	0.3 cm^2/m^2	C1
FRWNWDCA_RMN	Residential	Window framing, wood, caulked – minimum	0.3 cm^2/m^2	C1
FRWNWDCA_RMX	Residential	Window framing, wood, caulked – maximum	0.5 cm^2/m^2	C1
FRWNWDUC_RAV	Residential	Window framing, wood, uncaulked – best estimate	1.7 cm^2/m^2	C1
FRWNWDUC_RMN	Residential	Window framing, wood, uncaulked – minimum	1.5 cm^2/m^2	C1
FRWNWDUC_RMX	Residential	Window framing, wood, uncaulked – maximum	2.7 cm^2/m^2	C1
JTCEWL_RAV	Residential	Joints, ceiling wall – best estimate	1.5 cm^2/m	C1
JTCEWL_RMN	Residential	Joints, ceiling wall – minimum	0.16 cm^2/m	C1
JTCEWL_RMX	Residential	Joints, ceiling wall – maximum	2.5 cm^2/m	C1
JTFLWLCA_RAV	Residential	Joints, sole plate, floor/wall, caulked– best estimate	0.8 cm^2/m	C1
JTFLWLCA_RMN	Residential	Joints, sole plate, floor/wall, caulked – minimum	0.075 cm^2/m	C1
JTFLWLCA_RMX	Residential	Joints, sole plate, floor/wall, caulked – maximum	1.2 cm^2/m	C1
JTFLWLUC_RMN	Residential	Joints, sole plate, floor/wall, uncaulked – minimum	0.38 cm^2/m	C1
JTFLWLUC_RMX	Residential	Joints, sole plate, floor/wall, uncaulked – maximum	5.6 cm^2/m	C1
JTFLWLUC_RAV	Residential	Joints, sole plate, floor/wall, uncaulked – best estimate	4.0 cm^2/m	C1
PECA_RAV	Residential	Piping/Plumbing/Wiring penetrations, caulked – best estimate	2.0 cm^2/ item	C1
PECA_RMN	Residential	Piping/Plumbing/Wiring penetrations, caulked – minimum	1.0 cm^2/ item	C1
PECA_RMX	Residential	Piping/Plumbing/Wiring penetrations, caulked – maximum	2.0 cm^2/ item	C1
PEECCA_RAV	Residential	Electrical outlets/switches, gaskets – best estimate	0.15 cm^2/item	C1
PEECCA_RMN	Residential	Electrical outlets/switches, gaskets – minimum	0.08 cm^2/item	C1
PEECCA_RMX	Residential	Electrical outlets/switches, gaskets – maximum	3.5 cm^2/item	C1
PEECUC_RAV	Residential	Electrical outlets/switches, no gaskets – best estimate	2.5 cm^2/item	C1
PEECUC_RMN	Residential	Electrical outlets/switches, no gaskets – minimum	0.5 cm^2/item	C1
PEECUC_RMX	Residential	Electrical outlets/switches, no gaskets – maximum	6.2 cm^2/item	C1
PEUC_RAV	Residential	Piping/Plumbing/Wiring penetrations, uncaulked – best estimate	6.0 cm^2/ item	C1
PEUC_RMN	Residential	Piping/Plumbing/Wiring penetrations, uncaulked – minimum	2.0 cm^2/ item	C1
PEUC_RMX	Residential	Piping/Plumbing/Wiring penetrations, uncaulked – maximum	24.0 cm^2/ item	C1
VEBADACL_RAV	Residential	Vents, bathroom with damper closed– best estimate	10 cm^2/item	C1
VEBADACL_RMN	Residential	Vents, bathroom with damper closed – minimum	2.5 cm^2/item	C1
VEBADACL_RMX	Residential	Vents, bathroom with damper closed – maximum	20 cm^2/item	C1
VEBADAOP_RAV	Residential	Vents, bathroom with damper open– best estimate	20 cm^2/item	C1
VEBADAOP_RMN	Residential	Vents, bathroom with damper open – minimum	6.1 cm^2/item	C1
VEBADAOP_RMX	Residential	Vents, bathroom with damper open – maximum	22 cm^2/item	C1
VECS_RAV	Residential	Crawl space, 200 mm by 400 mm vent – best estimate	129 cm^2/item	C1
VEDYDANO_RAV	Residential	Vents, dryer without damper– best estimate	15 cm^2/item	C1
VEDYDANO_RMN	Residential	Vents, dryer without damper – minimum	12 cm^2/item	C1
VEDYDANO_RMX	Residential	Vents, dryer without damper – maximum	34 cm^2/item	C1
VEDYDAYE_RAV	Residential	Vents, dryer with damper– best estimate	3 cm^2/item	C1
VEDYDAYE_RMN	Residential	Vents, dryer with damper – minimum	2.9 cm^2/item	C1
VEDYDAYE_RMX	Residential	Vents, dryer with damper – maximum	7 cm^2/item	C1
VEKIDACA_RAV	Residential	Vents, kitchen tight gasket – best estimate	1 cm^2/item	C1
VEKIDACL_RAV	Residential	Vents, kitchen with damper open – best estimate	5 cm^2/item	C1
VEKIDACL_RMN	Residential	Vents, kitchen with damper open – minimum	1 cm^2/item	C1
VEKIDACL_RMX	Residential	Vents, kitchen with damper open – maximum	7 cm^2/item	C1
VEKIDAOP_RAV	Residential	Vents, kitchen with damper open – best estimate	40 cm^2/item	C1

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
VEKIDAOP_RMN	Residential	Vents, kitchen with damper open – minimum	14 cm^2/item	C1
VEKIDAOP_RMX	Residential	Vents, kitchen with damper open – maximum	72 cm^2/item	C1
WCCASEWE_RMN	Residential	Windows, casement with weatherstripping –minimum	0.1 cm^2/m	C1
WCCASEWE_RMX	Residential	Windows, casement with weatherstripping –maximum	3.0 cm^2/m	C1
WCCASEWE_RAV	Residential	Windows, casement with weatherstripping – best estimate	0.24 cm^2/m	C1
WHGS_RAV	Residential	Gas water heater – best estimate	20 cm^2/item	C1
WHGS_RMN	Residential	Gas water heater – minimum	15 cm^2/item	C1
WHGS_RMX	Residential	Gas water heater – maximum	25 cm^2/item	C1
WLCS_RAV	Residential	Crawl space, general (area for exposed wall) – best estimate	10 cm^2/m^2	C1
WLCS_RMN	Residential	Crawl space, general (area for exposed wall) – minimum	8 cm^2/m^2	C1
WLCS_RMX	Residential	Crawl space, general (area for exposed wall) – maximum	17 cm^2/m^2	C1
WLEXCC_RAV	Residential	Walls (exterior), cast-in-place concrete – best estimate	0.5 cm^2/m^2	C1
WLEXCC_RMN	Residential	Walls (exterior), cast-in-place concrete – minimum	0.049 cm^2/m^2	C1
WLEXCC_RMX	Residential	Walls (exterior), cast-in-place concrete – maximum	1.8 cm^2/m^2	C1
WLEXPC_RAV	Residential	Walls (exterior), precast concrete panel – best estimate	1.2 cm^2/m^2	C1
WLEXPC_RMN	Residential	Walls (exterior), precast concrete panel – minimum	0.28 cm^2/m^2	C1
WLEXPC_RMX	Residential	Walls (exterior), precast concrete panel – maximum	1.65 cm^2/m^2	C1
WNCASENW_RAV	Residential	Windows, casement, not weatherstripped – best estimate	0.28 cm^2/m	C1
WNDBNW_RAV	Residential	Windows, double hung, not weatherstripped – best estimate	2.5 cm^2/m	C1
WNDBNW_RMN	Residential	Windows, double hung, not weatherstripped –minimum	0.86 cm^2/m	C1
WNDBNW_RMX	Residential	Windows, double hung, not weatherstripped –maximum	6.1 cm^2/m	C1
WNDBNWSM_RAV	Residential	Windows, double hung with storm, not weatherstripped – best estimate	0.97 cm^2/m	C1
WNDBNWSM_RMN	Residential	Windows, double hung with storm, not weatherstripped –minimum	0.48 cm^2/m	C1
WNDBNWSM_RMX	Residential	Windows, double hung with storm, not weatherstripped –maximum	1.7 cm^2/m	C1
WNDBWE_RAV	Residential	Windows, double hung, weatherstripped – best estimate	0.65 cm^2/m	C1
WNDBWE_RMN	Residential	Windows, double hung, weatherstripped –minimum	0.2 cm^2/m	C1
WNDBWE_RMX	Residential	Windows, double hung, weatherstripped – maximum	1.9 cm^2/m	C1
WNDBWESM_RAV	Residential	Windows, double hung with storm, weatherstripped – best estimate	0.79 cm^2/m	C1
WNDBWESM_RMN	Residential	ndows, double hung with storm, weatherstripped – minimum	0.44 cm^2/m	C1
WNDBWESM_RMX	Residential	ndows, double hung with storm, weatherstripped – maximum	1.0 cm^2/m	C1
WNJA_RAV	Residential	Windows, jalousise – best estimate	3.38 cm^2/m	C1
WNSISHWE_RAV	Residential	Windows, single hung, weatherstripped – best estimate	0.87 cm^2/m	C1
WNSISHWE_RMN	Residential	Windows, single hung, weatherstripped – minimum	0.62 cm^2/m	C1
WNSISHWE_RMX	Residential	Windows, single hung, weatherstripped – maximum	1.24 cm^2/m	C1

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
WNSISLAL_RAV	Residential	Windows, single horizontal slider, aluminum – best estimate	0.8 cm^2/m	C1
WNSISLAL_RMN	Residential	Windows, single horizontal slider, aluminum – minimum	0.27 cm^2/m	C1
WNSISLAL_RMX	Residential	Windows, single horizontal slider, aluminum – maximum	2.06 cm^2/m	C1
WNSISLWD_RAV	Residential	Windows, single horizontal slider, wood – best estimate	0.44 cm^2/m	C1
WNSISLWD_RMN	Residential	Windows, single horizontal slider, wood – minimum	0.27 cm^2/m	C1
WNSISLWD_RMX	Residential	Windows, single horizontal slider, wood – maximum	0.99 cm^2/m	C1
WNSISLWE_RAV	Residential	Windows, single horizontal slider, weatherstripped – best estimate	0.67 cm^2/m	C1
WNSISLWE_RMN	Residential	Windows, single horizontal slider, weatherstripped – minimum	0.2 cm^2/m	C1
WNSISLWE_RMX	Residential	Windows, single horizontal slider, weatherstripped – maximum	2.06 cm^2/m	C1
WNSLALWE_RAV	Residential	Windows, double horizontal slider, aluminum, weatherstripped - best estimate	0.72 cm^2/m	C1
WNSLALWE_RMN	Residential	Windows, double horizontal slider, aluminum, weatherstripped – minimum	0.58 cm^2/m	C1
WNSLALWE_RMX	Residential	Windows, double horizontal slider, aluminum, weatherstripped –maximum	0.8 cm^2/m	C1
WNSLNW_RAV	Residential	Windows, double horizontal slider, not weatherstripped – best estimate	1.1 cm^2/m	C1
WNSLNW_RMN	Residential	Windows, double horizontal slider, not weatherstripped – minimum	0.019 cm^2/m	C1
WNSLNW_RMX	Residential	Windows, double horizontal slider, not weatherstripped – maximum	3.4 cm^2/m	C1
WNSLWDWE_RAV	Residential	Windows, double horizontal slider, wood, weatherstripped – best estimate	0.55 cm^2/m	C1
WNSLWDWE_RMN	Residential	Windows, double horizontal slider, wood, weatherstripped – minimum	0.15 cm^2/m	C1
WNSLWDWE_RMX	Residential	Windows, double horizontal slider, wood, weatherstripped – maximum	1.72 cm^2/m	C1

Appendix C2: RESMISC.lb3

Assorted residential airtightness values used in previous airflow modeling studies at NIST.

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
DRAT_RAV	Residential	Attic door, typical value	30 cm^2/item	C2
DRAT_RMN	Residential	Attic door, tight value	18 cm^2/item	C2
CE_RAV	Residential	General ceiling, typical value	1.8 cm^2/m^2	C2
CE_RMN	Residential	General ceiling, tight value	0.79 cm^2/m^2	C2
DRCTCL_RAV	Residential	Closet door, closed, typical value	0.9 cm^2/m	C2
DRCTCL_RMN	Residential	Closet door, closed, tight value	0.25 cm^2/m	C2
DRCTFR_RAV	Residential	Closet door frame, typical value	25 cm^2/item	C2
DRCTFR_RMN	Residential	Closet door frame, tight value	12 cm^2/item	C2
CPEN_RAV	Residential	HVAC ceiling penetration, typical value	5 cm^2/item	C2
CPEN_RMN	Residential	HVAC ceiling penetration, tight value	1 cm^2/item	C2
DREXSI_RAV	Residential	Door, exterior, single, typical value	21 cm^2/item	C2
DREXSI_RMN	Residential	Door, exterior, single, tight value	12 cm^2/item	C2
DREXFRWD_RAV	Residential	Door, exterior, wood, frame, typical value	1.7 cm^2/m^2	C2
DREXFRWD_RMN	Residential	Door, exterior, wood, frame, tight value	0.3 cm^2/m^2	C2
VEBA_RAV	Residential	Bathroom exhaust vent, typical value	20 cm^2/item	C2
VEBA_RMN	Residential	Bathroom exhaust vent, tight value	10 cm^2/item	C2
VEKI_RAV	Residential	Kitchen exhaust vent, typical value	40 cm^2/item	C2
VEKI_RMN	Residential	Kitchen exhaust vent, tight value	5 cm^2/item	C2
JTCEWL_RAV	Residential	Ceiling-wall joint, typical value	1.5 cm^2/m	C2
JTCEWL_RMN	Residential	Ceiling-wall joint, tight value	0.5 cm^2/m	C2
JTFLWL_RAV	Residential	Floor-wall joint, typical value	4 cm^2/m	C2
JTFLWL_RMN	Residential	Floor-wall joint, tight value	0.8 cm^2/m	C2
JTWLWL_RAV	Residential	Wall-wall joint, typical value	1.5 cm^2/m	C2
JTWLWL_RMN	Residential	Wall-wall joint, tight value	0.5 cm^2/m	C2
DRGACL_RAV	Residential	Garage door, closed, typical value	0.45 cm^2/m	C2
DRGACL_RMN	Residential	Garage door, closed, tight value	0.31 cm^2/m	C2
DRGAFRWD_RAV	Residential	Garage door frame, wood, typical value	1.7 cm^2/m^2	C2
DRGAFRWD_RMN	Residential	Garage door frame, wood, tight value	0.3 cm^2/m^2	C2
RFGA_RAV	Residential	Garage roof, typical value	1.8 cm^2/m^2	C2
RFGA_RMN	Residential	Garage roof, tight value	0.79 cm^2/m^2	C2
DWHA_RAV	Residential	Hall doorway, typical value	2.4 m^2/item	C2
DRINCL_RAV	Residential	Door, interior, closed, typical value	140 cm^2/item	C2
DRINCL_RMN	Residential	Door, interior, closed, tight value	75 cm^2/item	C2
DRINOP_RAV	Residential	Door, interior, open, typical value	2.1 m^2/item	C2
WLIN_RAV	Residential	Wall, interior, typical value	2.0 cm^2/m^2	C2
PEEC_RAV	Residential	Electrical outlet, typical value	2.5 cm^2/item	C2
PEEC_RMN	Residential	Electrical outlet, tight value	0.5 cm^2/item	C2
PEPL_RAV	Residential	Plumbing penetration, interior, typical value	6 cm^2/item	C2
PEPL_RMN	Residential	Plumbing penetration, interior, tight value	2 cm^2/item	C2
DREXSLGL_RAV	Residential	Door, exterior, sliding glass, typical value	22 cm^2/item	C2
DREXSLGL_RMN	Residential	Door, exterior, sliding glass, tight value	3 cm^2/item	C2
VEAT_RAV	Residential	Attic vent, based on attic floor area (1/300 ratio), typical value	33.33 cm^2/m^2	C2
WNDB_RAV	Residential	Window, double hung, typical value	2.5 cm^2/m	C2
WNDB_RMN	Residential	Window, double hung, tight value	0.65 cm^2/m	C2
WNFRWD_RAV	Residential	Window frame, wood, typical value	1.7 cm^2/m^2	C2
WNFRWD_RMN	Residential	Window frame, wood, tight value	0.3 cm^2/m^2	C2
WLEX_R	Residential	Wall, exterior	0.1 cm^2/m^2	C3
JTFLWL_R	Residential	Floor -wall joint	0.8 cm^2/m	C3

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
JTCEWL_R	Residential	Ceiling-wall joint	0.5 cm^2/m	C3
JTCR_R	Residential	Wall-wall corner joint	0.5 cm^2/m	C3
WN_R	Residential	Window	2 cm^2/m	C3
DRFREX_R	Residential	Exterior door frame	0.3 cm^2/m^2	C3
DREXSLGL_R	Residential	Door, exterior, sliding glass	3 cm^2/item	C3
DREX_R	Residential	Door, exterior	6 cm^2/item	C3
WLGAEX_R	Residential	Exterior garage wall	0.4 cm^2/m^2	C3
ITGAEX_R	Residential	Wall-floor and wall-ceiling interface, exterior garage wall	2 cm^2/m	C3
CECS_R	Residential	Crawl space ceiling	0.5 cm^2/m^2	C3
FLAT_R	Residential	Attic floor	0.5 cm^2/m^2	C3
PEDW_R	Residential	Duct penetration in crawl space ceiling or attic floor	1 cm^2/item	C3
VECS_R	Residential	Crawl space vent, based on floor area (1/150 ratio)	66.67 m^2/cm^2	C3
WLIN_R	Residential	Wall, interior	2.0 cm^2/m^2	C3
CEIN_R	Residential	Ceiling, interior	0.79 cm^2/m^2	C3
DRINCL_R	Residential	Door, interior, closed, including frame and undercut	250 cm^2/item	C3
WLEX_RM	Residential	Wall, exterior, manufactured home	0.067 cm^2/m^2	C4
JTFLWL_RM	Residential	Floor-wall joint, manufactured home	0.53 cm^2/m	C4
JTCEWL_RM	Residential	Ceiling-wall joint, manufactured home	0.33 cm^2/m	C4
JTCR_RM	Residential	Wall-wall corner joint, manufactured home	0.33 cm^2/m	C4
WN1_RM	Residential	Window, manufactured home	2.3 cm^2/item	C4
WN2_RM	Residential	Window, manufactured home	2.1 cm^2/item	C4
WN3_RM	Residential	Window, manufactured home	2.7 cm^2/item	C4
WN4_RM	Residential	Window, manufactured home	0.9 cm^2/item	C4
DREX_RM	Residential	Door, exterior, manufactured home	4 cm^2/item	C4
CECS_RM	Residential	Crawl space ceiling, manufactured home	1.33 cm^2/m^2	C4
FLAT_RM	Residential	Attic floor, manufactured home	0.67 cm^2/m^2	C4
WLIN_RM	Residential	Wall, interior, manufactured home	2.0 cm^2/m^2	C4
DRBACL_RM	Residential	Bathroom door, closed, including frame and undercut, manufactured home	330 cm^2/item	C4
DRINCL_RM	Residential	Interior (bedroom) door, closed, including frame and undercut, manufactured home	410 cm^2/item	C4
DRBAOP_RM	Residential	Bathroom door, open, manufactured home	1.3 m^2/item	C4
DRINOP_RM	Residential	Interior (bedroom) door, open, manufactured home	1.6 m^2/item	C4

Appendix C3: C&ISUM.lb3

Summary values from database of commercial and institutional building airtightness values.

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
WLEXMA_CAV	Commercial	Exterior wall, masonry, mean	4.2 cm^2/m^2	C5
WLEXMA_C+S	Commercial	Exterior wall, masonry, mean plus one standard deviation	6.9 cm^2/m^2	C5
WLEXMA_C-S	Commercial	Exterior wall, masonry, mean minus one standard deviation	1.5 cm^2/m^2	C5
WLEXMA_CMN	Commercial	Exterior wall, masonry, minimum	0.6 cm^2/m^2	C5
WLEXMA_CMX	Commercial	Exterior wall, masonry, maximum	11.4 cm^2/m^2	C5
WLEXCP_CAV	Commercial	Exterior wall, concrete panel, mean	4.0 cm^2/m^2	C5
WLEXCP_C+S	Commercial	Exterior wall, concrete panel, mean plus one standard deviation	6.9 cm^2/m^2	C5
WLEXCP_C-S	Commercial	Exterior wall, concrete panel, mean minus one standard deviation	1.2 cm^2/m^2	C5
WLEXCP_CMN	Commercial	Exterior wall, concrete panel, minimum	1.1 cm^2/m^2	C5
WLEXCP_CMX	Commercial	Exterior wall, concrete panel, maximum	10.0 cm^2/m^2	C5
WLEXFRMA_CAV	Commercial	Exterior wall, frame/masonry, mean	9.1 cm^2/m^2	C5
WLEXFRMA_C+S	Commercial	Exterior wall, frame/masonry, mean plus one standard deviation	13.2 cm^2/m^2	C5
WLEXFRMA_C-S	Commercial	Exterior wall, frame/masonry, mean minus one standard deviation	4.9 cm^2/m^2	C5
WLEXFRMA_CMN	Commercial	Exterior wall, frame/masonry, minimum	4.5 cm^2/m^2	C5
WLEXFRMA_CMX	Commercial	Exterior wall, frame, maximum	19.9 cm^2/m^2	C5
WLEXFR_CAV	Commercial	Exterior wall, frame, mean	8.6 cm^2/m^2	C5
WLEXFR_C+S	Commercial	Exterior wall, frame, mean plus one standard deviation	13.0 cm^2/m^2	C5
WLEXFR_C-S	Commercial	Exterior wall, frame, mean minus one standard deviation	4.3 cm^2/m^2	C5
WLEXFR_CMN	Commercial	Exterior wall, frame, minimum	3.1 cm^2/m^2	C5
WLEXFR_CMX	Commercial	Exterior wall, frame, maximum	15.6 cm^2/m^2	C5
WLEXMN_CAV	Commercial	Exterior wall, manufactured, mean	4.3 cm^2/m^2	C5
WLEXMN_C+S	Commercial	Exterior wall, manufactured, mean plus one standard deviation	7.0 cm^2/m^2	C5
WLEXMN_C-S	Commercial	Exterior wall, manufactured, mean minus one standard deviation	1.5 cm^2/m^2	C5
WLEXMN_CMN	Commercial	Exterior wall, manufactured, minimum	2.4 cm^2/m^2	C5
WLEXMN_CMX	Commercial	Exterior wall, manufactured, maximum	8.7 cm^2/m^2	C5
WLEXME_CAV	Commercial	Exterior wall, metal, mean	4.6 cm^2/m^2	C5
WLEXME_C+S	Commercial	Exterior wall, metal, mean plus one standard deviation	7.2 cm^2/m^2	C5
WLEXME_C-S	Commercial	Exterior wall, metal, mean minus one standard deviation	1.9 cm^2/m^2	C5
WLEXME_CMN	Commercial	Exterior wall, metal, minimum	2.0 cm^2/m^2	C5
WLEXME_CMX	Commercial	Exterior wall, metal, maximum	8.0 cm^2/m^2	C5
WLEXCW_CAV	Commercial	Exterior wall, curtain wall, mean	2.7 cm^2/m^2	C5
WLEXCW_C+S	Commercial	Exterior wall, curtain wall, mean plus one standard deviation	5.6 cm^2/m^2	C5
WLEXCW_CMN	Commercial	Exterior wall, curtain wall, minimum	0.8 cm^2/m^2	C5
WLEXCW_CMX	Commercial	Exterior wall, curtain wall, maximum	6.9 cm^2/m^2	C5
WLEXOF_CAV	Commercial	Exterior wall, office building, mean	4.1 cm^2/m^2	C5
WLEXOF_C+S	Commercial	Exterior wall, office building, mean plus one standard deviation	7.8 cm^2/m^2	C5

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
WLEXOF_C-S	Commercial	Exterior wall, office building, mean minus one standard deviation	0.4 cm^2/m^2	C5
WLEXOF_CMN	Commercial	Exterior wall, office building, minimum	0.6 cm^2/m^2	C5
WLEXOF_CMX	Commercial	Exterior wall, office building, maximum	19.9 cm^2/m^2	C5
WLEXSC_IAV	Institutional	Exterior wall, school, mean	3.1 cm^2/m^2	C5
WLEXSC_I+S	Institutional	Exterior wall, school, mean plus one standard deviation	5.1 cm^2/m^2	C5
WLEXSC_I-S	Institutional	Exterior wall, school, mean minus one standard deviation	1.0 cm^2/m^2	C5
WLEXSC_IMN	Institutional	Exterior wall, school, minimum	0.4 cm^2/m^2	C5
WLEXSC_IMX	Institutional	Exterior wall, school, maximum	8.6 cm^2/m^2	C5
WLEXID_NAV	Industrial	Exterior wall, industrial building, mean	3.8 cm^2/m^2	C5
WLEXID_N+S	Industrial	Exterior wall, industrial building, mean plus one standard deviation	7.9 cm^2/m^2	C5
WLEXID_NMN	Industrial	Exterior wall, industrial building, minimum	0.4 cm^2/m^2	C5
WLEXID_NMX	Industrial	Exterior wall, industrial building, maximum	15.6 cm^2/m^2	C5
WLEXRE_CAV	Commercial	Exterior wall, retail, mean	6.9 cm^2/m^2	C5
WLEXRE_C+S	Commercial	Exterior wall, retail, mean plus one standard deviation	10.5 cm^2/m^2	C5
WLEXRE_C-S	Commercial	Exterior wall, retail, mean minus one standard deviation	3.3 cm^2/m^2	C5
WLEXRE_CMN	Commercial	Exterior wall, retail, minimum	0.7 cm^2/m^2	C5
WLEXRE_CMX	Commercial	Exterior wall, retail, maximum	12.0 cm^2/m^2	C5
WLEXRS_CAV	Commercial	Exterior wall, restaurant, mean	3.8 cm^2/m^2	C5
WLEXRS_C+S	Commercial	Exterior wall, restaurant, mean plus one standard deviation	5.2 cm^2/m^2	C5
WLEXRS_C-S	Commercial	Exterior wall, restaurant, mean minus one standard deviation	2.3 cm^2/m^2	C5
WLEXRS_CMN	Commercial	Exterior wall, restaurant, minimum	1.4 cm^2/m^2	C5
WLEXRS_CMX	Commercial	Exterior wall, restaurant, maximum	5.5 cm^2/m^2	C5
WLEXAS_NAV	Institutional	Exterior wall, assembly, mean	3.7 cm^2/m^2	C5
WLEXAS_N+S	Institutional	Exterior wall, assembly, mean plus one standard deviation	5.8 cm^2/m^2	C5
WLEXAS_N-S	Institutional	Exterior wall, assembly, mean minus one standard deviation	1.5 cm^2/m^2	C5
WLEXAS_NMN	Institutional	Exterior wall, assembly, minimum	1.8 cm^2/m^2	C5
WLEXAS_NMX	Institutional	Exterior wall, assembly, maximum	6.3 cm^2/m^2	C5
WLEXHC_IAV	Institutional	Exterior wall, healthcare, mean	5.6 cm^2/m^2	C5
WLEXHC_I+S	Institutional	Exterior wall, healthcare, mean plus one standard deviation	7.5 cm^2/m^2	C5
WLEXHC_I-S	Institutional	Exterior wall, healthcare, mean minus one standard deviation	3.7 cm^2/m^2	C5
WLEXHC_IMN	Institutional	Exterior wall, healthcare, minimum	3.7 cm^2/m^2	C5
WLEXHC_IMX	Institutional	Exterior wall, healthcare, maximum	7.6 cm^2/m^2	C5
WLEXSP_CAV	Commercial	Exterior wall, sports facility, mean	7.4 cm^2/m^2	C5
WLEXSP_C+S	Commercial	Exterior wall, sports facility, mean plus one standard deviation	10.1 cm^2/m^2	C5
WLEXSP_C-S	Commercial	Exterior wall, sports facility, mean minus one standard deviation	4.8 cm^2/m^2	C5
WLEXSP_CMN	Commercial	Exterior wall, sports facility, minimum	3.7 cm^2/m^2	C5
WLEXSP_CMX	Commercial	Exterior wall, sports facility, maximum	9.8 cm^2/m^2	C5

Appendix C4: C&IMISC4.lb3

Assorted commercial, institutional and high-rise residential airtightness values.

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
WLEXPC6A_C	Commercial	Exterior Wall: Precast concrete panel, Building A	2.19 cm^2/m^2	C6
WNIO6A_CMN	Commercial	Inoperable window, Building A, minimum	0.58 cm^2/m	C6
WNIO6A_CMX	Commercial	Inoperable window, Building A, maximum	1.73 cm^2/m	C6
WLEXTV6AA_C	Commercial	Exterior Wall: Tile veneer, Building AA	1.34 cm^2/m^2	C6
WNIO6AA_CAV	Commercial	Inoperable window, Building AA, typical	0.58 cm^2/m	C6
WLEXPC6C_C	Commercial	Exterior Wall: Precast concrete panel, Building C	1.96 cm^2/m^2	C6
WNOO6C_CMN	Commercial	Operable window, Building C, minimum	1.73 cm^2/m	C6
WNOO6C_CMX	Commercial	Operable window, Building C, maximum	3.46 cm^2/m	C6
WLEXBR6H_C	Commercial	Exterior Wall: Brick veneer, Building H	0.62 cm^2/m^2	C6
WLEXBR6N_C	Commercial	Exterior Wall: Brick veneer, Building N	2.35 cm^2/m^2	C6
WNIO6N_CAV	Commercial	Inoperable window, Building N, typical	0.86cm^2/m	C6
WLEXBR6P_C	Commercial	Exterior Wall: Brick veneer, Building P	1.14 cm^2/m^2	C6
WLEXPC6S_C	Commercial	Exterior Wall: Precast concrete panel, Building S	3.01 cm^2/m^2	C6
WLEXPC7O_C	Commercial	Exterior Wall: Precast concrete panel, Building O	6.88 cm^2/m^2	C7
WLEXCW8A_C	Commercial	Exterior Wall: Glass and metal curtain wall, Building A	5.07 cm^2/m^2	C8
WLEXPC8B_C	Commercial	Exterior Wall: Precast concrete panel, Building B	2.51 cm^2/m^2	C8
WLEXPC9A_C	Commercial	Exterior Wall: Precast concrete panel, Building A	3.59 cm^2/m^2	C9
WLEXPC9B_C	Commercial	Exterior Wall: Precast concrete panel, Building B	1.79 cm^2/m^2	C9
WLEXPC9C_C	Commercial	Exterior Wall: Precast concrete panel, Building C	1.79 cm^2/m^2	C9
WLEXCW9D_C	Commercial	Exterior Wall: Curtain wall, Building D	2.03 cm^2/m^2	C9
WLEXCW9E_C	Commercial	Exterior Wall: Curtain wall, Building E	1.14 cm^2/m^2	C9
WLEXPC9F_C	Commercial	Exterior Wall: Precast concrete panel, Building F	1.14 cm^2/m^2	C9
WLEXPC9G_C	Commercial	Exterior Wall: Precast concrete panel, Building G	1.67 cm^2/m^2	C9
WLEXCW9H_C	Commercial	Exterior Wall: Curtain wall, Building H	0.78 cm^2/m^2	C9
WLEX10_NAV	Industrial	Exterior Wall: Average	0.96 cm^2/m^2	C10
WLEX10_NMN	Industrial	Exterior Wall: Minimum	0.48 cm^2/m^2	C10
WLEX10_NMX	Industrial	Exterior Wall: Maximum	2.40 cm^2/m^2	C10
WLEXSC11_IAV	Institutional	Exterior Wall: School, average	1.44 cm^2/m^2	C11
WLEXSC11_IMN	Institutional	Exterior Wall: School, minimum	0.48 cm^2/m^2	C11
WLEXSC11_IMX	Institutional	Exterior Wall: School, maximum	1.60 cm^2/m^2	C11
WLEXSC12_IAV	Institutional	Exterior Wall: School, average	4.48 cm^2/m^2	C12
WLEXSC12_IMN	Institutional	Exterior Wall: School, minimum	3.20 cm^2/m^2	C12
WLEXSC12_IMX	Institutional	Exterior Wall: School, maximum	4.80 cm^2/m^2	C12
WLEXRE13_CAV	Commercial	Exterior Wall: Retail stores/shopping malls, average	7.84 cm^2/m^2	C13
WLEXRE13_CMN	Commercial	Exterior Wall: Retail stores/shopping malls, minimum	4.00 cm^2/m^2	C13
WLEXRE13_CMX	Commercial	Exterior Wall: Retail stores/shopping malls, maximum	11.20cm^2/m^2	C13
WLELCC14A_C	Commercial	Elevator shaft wall, cast-in-place concrete, 17 story office building	5.55 cm^2/m^2	C14
WLELCC14B_C	Commercial	Elevator shaft wall, cast-in-place concrete, 14 story office building	2.25 cm^2/m^2	C14
WLELCC14C_C	Commercial	Elevator shaft wall, cast-in-place concrete, 12 story office building	1.72 cm^2/m^2	C14
WLELCOBL14DC	Commercial	Elevator shaft wall, concrete block, 6 story office building	5.55 cm^2/m^2	C14
WLELCC14E_C	Commercial	Elevator shaft wall, cast-in-place concrete, 16 story office building	0.75 cm^2/m^2	C14

Element Name	Building Type	Description	Value (ELA at 4 Pa)	Reference
WLELTIBL14F_C	Commercial	Elevator shaft wall, clay tile block, 10 story office building	6.15 cm^2/m^2	C14
WLELCC14G_C	Commercial	Elevator shaft wall, cast-in-place concrete, 14 story office building	2.25 cm^2/m^2	C14
WLSRCC14A_C	Commercial	Stair shaft wall, cast-in-place concrete, 19 story office building	0.45 cm^2/m^2	C14
WLSRCC14B_C	Commercial	Stair shaft wall, cast-in-place concrete, 23 story office building	0.07 cm^2/m^2	C14
WLSRCC14C_C	Commercial	Stair shaft wall, cast-in-place concrete, 28 story office building	0.15 cm^2/m^2	C14
WLSRCC14D_C	Commercial	Stair shaft wall, cast-in-place concrete, 23 story office building	0.41 cm^2/m^2	C14
WLSRCC14E_C	Commercial	Stair shaft wall, cast-in-place concrete, 15 story office building	0.30 cm^2/m^2	C14
WLSRCC14F_C	Commercial	Stair shaft wall, cast-in-place concrete, 17 story office building	1.42 cm^2/m^2	C14
WLSRTIBL14GC	Commercial	Stair shaft wall, clay tile block, 11 story office building	0.67 cm^2/m^2	C14
WLSRCC14H_C	Commercial	Stair shaft wall, cast-in-place concrete, 12 story office building	0.37 cm^2/m^2	C14
DREL14_CMN	Commercial	Elevator doors, 7 office buildings, minimum	188 cm^2/door	C14
DREL14_CMX	Commercial	Elevator doors, 7 office buildings, maximum	263 cm^2/door	C14
DRSR14_CMN	Commercial	Stair shaft doors, 8 office buildings, minimum	75 cm^2/door	C14
DRSR14_CMX	Commercial	Stair shaft doors, 8 office buildings, maximum	188 cm^2/door	C14
FLCO15_CMN	Commercial	Floor: Office building, reinforced concrete, minimum	0.18 cm^2/m^2	C15
FLCO15_CMX	Commercial	Floor: Office building, reinforced concrete, maximum	0.35 cm^2/m^2	C15
WLEX16A_R	Residential	Exterior Wall: Individual apartment (#405) in high-rise building	1.87 cm^2/m^2	C16
WLEX16B_R	Residential	Exterior Wall: Individual apartment (#509) in high-rise building	2.36 cm^2/m^2	C16
WLEX16C_R	Residential	Exterior Wall: Individual apartment (#609) in high-rise building	2.33 cm^2/m^2	C16
WLEX16D_R	Residential	Exterior Wall: Individual apartment (#1009) in high-rise building	1.57cm^2/m^2	C16
WLEXBRBL17R	Residential	Exterior Wall: 5-story apartment building, brick and block backup	2.55 cm^2/m^2	C17
FLCEAP17_RMN	Residential	Floor/ceiling interface: 5-story apartment building, minimum	0.11 cm^2/m^2	C17
FLCEAP17_RMX	Residential	Floor/ceiling interface: 5-story apartment building, maximum	0.43 cm^2/m^2	C17
FLCEAP17_RAV	Residential	Floor/ceiling interface: 5-story apartment building, average	0.32 cm^2/m^2	C17
WLINAP17_RMN	Residential	Interior partition: 5-story apartment building, minimum	0.37 cm^2/m^2	C17
WLINAP17_RMX	Residential	Interior partition: 5-story apartment building, maximum	2.25 cm^2/m^2	C17
WLINAP17_RAV	Residential	Interior partition: 5-story apartment building, average	1.12 cm^2/m^2	C17
WLEXAP18_R	Residential	Exterior Wall: Multi-story apartment building	1.46 cm^2/m^2	C18
WLEXAP19D_R	Residential	Exterior Wall: Multi-story apartment building D	1.65 cm^2/m^2	C19
WLEXAP19V_R	Residential	Exterior Wall: Multi-story apartment building V	2.62 cm^2/m^2	C19

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Input Data for Multizone Airflow and IAQ Analysis

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