

TAB C-11

ACCEPTABLE INDOOR AIR QUALITY PLANNING, DESIGN, AND CONSTRUCTION CRITERIA

CODES AND STANDARDS

- ANSI/AIHA Z9.5-1992: American National Standard for Laboratory Ventilation
- ASHRAE Standard 62-1999: Ventilation for Acceptable Indoor Air Quality, 1999
- The University of Arizona Manual of Design and Specification Standards (MDSS)
- SMACNA: IAQ Guidelines for Occupied Buildings Under Construction, First Edition, November, 1995

A. DESIGN

Purpose: To facilitate communication and improve understanding of indoor air quality issues among members of the design team and between the design team and the University and provide the basis for evaluating indoor air quality issues and the performance of the HVAC system during the commissioning process.

1. Identify and document all heating, ventilating, and air conditioning (HVAC) system design requirements, assumptions, and criteria. The following information shall be provided:
 - 1.1 Indoor design conditions for each building space:
 - a. Temperature
 - b. Relative humidity by season
 1. Maximum space humidity during all seasons: 50%
 - c. Pressure relationship between adjacent areas
 - 1.2 Outdoor design parameters:
 - a. Dry bulb and wet bulb temperatures
 - b. Relative humidity
 - c. Prevailing wind direction by season
 - 1.3 Building space information:
 - a. Type
 - b. Occupancy densities
 - c. Activities
 - d. Use patterns
 - 1.4 Internal loads for each building space:
 - a. Lighting
 - b. Equipment
 - c. People
 - d. Infiltration
 - e. Any special or unusual electrical, thermal, or moisture loads
 - 1.5 Any odorous or hazardous pollution sources for which additional measures, e.g., local exhaust, additional dilution ventilation, are required.

- 1.6 Criteria utilized to determine outside air requirements for each building space.
 - a. Minimum outside airflow rates shall be clearly indicated on design drawings.
 - 1.7 Classification of air assumptions for exhaust and recirculation air streams shall be in accordance with Appendix A.
 - 1.8 Air cleaning and filtration efficiencies and filter area.
 - a. Filter area shall be clearly indicated on design drawings.
 - 1.9 Means by which outdoor air quality has been assessed and outdoor air contaminants of concern (if any) and air filtration requirements determined to establish outdoor air intake location(s).
 - a. The building site shall be surveyed for sources of contaminants (health, odor, or sensory irritation contaminants).
 - 1.10 Criteria used to determine locations of air devices (e.g., supply, return, exhaust, etc.) to ensure proper dilution and mixing of air within each building space.
 - 1.11 Means by which and locations where outdoor air can be measured and balanced.
 - 1.12 Means by which temporary exhaust can be provided in the future to control strong source contaminants during shell space construction. For further information, refer to Appendix B.
 - 1.13 Applicable codes, standards, regulations, etc.
 - 1.14 Narrative describing the design and operation of the HVAC systems during occupied and unoccupied periods.
 - 1.15 Description of HVAC system control sequence of operation and identification of control system setpoints.
 - 1.16 Minimum and maximum flow rates for terminal units.
 - 1.17 Description of building envelop construction, including locations of vapor and air retarders.
 - 1.18 HVAC calculations, including cooling load, heating load, and exhaust flow rate calculations.
2. Integrate prudent design principles and features as indicated in the following paragraphs.
 - 2.1 Locate outdoor air intakes away from known sources of contaminants, including, but not limited to, exhaust and vent outlets, plumbing stacks, emergency generator exhaust stacks, loading dock areas, flue stacks, and areas where people might congregate to smoke. For further information, refer to Appendix C.
 - a. Preferred location of outdoor air intakes is above roof level.
 - b. Outdoor air intakes should preferably not be located at ground level.
 - 2.2 Locate exhaust and vent outlets away from operable windows and doors and property line. For further information, refer to Appendix D.
 - 2.3 Bird screens shall be located over outdoor air intakes.
 - a. Bird screens shall be constructed of galvanized or stainless steel. Bird screens shall be ¼-inch mesh.

- b. Bird screens shall be accessible for cleaning.
- 2.4 Outdoor air intakes shall be protected from rain entrainment by louvers, mist eliminators, or rain hoods. For further information, refer to Appendix E.
- 2.5 Recirculation of air (for further information, refer to Appendix A):
- a. Recirculation of Class 1 air is allowed.
 - b. Recirculation of Class 2 air within the same room is allowed; recirculation of Class 2 air is allowed in other rooms if particulates are filtered or the air is sufficiently diluted with Class 1 air.
 - c. Class 3 air can only be recirculated within the same room.
 - d. Class 4 air can be exhausted or recirculated if the air is filtered to Class 2 air criteria.
 - e. Class 5 air must be exhausted.
- 2.6 Provide access doors to the following components for inspection and cleaning purposes: outdoor air intakes or plenums; upstream and downstream surfaces of cooling and heating coils; air washers; evaporative sections and coolers; other heat exchangers; air cleaners; drain pans; fans, filters, damper sections, humidifiers; and air flow measuring stations (other than unit flow sensors).
- a. Access doors shall be factory-fabricated, readily openable, and airtight.
 - b. Access doors shall be clearly indicated on the design drawings.
 - c. Access doors shall be clear of all obstructions and provide full access.
 - c. Air handling unit access doors shall be full man-doors or as large as equipment will allow.
 - e. Ductwork access doors shall be as large as ductwork will allow. If possible, ductwork access doors shall have a minimum size of 18-inches by 18-inches; 24-inch by 24-inch access doors shall be provided where possible. Hard ceiling or wall access doors shall be fire-rated and have a minimum size of 24-inches by 24-inches.
- 2.7 Air handling equipment shall be designed for no water droplet carryover. The MDSS requires air-handling equipment to have draw-through cooling coils having a maximum face velocity of 400 fpm properly and evenly distributed across the face of the cooling coil.
- 2.8 Drain pans shall be pitched towards the drain and shall be appropriately trapped. For further information, refer to Appendices F and G.
- 2.9 No internal exposed thermal insulation is permitted except as allowed by the MDSS.
- a. Supply ductwork shall be wrapped on its outside surface with thermal insulation in accordance with the MDSS.
 - b. Internal exposed thermal insulation shall not be installed in medical areas, clean rooms, or high velocity ductwork.
 - c. Internal exposed thermal insulation may be used in acoustically critical applications where the University's written permission has been obtained.
 - d. If permitted, internal exposed thermal insulation shall be elastomeric closed cell, cleanable, non-biodegradable, impermeable to water and moisture, and secured with welded pins and non-flammable adhesive. Internal exposed thermal insulation must have metal nosing or sleeves over leading edges at fan discharge, around access door openings, and at any point where the insulation is preceded by internally uninsulated duct. Internal exposed thermal insulation shall be kept away from intake screens, mist eliminators, louvers, and rain.
- 2.10 Air handling equipment and ductwork shall not be constructed of porous or semi-porous materials, e.g., concrete masonry units (CMU) or gypsum wallboard (GWB).
- 2.11 Potable water shall be used in direct evaporative humidifiers, air washers, and evaporative coolers.

- 2.12 Provide humidification only when absolutely necessary or when it is a special project requirement.
 - a. Utilize steam-to-steam-type humidifiers only.
- 2.13 Provide continuous water bleed or automatic periodic drain combined with chemical water treatment to control scale and microbial growth in air handling systems designed to recirculate water from an open storage tank or sump of an evaporative cooler, air washer, or evaporative section of air handling equipment.
 - a. If water treatment chemicals are used they shall not enter the air stream or must be acceptable for use in evaporative equipment and approved for this use by the University's Risk Management & Safety Department. To determine the acceptability of water treatment chemicals, contact the National Antimicrobial Information Network at 1-800-447-6349.
- 2.14 Filters shall be selected as appropriate for the application. For further information, refer to Appendix H.
 - a. Filters for air handling equipment whose flow rate exceeds 4,500 cfm shall have a minimum sixty percent (60%) efficiency pre-filters and final filters with 80-85% minimum efficiency when passing a three (3) micron particle.
 - b. Filters for all other air handling equipment shall have a minimum efficiency of sixty percent (60%) when passing a three (3) micron particle.
 - c. Filter area shall be based on 400 fpm face velocity.
 - d. Filter rack shall be constructed to allow no bypass of air.
- 2.15 Supply ductwork located in a return air plenum, chilled water supply and return piping, and domestic cold water piping below 55 degrees F shall be properly insulated to prevent condensation from forming. For further information, refer to Appendix I.
- 2.16 Insulation subject to damage or a reduction in thermal resistivity if it were to become wet shall be enclosed in a vapor retarder.
- 2.17 Outdoor air intake controls shall maintain no less than ninety percent (90%) of the design outside air flow rate at all times. For variable air volume (VAV) systems, refer to Appendix J.
- 2.18 Air handling system controls shall include an "optimum start-stop" provision to ensure that acceptable temperature, humidity, and ventilation is provided prior to daily space occupancy. For further information, refer to Appendix K.
- 2.19 Carbon dioxide (CO₂)-based demand control ventilation may be used, but must have a minimum outdoor air flow rate to control building sources. Refer to ASHRAE Standard 62-1999, paragraph 6.3.1 and Appendix D, "Rationale for minimum Physiological Requirements for Respiration Air Based on CO₂ Concentration" to determine the minimum outdoor airflow rate per person required for a specified CO₂ concentration.
- 2.20 Construction of the building envelope shall comply with all applicable code requirements relating to the control of water and water vapor penetration, air filtration, and entry of radon and other soil gases.
- 2.21 HVAC systems shall be designed to provide at all times no less than the minimum total amount of outdoor air required for ventilation by Table 2 of ASHRAE 62-1999.

- 2.22 Zone minimum airflow rates shall provide minimum outdoor air ventilation airflow rates during space occupancy.
- 2.23 Mechanical rooms shall not be used as air plenums. Air routed through mechanical rooms shall use hard ductwork only.
- 2.24 Utility fans serving fume hoods shall have a 3,000 feet per minute minimum discharge velocity in a vertically upwards direction and shall discharge at a minimum of ten (10) feet above the adjacent roof line. For further information, refer to ANSI/AIHA Z9.5.
- 2.25 Direct evaporative cooling may be used in air handling equipment only after the University's written permission has been obtained.
- 2.26 Direct evaporative cooling equipment:
 - a. Must limit space relative humidity to less than fifty percent (50%).
 - b. Must have no filter bypass.
 - c. Must be completely accessible, both upstream and downstream, for inspection and cleaning.
 - d. Must have no water droplet carryover. Manufacturers' recommendations for maximum allowable face velocities must be followed.
 - e. Must have filters upstream that have a minimum sixty- percent (60%) efficiency when passing a three-(3) micron particle.
 - f. Must have a water treatment system to prevent scale formation and anti-microbial growth that utilizes potable make-up water, blowdown, and water treatment chemicals.
 - g. Must use water treatment chemicals that do not enter the air stream or must be acceptable for use in evaporative equipment and approved for this use by the University's Risk Management and Safety Department. To determine the acceptability of water treatment chemicals, contact the National Antimicrobial Information Network at 1-800-447-6349.

B. CONSTRUCTION

Purpose: To ensure that work procedures and appropriate controls are utilized to minimize degradation of building indoor air quality during construction, renovation, remodeling, and maintenance activities.

1. Initial Planning

- 1.1 The party responsible for construction, renovation, remodeling, and/or maintenance activities must prepare a plan that addresses how indoor air quality issues will be handled during these activities.
 - a. If the activity only involves University staff, the responsible party will be a University department, e.g., Facilities Management, Facilities Design and Construction, Space Management, etc.
 - b. If the activity involves an outside consultant, the responsible party will be the consultant.
 - c. The University department or consultant shall contact and consult with the University's Risk Management & Safety Department during plan preparation.
 - d. The plan must be approved by the University's Risk Management and Safety Department prior to the beginning of construction.
- 1.2 The plan shall include the following information at a minimum.
 - a. Identification of potential work-related airborne contaminants, e.g., dusts and odorous or hazardous substances.
 - b. Identification of how contaminants may spread through the building.

- c. Identification of how building occupants will be affected by the spread of such contaminants.
 - d. Identification and selection of feasible, specific control measures to keep dusts and odorous and hazardous substances out of occupied areas. These measures could include work area containment, modification of HVAC operation, reduction of emissions, intensification of housekeeping, rescheduling of work hours, moving occupants, defining re-occupancy criteria, etc.
- 2. Isolation of major construction, renovation, remodeling, and maintenance activities in occupied buildings. For further information, refer to Appendix L.
 - 2.1 Affected areas in occupied buildings shall be isolated from adjacent non-affected areas through the use of temporary walls, plastic sheeting, or other vapor retarding barriers.
 - 2.2 Affected areas shall be maintained at a negative pressure relative to surrounding non-affected areas.
 - 2.3 Recirculating air ducts shall be temporarily capped and sealed. If particulates are the only indoor air quality concern, appropriate filters may be used in place of capping and sealing the ducts.
- 3. Protection of the building HVAC system from dust and moisture during major construction, renovation, remodeling, and maintenance activities in occupied buildings.
 - 3.1 Supply air systems shall not be operated without filters in place.
 - a. Filters shall have a minimum sixty- percent (60%) efficiency when passing a three- (3) micron particle.
 - 3.2 Building materials subject to degradation from ambient environmental exposure shall be protected and replaced if damaged.
 - a. Air handling equipment and ductwork shall be stored in a clean, dry location prior to installation and openings shall be securely covered to prevent entry of dust, moisture, and general construction debris and dirt.
 - 3.3 In new construction air-moving equipment shall be used to "flush" the building to reduce off gassing of interior furnishings and finishes a minimum of 48 hours prior to building occupancy. For further information, refer to Appendix M.
 - a. Temporary filters shall be utilized in the air handling equipment during this period.
 - b. Filters shall be replaced after the flushing of the building has been completed.
 - c. Filters shall have a minimum sixty- percent (60%) efficiency when passing a three- (3) micron particle.
- 4. Notification of building occupants of major construction, renovation, remodeling, and maintenance activities.
 - 4.1 Notify potentially affected building occupants of planned work via Facilities Management's alert notification procedure. A brief description of the work and the precautions that will be taken to protect the occupants' indoor air quality shall be included.
- 5. Substitution of equipment and/or materials:
 - 5.1 Substitution of equipment and/or materials that may affect the HVAC system or its ability to maintain acceptable indoor air quality shall be reviewed by the University for consistency with

documented design criteria.

5.2 Requests for substitution of equipment and/or materials shall be made in accordance with the requirements of Section 01600, Material and Equipment, of the MDSS (refer to MDSS tab D, Boilerplate).

6. Ongoing management after work has begun:

6.1 Specifications shall be monitored and enforced.

6.2 Periodic updates on progress shall be provided to building occupants.

APPENDIX A

CLASSIFICATION OF AIR

Return air, transfer air, and exhaust air shall be classified as follows:

Class 1: Air drawn from spaces without unusual sources of contaminants such as offices, conference rooms, classrooms, lobbies, retail spaces, coffee stations, storage rooms (except those housing high-emitting products such as paint supplies), equipment rooms such as air handling equipment rooms, elevator machine rooms, individual dwelling units including hotel rooms, and electrical/telephone closets.

Class 2: Air drawn from spaces that may have mild contaminant intensity, such as copy rooms, printer rooms, dining areas and break rooms, kitchenettes or dining areas with ovens or other cooking or food dispensing capability such as steam tables, cafeterias, laundry rooms, locker rooms, residential kitchens (general or hood exhaust), limited access non-residential toilet rooms (such as those in office buildings and other spaces not open to the general public), and residential or single toilet rooms and bathrooms (except those to patient rooms of health care facilities). For the purpose of this section, a copy or printer room is a room whose primary purpose is to house copy machines and printers, respectively. Air drawn from a room housing the occasional or personal copier or printer may be considered Class 1 air. [Air exhausted from limited access non-residential toilet rooms are placed in this category because the expected frequency of use of these facilities, combined with the minimum exhaust are rates prescribed in the Design Section 2.21., generally result in exhaust gases that have mild odor intensity. Exhaust from toilet rooms that are publicly accessible, particularly those that are heavily used at times such as in airports, theaters, and other assembly spaces, can be expected to have much higher contaminant concentrations and thus qualify as Class 3 air.]

Class 3: Air drawn or vented from locations with significant contaminant intensity, such as nonresidential and public toilet rooms (except those listed above under Class 2), toilet rooms and bathrooms to patient rooms of health care facilities, janitor's closets, commercial kitchens (general and non-grease hoods), laboratories (general exhaust), dry-cleaning processing establishment (general exhaust), indoor swimming pools, diazo printing rooms, and plumbing vents.

Class 4: Air drawn or vented from locations with noxious or toxic fumes or gases, such as paint spray booth, garages, tunnels, kitchens (grease hood exhaust), chemical storage rooms, refrigerating machinery rooms, natural gas and propane burning appliance vents, and soiled laundry storage.

Class 5: Effluent or exhaust air having a high concentration of dangerous particles, bio-aerosols, or gases such as that from fuel burning appliance vents other than those burning natural gas and propane, uncleaned fume hood exhaust, evaporative condenser and cooling tower outlets [due to possible microbial contamination such as legion Ella, the causative agent of Legionnake's Disease and Pontiac Fever].

APPENDIX B

SUPPLEMENTAL EXHAUST

The design documents shall indicate the means by which supplemental exhaust can be provided to meet the requirements of Construction Section 2.2. This section does not require special systems to be installed since they may be installed on a temporary basis, for example by temporarily removing windows for exhaust fans. Rather, this section requires only that the means be indicated in design documents so that it is available when the need for supplemental exhaust occurs in the future.

It is not uncommon for spaces to be temporarily exposed to strong sources of contaminants, such as during remodeling or after an accidental spill of a volatile liquid. These occurrences may be handled by temporary exhaust systems. In many cases, temporary exhaust is difficult to provide such as, in interior spaces of large buildings. To improve flexibility in future renovations, exhaust systems such as those serving toilet rooms can be designed to include additional capacity that may be manually (or automatically) invoked as needed during the building life. Smoke removal systems might also be used for this purpose if approved by the local fire district.

APPENDIX C

LOCATION OF OUTDOOR AIR INTAKES

[This section requires minimum separation distances for outdoor air intakes from known sources of contaminants adjacent to and in the vicinity of the building in order to minimize the introduction of contaminants.] Outdoor air intakes shall be located such that the distance measured from the closest point of the intake opening to the object, or point, listed in Table C1 exceeds the minimum separation distance listed in Table C1. See also Appendix D for restrictions relative to exhaust air outlets.

Exception: Shorter separation distances are acceptable if it can be shown that an equivalent rate of introduction of outdoor air contaminants will be attained using an alternative design, and if approved by the authority having jurisdiction.

The distances required in this section are minimums; in general, locating intakes as far as practical from contaminants sources reduces the likelihood of entrainment. Prevailing winds and airflow patterns around the building and building elements may also be important considerations for intake locations.

**Table C1.
Air Intake Minimum Separation Distance**

Object	Minimum Distance, m (ft)
Property line	1 (3)
Garage entry, loading area, or drive-in Queue (Note 1)	7 (25)
Driveway or street	3 (10)
Limited access highway	7 (25)
Mantels or ledges (Note 2)	1 (3)
Landscaped grade (Notes 3,4)	2 (6)
Roof or grade (Note 4)	0.25 (0.75)
Cooling Towers (Note 5)	5 (15)

Note 1: These areas are likely locations where vehicles will be paused and idling, such as while paying parking fees or waiting for traffic in the case of the garage entry, while loading or unloading materials in case of the loading area, or waiting in line for drive-in restaurant or bank service in the case of the drive-in queue.

Larger separation distances may be needed if the intake is located directly above the likely location.

Note 2: Applies to mantles or ledges that are sloped less than 45 degrees from the horizontal and that are more than 0.15 m (6 in.) wide. [Such ledges tend to become bird nesting or "resting" places.]

Note 3: Landscaped grade is soil, lawn, shrubs, or any plant life within 0.5 m (1.5 ft) horizontally of intake. [The purpose of this section is to minimize the introduction of pollen, odors and vapors from biodegrading materials, pesticides, bacteria, etc. from landscaping.]

Note 4: Intake must be at least 0.2 m (8 in.) above the average maximum snow depth at the intake.

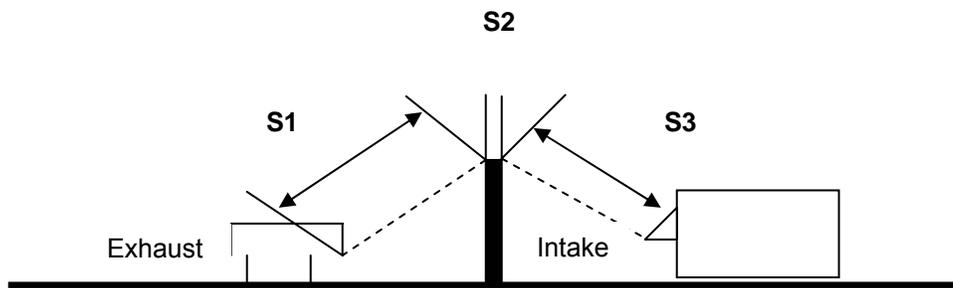
Note 5: Applies to closest wetted surface of tower, such as intake or basin. See Appendix D for separation distance from tower discharge.

APPENDIX D

LOCATION OF EXHAUST AIR AND VENT OUTLETS

Exhaust air and vent outlets shall be located no closer to property lines, outdoor air intakes, windows, and doors, both those on the subject property and those on adjacent properties, than the minimum separation distance S listed in Table D1. S is defined as the shortest "stretched string" distance measured from the closest point of the outlet opening to the closest point of the outdoor air intake opening, window or door opening, or property line along a trajectory as if a string were stretched between them. [For example, if a wall separates an intake from an exhaust as shown Th Figure D1 below the distance S is taken from the exhaust outlet in a straight line to the top of the wall over the wall then in a straight line to the intake. In this case, S-S1 + S2 + S3.1

Figure D1.



**Table D1
Exhaust Outlet Minimum Separation Distance (S), M (ft)**

Object	Exhaust Air Class (see Appendix A for definition)				
	1	2	3(Note 1)	4(Note 1)	5(Note 1)
Outdoor air intake	Equation D1	Equation D1	Equation D1 (Note 2)	Equation D1 (Note 2,6)	Equation D1 (Note 2,6)
Operable window or door (Note 3)	0.3(1)	Half of Equation D1 (Note 4)	Half of Equation D1 (Note 4)	Half of Equation D1 (Note 4, 6)	Equation D1 (Note 6)
Property line	0	1.5 (5)(Note 5)	3 (10) (Note 5)	3 (10)	5 (15)

Note 1: Laboratory exhaust air outlets shall be in compliance with NFPA 45-1992.

Note 2: Class 3, 4 and 5 air outlets that terminate in an equipment well that also encloses an outdoor air intake shall meet the requirements of Table D1 and, in addition, shall either: a) terminate at or above the highest enclosing wall and discharge air upward at a velocity exceeding 5 m/s (1000 fpm); or b) terminate 1 m (3ft) above the highest enclosing wall (with no minimum velocity). For the purpose of this section, an equipment well is an area (typically on the roof) enclosed on three or four sides by walls that are less than 75% free area, and the lesser of the length and width of the enclosure is less than 3 times the average height of the walls. The free area

of the wall is the ratio of area of the openings through the wall, such as openings between louver blades and undercuts, divided by the gross area (length times height) of the wall.

Note 3: Operable doors and windows that are required as part of a natural ventilation system shall comply with the row labeled "outdoor air intake."

Note 4: Separation distance S is one half of the requirement of Equation D1.

Note 5: For Class 2 and 3 air, where the property line abuts a street or other publicway, no minimum separation is required if exhaust termination is 3m (10 ft) above grade.

Note 6: For Class 5 exhausts located below intakes or operable windows and doors, distance S in Equation D1 shall be a horizontal separation only; no credit may be taken for any vertical separation.

Where Equation D1 is referenced in Table D1, minimum separation distance S shall be determined as:

$$S = 0.04\sqrt{Q}(\sqrt{D} - V/2) \quad (5-1a) \text{ (SI)}$$

$$S = 0.09\sqrt{Q}(\sqrt{D} - VA/400) \quad (5-1b) \text{ (IP)}$$

Where:

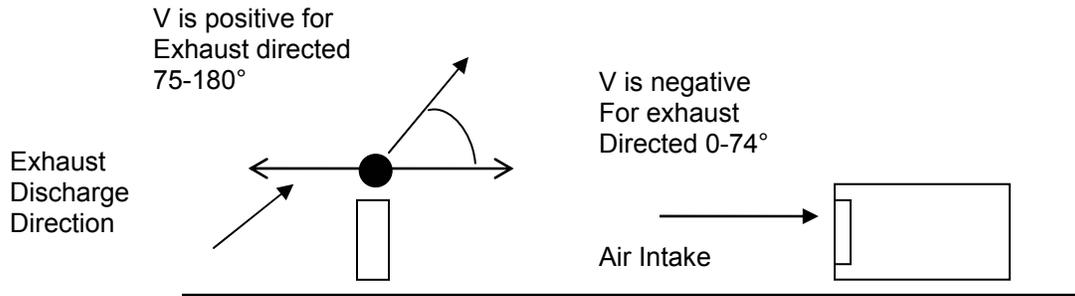
Q = Exhaust air volume, L/s (cfm). The value used in Equation D1 shall not be less than 75 L/s (150 cfm) nor exceed 1500 L/s (300 cfm) regardless of actual volume. For gravity vents such as plumbing vents, use an exhaust rate of 75 L/s (150 cfm). For flue vents from fuel burning appliances, assume a value of 0.43 L/s per kW of combustion input (250 cfm per million Btu/hr) or obtain actual rates from the combustion appliance manufacturer.

D = Dilution factor determined as a function of exhaust air class (see Appendix A) in the table below:

Exhaust Air Class	Dilution Factor, D
1	5
2	10
3	15
4	25
5	50

V = Exhaust air discharge velocity, m/s (fpm). V shall have a positive value when the exhaust is directed 75° to 180° away from the object, and shall have a negative value when the exhaust is directed 0 to 74 towards the object) as shown in Figure D2. V shall be set to 0 in Equation 5-1 for vents from gravity (atmospheric) fuel fired appliances, plumbing vents and other non-powered exhausts, or if the exhaust discharge is covered by a cap or other device that dissipates the exhaust air stream. For hot gas exhausts such as combustion products, an effective additional 2.5 m/s (500 fpm) upward velocity shall be added to the actual discharge velocity.

Figure D2.



Exceptions:

1. Shorter separation distances are acceptable if it can be shown that equivalent dilution factors will be attained using an alternative design, and if approved by the authority having jurisdiction.
2. Outdoor air intakes need not be separated from furnace vents and other fuel-fired appliance vents that are a part of a unitary or factory packaged heating/ventilating unit that is manufactured within 2 years of the publication date of this standard. This exception applies to the separation of the outdoor air intake and vent discharge of the unit itself and does not exempt maintaining separation distances from one unit to another adjacent unit. [The 2-year time delay is to allow manufacturers an opportunity to redesign and remanufacture equipment in order to meet the separation distances required by this section.]

Separation distances do not apply when exhaust system and outdoor air intake systems do not operate simultaneously.

Note that even where the required minimum separation distances are maintained, reentrainment of odors and toxic gases may still occur depending on wind conditions, building geometry, and exhaust design. An analysis of the air flow pattern around buildings and exhaust plume behavior using the methods described in the AHSRAE handbook, Fundamentals, Chapter 14 can provide more accurate information to assess the potential for reentrainment and to determine adequate separation distances.

[Equation D1 may be summarized as follows:

Class of Air	Dilution Factor D	Square Root of D (\sqrt{D})	Separation Distance At Zero Discharge Velocity		Minimum Discharge Velocity For Zero
			Minimum (75 L/s. 150 cfm)	Maximum (1500 L/s. 3000 cfm)	Separation Distance
1	5	2.24	2.5	11.0	894
2	10	3.16	3.5	15.6	1265
3	15	3.87	4.3	19.1	1549
4	25	5.00	5.5	24.6	2000
5	50	7.07	7.8	34.9	2828

Example 1: a 2000 L/s (4000 cfm) dome type exhaust fan used for toilet exhaust (class 3 air per Section 5.4.1) is located on a roof near a rooftop unit. For class 3 air the intake must be located per Equation D1. Since the exhaust fan discharge velocity is not directed away from the air intake (discharge is down to roof which then deflects out evenly in all directions), the velocity in Equation D1 is taken as zero. Since the exhaust volume exceeds 1500 L/s (3000 cfm), the value of Q in Equation D1 is taken as 1500 L/s (3000 cfm). The equation (in I-P units) is solved as:

$$S = 0.09 \sqrt{3000} (\sqrt{15-0}/400) \\ = 19 \text{ ft}$$

Example 2: Instead of a dome exhaust fan in the previous example, an up-blast exhaust fan is used. The discharge velocity as obtained from manufacturer's data is 6.5 m/s (1300 fpm). The required separation distance is now:

$$S = 0.09 \sqrt{3000} (\sqrt{15-1300}/400) \\ = 3 \text{ ft}$$

Example 3: The flue from a forced draft 880 kW (3 million Btu/hr) input natural gas boiler is located near an operable window. The discharge air quantity is approximately 380 L/s (750 cfm) assuming 0.43 L/s per kW of combustion input (250 cfm per million Btu/hr) (per definition of 0 above). The flue is terminated with a flue cap. So no credit for discharge velocity can be taken. However the flue gas is hot and buoyant and thus a 2.5 m/s (500 fpm) upward velocity may be assumed. The minimum separation distance (in SI units) is:

$$S = 0.04 \sqrt{380} (\sqrt{50-2.5}/2) \\ = 4.6 \text{ m}$$

As a Class 5 air stream, distance S becomes a horizontal separation distance (no credit for vertical separation) when the discharge is below the window (see Note 6 to Table D1).

Example 4: A rooftop AC unit has an outdoor air intake and economizer relief/exhaust outlet (class 1 air per Appendix A) configured as shown in the section below. The relief air (5000 cfm) is directed away from the intake at 2.5 m/s (500 fpm). (If the exhaust outlet distance above the roof is so small that air will be substantially deflected toward the intake, V should be assumed to be zero in Eq. D1) Since the horizontal separation is zero, the minimum separation distance S is simply the vertical distance D in the figure below. Using the maximum value of 3000 cfm in equation D1, this distance must be:

$$S = 0.09 \sqrt{3000} (\sqrt{5-500}/400) \\ = 4.9 \text{ ft}$$

This separation is required not because Class 1 air is unhealthy, but to ensure the air entering the outdoor air is primarily unventilated outdoor air. This example demonstrates that it is impractical to place the intake and discharge as shown without significant recirculation. Possible solutions: Move the intake to the opposite side of the unit; increase the discharge velocity to more than 4.5 m/s (900 fpm); or add a baffle between the intake and discharge to increase the "stretched string" separation distance.

APPENDIX E

RAIN ENTRAINMENT

Outdoor air intakes shall be protected from rain entrainment by use of one of the following:

- a. Louvers or mist-eliminators designed to limit water penetration to 3 mL per m² (0.01 oz per ft²) of free area when tested in accordance with AMCA Standard 500-1994 (15 minute test period).
- b. Rain hoods sized for no more than 5 m/s (1000 fpm) face velocity and tilted at least 45 degrees downward from the vertical.
- c. Louver or mist-eliminators in conjunction with a drain pan complying with Appendix F.

Exposed Internal insulation shall not be located within 0.5 m (1.5 ft) downstream of the air intake louver, eliminator, or screen.

[Water droplets entrained in HVAC system outdoor air inlets provide niches for microbial growth.]

These rain entrainment requirements may not be adequate to control entrainment of snow. Preheat coils with downstream filters or some other scheme may be needed to avoid snow build-up inside outdoor air intakes or on filters.

APPENDIX F

DRAINS AND DRAIN PANS

Drain pans located in supply air ducts, plenums, fan coil units, and other locations shall be sloped and trapped as required to meet the testing requirements in Appendix G. Drains located upstream of fans (those negatively pressurized relative to outdoors or those negatively pressurized to air in a mechanical equipment room) shall have traps having a depth and height differential between inlet and outlet equal to or greater than the fan design static pressure₁ or otherwise sufficient to maintain a water seal and allow complete pan drainage with fans on or off. Traps shall have a means of inspection to verify that the water seal has been maintained [such as an open or screened tee on the downstream end of the trap].¹

Condensate traps exhibit many failure modes that can impact on indoor air quality. Trap failures due to freeze-up, drying out, breakage, blockage, and/or improper installation can compromise the seal against air ingestion through the condensate drain line. Traps with insufficient height between the inlet and outlet on draw-through systems can cause the drain to back-up when the fan is on, possibly causing drain pan overflow or water droplet carryover into the duct system. The resulting moist surfaces can become sources of biological contamination. Seasonal variations, such as very dry or cold weather may adversely affect trap operation and condensate removal.

Exception: Secondary or auxiliary drain pans intended only for emergency overflow collection.

APPENDIX G

TESTING OF DRAINS AND DRAIN PANS

Drainage of pans under cooling coils, air washers, humidifiers, outdoor air intake plenums, and other duct or plenum mounted drain pans shall be tested to ensure proper slope and drainage to prevent conditions of water stagnation that result in microbial growth. Drainage shall be tested using the following procedure:

- a. Temporarily plug the drain and cover the entire pan with 13 mm (1/2 in.) water (or to the maximum allowed by the height of the pan)
- b. Start the fan if it is downstream of pan (in the draw through position). [The fan system must be in operation to test for improperly trapped drains that become air locked when the fan creates a negative pressure in the cold plenum.] Stop the fan if it is upstream of the pan (in the blow through position). [Fan operation assists in coil drainage of blow-through system so the pan must be tested with the fan off]
- c. Remove the temporary plug and observe the performance of the system. Drainage is considered acceptable when the pan drains within 3 minutes to leave puddles no more than 50 mm (2 in.) in diameter and no more than 3 mm (1/8 in.) deep.
- d. For draw-through systems, check to see that the water seal is maintained in the trap with the fan operating. Stop the fan and recheck the seal. The trap is considered acceptable if the water seal is maintained in the trap with the fan both OFF and ON. [Traps are not required by this Standard for blow-through systems since supply air leakage out of untrapped drains is not an IAQ issue. Traps can be provided to eliminate this air leakage for energy conservation purposes.]

Exception: Secondary or auxiliary drain pans intended only for emergency overflow collection need not be tested.

APPENDIX H

MINIMUM AIR CLEANING AND FILTRATION

Mechanical systems that supply air to an occupied space through supply ductwork exceeding 3 m (10 ft) in length or through a humidifier, evaporative cooler, fin-tube heating coil, or cooling coil, shall be provided with particulate filters or air cleaners having a minimum efficiency of 60% when tested in accordance with ASHARE Standard 52.2 for 3 μ m particles. [This standard is pending approval. If it has not been published before this document, the requirement will reference 25-30% efficient filter as rated by ASHRAE Standard 52.1, Atmospheric Dust Spot Method.] Filters racks shall be designed to minimize the bypass of air around the filter media or filter cartridge frames when the fan is operating. [This section is intended to reduce the accumulation in duct systems and on duct components of dirt which may become a source of microbial growth or which may clog the system and affect airflow. It is not intended to address the possible use of cleaning return air to be used in lieu of outdoor air; which is covered in Section 6.4.]

The 60% filtration for 3 μ m particles is a minimum filtration requirement but some particulate accumulation within the ventilation system can still be expected over the life of the system. Where the system design can accommodate higher efficiency levels, efficiency levels of >65% for 1-3 μ m particles will improve indoor air quality with respect to particles and will reduce particulate accumulation in air distribution systems where cleaning is often difficult. Efficiency levels >65% efficiency for particles >0.3 μ m will be most effective where potentially large concentrations of respirable particles may occur.

APENDIX I

INSULATION OF COLD SURFACES

Insulation shall be provided on the following ductwork and piping where located within the building envelope:

- a) Unlined cooling supply ductwork.

Exception:

1. Cooling ducts located within air-conditioned spaces.
2. In other than humid climates, cooling supply ductwork in return air plenums.

[The dewpoint of the return air will generally be less than the surface of the ductwork supplying air to the space. This exception does not apply to humid climates because condensation can occur due to infiltration of humid air into the ceiling plenum and during cool-down transients after moisture has built up in the space when the system was off. Note that insulation of supply ducts in plenums may be required by other codes or may be required to prevent excessive heat gain to supply air]

- b) Chilled water supply and return piping, domestic cold water piping where primary water supply can be expected to be below 13°C (55°F) during the cooling season.
- c) Domestic cold water piping where primary water supply can be expected to be below 13°C (55°F) during the cooling season.

The thickness of insulation shall be as required to prevent condensation on cold surfaces. Insulation that is subject to damage or reduction in thermal resistivity if wetted shall be enclosed with a vapor retarder sealed in accordance with manufacturer's recommendations to maintain the continuity of the barrier. Special coatings that inhibit condensation are an alternative to insulation if approved by the authority having jurisdiction.

[The purpose of this section is to prevent condensation, which may cause material damage or microbial growth in indoor spaces. This section does not consider energy usage, which is covered by ASHRAE 90.1 - 1989.]

APPENDIX J

OUTDOOR AIR INTAKE CONTROL

Variable air volume systems (except those supplying 100% outdoor air) shall include controls and devices to measure outdoor airflow at the air handler and designed to maintain outdoor airflow not less than 90% of required levels over the expected supply air operating range. [A major consideration with VAV systems is that the negative pressure behind the outdoor air intake in the mixed air plenum will typically vary with supply air volume and at low supply volumes sufficient outdoor air flow may not be maintained if a fixed outdoor air intake damper position or even if a dedicated fixed minimum air intake is used. In most cases, an active outdoor air control system must be provided to ensure minimum rates are maintained.]

Acceptable air intake measuring devices include those that measure intake volume directly by measuring air velocity through an outdoor air duct or inlet of fixed area (e.g. duct mounted pilot or hot wire anemometer) or differential pressure across a fixed orifice (e.g. wide open damper or other non-adjustable duct mounted obstruction). If the system includes an outdoor air economizer; a separate minimum outdoor air damper may also be required in order to ensure adequate velocity across the intake for an adequate measurement. Note that a fixed speed outdoor air fan without control devices will not maintain rates within the required accuracy unless the fan curve is relatively steep with respect to changes in pressure and/or if the pressure changes in the mixing plenum are relatively small compared to the fan total pressure requirement. Using return air, outdoor air, and mixed air temperatures or CO₂ concentrations to measure air intake percentage is usually inaccurate when the outdoor and indoor values are close together and thus should not be used for this application unless it can be shown to meet the >90% accuracy requirement. Similarly, measuring outdoor air by taking the difference between supply and return air flow measurements will also seldom meet the >90% accuracy requirement due to cumulative errors in air flow measurement and the generally small outdoor air flow rate relative to supply and return air flow rates.

APPENDIX K

PRE-OCCUPANCY OPERATION

Ventilation systems shall be operated prior to the time any space served is expected to be occupied for a period of time determined in accordance with the requirement specified below and documented in the ventilation system design documentation (see Design Section 2.18).

Ventilation systems shall include either manual or automatic on/off controls that allow the fan system to operate whenever the spaces served are occupied. When thermostats used to control heating or cooling for systems that also supply required ventilation air include a manual switch accessible to untrained personnel that allows the fan to operate only upon calls for heating or cooling, controls shall be included to ensure the hourly average outdoor air supply rate and overall supply air rate are maintained. [Thermostats often have an "auto" position on the thermostat or subbase fan switch that cycles the fan only when heating or cooling is required. When the fan system also supplies ventilation outdoor air, this causes air supply to be discontinuous. Since many untrained people do not understand this, the switch is often placed in the "auto" position, resulting in inadequate ventilation.]

To comply with this section, the thermostat may be provided without an "auto" position, or with the control sequence in the "auto" position modified in a manner that either operates the fan on a continuous basis when the space is expected to be occupied or that activates a time or other device to ensure that hourly average supply air and outdoor air rates are maintained. Systems operated in this manner must be capable of supply more than minimum rates when the system is on in order to compensate for the time the system is allowed to cycle off.

In general, to comply with this section, programmable timeclock thermostats must be capable of operating the fan on the time schedule rather than simply changing setpoints on a time schedule. Note that many residential thermostats do not have this capability.

APPENDIX L

ISOLATION OF MAJOR CONSTRUCTION AREAS

Spaces of an occupied building that are undergoing major construction, renovation, or remedial work that become a temporary but significant source of indoor air contaminants (term "construction areas" hereinafter) shall be isolated from directly adjacent non-construction areas using temporary walls, plastic sheeting, or other vapor retarding barriers. These construction areas shall be maintained at a negative pressure relative to the adjacent non-construction areas by either exhausting construction areas and/or pressurizing adjacent areas. Recirculating return air ducts from construction area shall be temporarily capped and sealed to prevent the spread of contaminants to occupied areas served by the same system. Where particles are the only contaminant of concern, in lieu of capping off return ducts, return air shall be filtered as required to reduce particles with mean diameters less than 10 μm (PM_{10}) to concentrations below those listed in table 5-1. For the purposes of this section, major construction areas within a building undergoing construction activities that require the temporary displacement of occupants for more than 48 hours, or new construction where spaces are newly completed (no former occupants). [This definition is intended to include major tenant work such as complete remodels plus major revisions that include demolishing or finishing drywall partitions, installation of new furnishings and carpeting. Minor touch-up painting and replacement of a small area of carpet are not considered significant contaminant sources.]

These requirements are also applicable to any other construction or installation of materials that generate significant contaminants. Contaminant concentrations within the construction zone itself are covered by applicable construction workplace standards from ACGIH, OSHA, or other local authority. Refer also to IAQ Guidelines for Occupied Buildings under Construction (SMACNA, 1995a).

APPENDIX M

PURGING OF MAJOR CONSTRUCTION AREAS

After construction is complete, major construction areas, as defined in Appendix L, shall be purged by supplying or exhausting no less than the design outdoor air rate required by Section 6 for a period of no less than 48 hours before occupancy. When spaces are exhausted, make-up air may be drawn from adjacent non-construction spaces rather than the outdoors. The requirements of Appendix L, pressurization relationships to adjacent spaces, shall apply until the 48-hour period is complete.

Exception: If it can be demonstrated that an alternative ventilation scheme can provide similar results and if approved by the authority having jurisdiction.

These procedures are also suitable for any other construction or installation of materials that generate significant contaminants. Depending on the new materials in the space and the rate at which they off-gas, a shorter or longer purge period may be required. When ambient conditions and the HVAC system design permit. The effectiveness of the purge, can be enhanced by ventilating spaces at rates far exceeding minimum ventilation rates.