IAQ Indoor Air Quality

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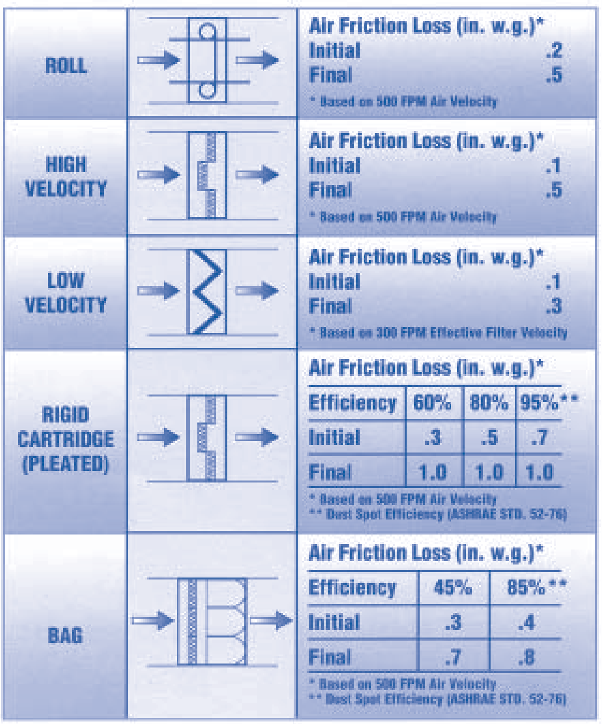
12 The proposed performance rating method for air filterswill identify the effectiveness of the filter with the particle size that is appropriate to that type of filter. Low effectiveness filters will be tested with coarse dust, medium effectiveness filters with 1 to 3 micron dust, and high-efficiency filters with 0.3 to 1 micron dust. The 2" thickness pleated media panel filters that are used in commercial buildings constructed on a tight budget will fall into one of the low classifications; the 65% efficiency bag and cartridge filters that are used in median-budget commercial applications will fall into one of the medium classifications; and the 90% efficiency box



12. Media Filter Styles and Pressure Drops filters that are used in hospitals and high-budget commercial applications will fall into one of the high effectiveness classifications.

Higher efficiency medias have greater pressure drops, and the pressure drop increases substantially as the media becomes dirty (Figure 12). The pressure drop is also related to the area of media exposed to airflow. Increasing the airway depth of the filter by pleating the media or arranging the media as a bag extending downstream provides a larger media surface in a much smaller crosssectional area filter. The useful life of the filter is limited by the maximum pressure drop which can be tolerated, usually between 1.0 and 1.5 in. w.g. The dirt holding capacity identifies how much dirt can be captured before the pressure drop reaches the maximum value. A filter with a larger media area usually has a greater dirt holding capacity and therefore, a longer life.

The selection of a media-type filter bank consists of first choosing the type of media that will capture the desired particle size effectively at an acceptable air friction loss, and then optimizing the area of media to fit within the available space and provide a reasonable balance of initial cost, useful life, and fan energy consumption.

As mentioned previously, the growth of microorganisms is promoted by dust, moisture, and warm temperatures. It is limited by lack of food and water. Good filtration can remove the dust, dirt, and lint that provide food for microorganisms. In addition, good filtration reduces building cleaning and redecorating costs and high-efficiency filters reduce the spread of communicable diseases caused by bacteria and viruses.

Filtration really functions as a dilution process of the air in the conditioned space. Contaminated room air is diluted with a fresh supply of air that has had specific particles removed by the air filters. The mixture of supply and room air is returned to the air handler to be filtered again. The goal is to reduce particle contaminants in the space to an acceptable level. Where high levels of specific particulates are involved, the filtration must be appropriate for removal of the specific contaminant. Particulate filters or gaseous treatment devices can be located in the outdoor air stream, the return air stream, the mixture of outdoor and return air, or as separate re circulating systems within the occupied spaces.

Depending upon the source of the contaminant and the outdoor climate, it may be more practical to use 100% outdoor air to control a contaminant that cannot be easily removed from return air, or to use minimum outdoor airflow at all times where the outdoor air must be treated to make it acceptable for use.

Ventilation Standards

As part of the normal, physiological process called *respiration*, human beings remove oxygen from the air they inhale and add carbon dioxide to the air they exhale. The rate at which this takes place depends upon the degree of physical activity. The greater the exertion, the greater the rate of oxygen uptake and carbon dioxide rejection. About 3 to 5 CFM of outdoor air per person is required to provide the oxygen needed at activity levels normally encountered in comfort commercial applications.

A person's respiration and metabolic efficiency is subject to gas concentration. Inadequate indoor air quality strategies may result in excess carbon dioxide levels. Above about 1,000 parts per million (PP M) , drowsiness, headaches, and impaired concentration levels are observed. Based on average occupancy and activity levels, and typical outdoor air CO_2 levels, about 15 CFM of outdoor air is required for each person in order to maintain indoor air CO_2 at 1,000 PPM or less. This is the origin of the current recommended ventilation rates of 15 to 20 CFM per person. Earlier ventilation standards of 5 to 7.5 CFM per person, which were practiced in the late 1970s and throughout the 80s, were based on oxygen makeup.

It is important to remember that even where outdoor air is very polluted, it still contains one component essential for life and health, oxygen. The oxygen consumed by people within the conditioned space must be replenished at an adequate rate.

Other Contaminants

Where the outdoor airflow rate is determined by the above ventilation standards, it is assumed that the level of other contaminants in the outdoor air is sufficiently low to prevent excess concentrations within the building. The quality of the outdoor air is monitored and reported by state or local EPA agencies. Their reports, or site specific monitoring, are used to determine whether the outdoor air is suitable for use without being treated to remove specific contaminants. Where outdoor air treatment is needed, it is usually necessary to remove gaseous contaminants, primarily vehicular traffic or industrial fumes.

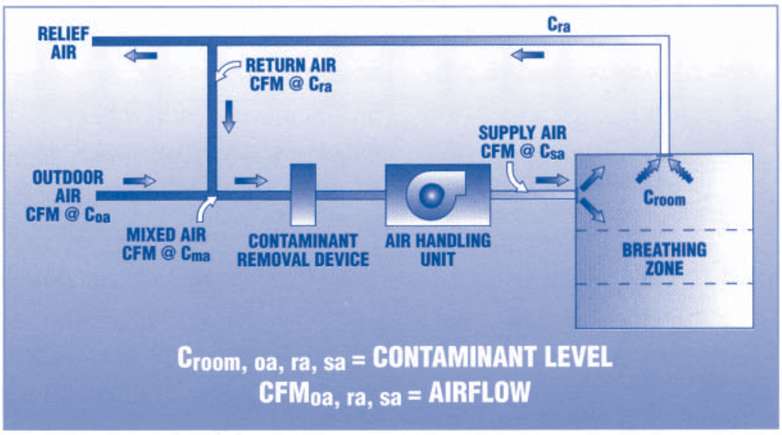
Example: ***A building is located at a heavily traveled freeway intersection and the outdoor air is contaminated with auto and truck engine fumes. Bringing in additional ventilation air will not eliminate the fumes. The ventilation airflow should be kept to a reasonable minimum amount. Chemical treatment should be used to control the fumes in the ventilation air.***

Contaminant Concentration Level - O.A. Dilution Example

13 Figure 13 shows the dilution process for a simple HVAC system.

The contaminant removal device can be a filter (mechanical) or a gaseous treatment device (chemical). The contaminant level in the mixed air entering the contaminant removal device is found using the mixed air formula:

$$C_{ma} = (\%OA \times C_{oa}) + (\%RA \times C_{ra})$$



13. Contaminant Dilution

Where:

C = contaminant concentration

oa = outdoor air

ra = return air

ma = mixture of outdoor and return air

The contaminant level in the supply air leaving the contaminant removal device is determined by the contaminant removal effectiveness of the device:

$$C_{sa} = C_{ma} \times (1 - \text{effectiveness})$$

Where:

sa = supply air

14 The average contaminant concentration in the room is determined by the rate at which the local room contaminant is released, and the flow rate and concentration level of the supply air:

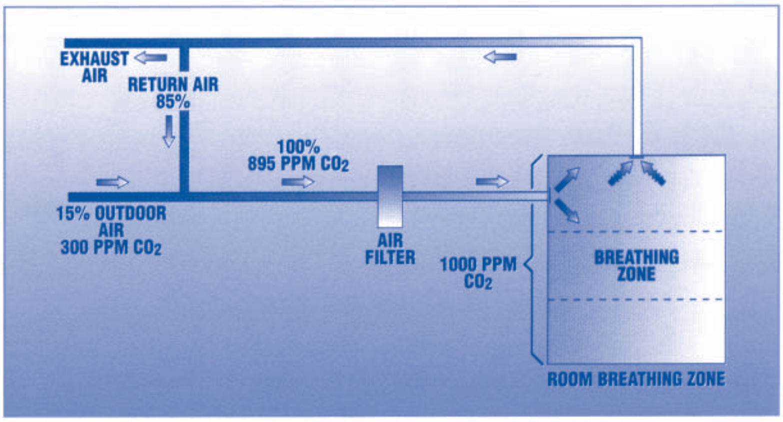
$$C_{rm} = C_{sa} + (\text{contaminant release rate/ supply flow rate})$$

Where:

rm = room

sa = supply air

Example: To illustrate the use of the mixed air formula and how outdoor air can be used to dilute a contaminant, consider an air system which includes an IAQ control loop. It mixes outdoor and return air to ensure that indoor CO_2 levels do not exceed a userselectable CO_2 concentration; let's say 1,000 PPM.



14. Contaminant Dilution Example

Let's assume the space is presently at 1,000 PPM CO_2, If the outdoor air CO_2 concentration is only 300 PPM and 15% outdoor air is used, then the mixed air concentration, which will go to the space without further removal is:

$$C_{ma} = (\%OA \times C_{oa}) + (\%RA \times C_{ra})$$
$$= (.15 \times 300) + (.85 \times 1{,}000)$$
$$= 895 \text{ PPM}$$

This means that the air supplied to the space has the capability of absorbing 105 PPM of contaminant before it reaches the design concentration limit. The concentration of the contaminant is diluted by the outdoor air, which is less contaminated by CO_2 than room air. In this example, more outdoor air will increase the dilution of CO_2, and less will decrease the dilution of CO_2, Any increase in outdoor air CO_2 concentration will require a higher ventilation rate to accomplish the same dilution rate.

Likewise, any increase in the contaminant (CO_2) generation rate within the space will require a higher ventilation rate.

When outdoor air CO_2 concentration becomes equal to or greater than indoor air concentration, the outdoor air will no longer dilute the contaminant indoors. Then the minimum outdoor air should be introduced and the outdoor air, or mixed air, sent through a gaseous treatment device to reduce the contaminant to the desired concentration.

The above dilution calculations form a closed loop which is best solved by iterative calculation. This procedure and the appropriate formulas covering many other variations are provided in ASHRAE Standard 62.

The return air contaminant level will be the same as the room contaminant level if the supply air is mixed uniformly in the room. Otherwise, the breathing zone contaminant level can be considerably higher. The return air contaminant level will approach the supply air contaminant level if the supply air bypasses the breathing zone.

15 The concept of "ventilation effectiveness" is used by ASHRAE to rationalize the importance of good room air diffusion, and the fact that ventilation air is not useful unless it is properly distributed to the breathing zone. The "breathing zone" can be a small portion of the conditioned space in a building with high ceilings.

Example: An exterior office with 9' ceilings has air supplied through low induction, horizontal pattern ceiling diffusers and air returned through the ceiling plenum. When the supply air is warm during winter operation, it will tend to short circuit into the ceiling plenum, bypassing the 4' to 6' high breathing zone, as shown in Figure 15.

This situation can be corrected by relocating the return air to the floor level, or by relocating the supply air to under the window. Use of a vertical projection supply diffuser with a high induction ratio would improve the ventilation air penetration into the breathing zone.

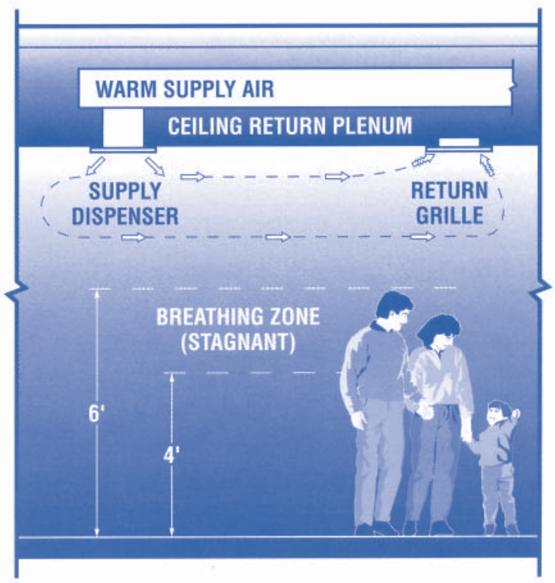
CONTAMINANT CONTROL OPTIMIZATION

In summary, the contaminant control process is optimized by adjustment of the many variables that are involved:

- Local exhaust
- Air treatment device effectiveness and location
- Outdoor airflow rate
- Supply airflow rate

HVAC Design for IAQ

Now that TEQ, IEQ, and IAQ have been defined, responsibility for IAQ established, common causes and solutions for IAQ problems presented, and contaminant control discussed, we will look more closely at the industry standard for acceptable IAQ.



15. Ventilation Air Can Bypass Breathing Zone

ASHRAE 62-1989

ASHRAE 62-1989 is the current industry standard relating to IAQ. It identifies system design procedures which may be used by a prudent engineer to minimize the possibility of inadequate contaminant control. Building construction codes are gradually being modified to include some or all of these items. The starting point for improving

HVAC system design from an IAQ viewpoint is to become familiar with this standard, which can be obtained from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329, phone: 1-800-527-4723.

The provisions of ASHRAE 62 require careful study and interpretation. Many official interpretations of specific provisions have been published by ASHRAE. Specific interpretations can be obtained from ASHRAE by members for any additional issues which require clarification. This Engineering Guide is not intended to be a substitute for ASHRAE 62, but is intended to provide supplemental information and suggestions that will help the designer meet or exceed the IAQ requirements of the current building. Comments made in this guide regarding the standard represent our current opinions regarding specific ASHRAE Standard 62 provisions. They should not be construed to represent the policy or official interpretation of ASHRAE.

ASHRAE 62 and the building construction codes relating to IAQ will probably be revised periodically, as better data becomes available, until a reasonable balance is obtained between the cost and benefits of improved IAQ. Perfect IAQ, if it were obtainable, would be prohibitively costly while poor IAQ is unacceptably costly to our health. The HVAC designer must become aware of the cause/effect relationships of various IAQ problems and solutions so that the design process can keep up with changing requirements. At all times, it is prudent to treat the code requirements as minimum requirements, to minimize the possibility of expensive alterations early in the building life.

ASHRAE 62 identifies a number of issues to be addressed during the HVAC design process. Failure to properly address any of these items may be construed as inadequate design, regardless of whether the standard is referenced in the applicable construction code. Before beginning a design, the designer should become familiar with the standard in its entirety. The following comments on selected excerpts from Chapter 5 of the standard are intended to stimulate this familiarization. It is essential to distinguish between "shall" and "should" in the various recommendations.

"5.1 ...provision for airflow measurement should be included."

The technology to monitor ventilation airflow is available. The proper ventilation airflow rate is more likely to be provided if provision is made to measure the airflow and compare actual to design CFM, displaying this information conveniently.

"5.2 The design documentation shall state assumptions... "

Documentation is mandatory. Failure to properly document the design assumptions is evidence of inadequate design.

"5.4 When the supply of air is reduced (VA V systems) ...provision shall be made to maintain acceptable indoor air quality... "

The recommended ventilation flow must

be provided when the airflow is at the lowest rate that will occur during occupancy of the space.

"5.5 ...Makeup air inlets and exhaust air outlets shall be located to avoid contamination of the makeup air."

The HVAC designer is responsible for coordinating the locations of air inlets and exhaust air outlets to obtain the best protection against all identifiable hazards, including re circulation of exhaust air.

"5.6 Ventilating ducts and plenums shall be constructed and maintained to minimize the opportunity for growth and dissemination of microorganisms... "

Although the methods are not specified, possible methods include limiting the use of duct liner to essential areas, use of duct liner treated with biocide, protection of internal insulation against water damage from cooling coil carryover or maintenance activities, providing duct lining with smooth surfaces that can be more easily cleaned, and installing acoustical lining in large plenums with access for inspection, cleaning, and/or replacement of the lining.

"5.9 ...Air filters and dust collectors shall be selected for the particle size and loading encountered... "

The designer must identify whether the primary purpose of the filter is to protect the HVAC equipment, the building occupants, or a manufacturing process. The filter selection must be appropriate to that purpose.

"5.10 When compliance with this section does not provide adequate control of gaseous contaminants...other scientifically proven technology shall be used. "

The designer must provide treatment for gaseous contaminants if they are present and if they will not be controlled by dilution with untreated ventilation air.

"5.12 ...Air handling unit condensate pans shall be designed for self-drainage... Provision shall be made for periodic in-situ cleaning of cooling coils and condensate pans. Air handling and fan coil units shall be easily accessible for inspection and preventative maintenance... "

These measures are intended to prevent microbiological contamination that may result in Legionnaires disease or other human health hazards. Most of the responsibility for the first two items belongs to the equipment manufacturer. However, the designer has primary responsibility for accessibility for inspection and maintenance, especially in the case of equipment located in ceiling plenums and on roofs.

Chapter 6 of ASHRAE 62 offers the choice of two procedures to determine the appropriate ventilation air quantity. The Ventilation Rate Procedure is a prescriptive method which is appropriate for most designers and most projects. The Indoor Air Quality Procedure is a performance method which can be used by sophisticated designers to provide optimum cost/performance solutions, especially for projects with unusual IAQ situations. This discussion is limited to the Ventilation Rate Procedure. Regardless of which procedure is used, the design must also meet the requirements of Chapter 5.

HVAC SYSTEM SELECTION CONSIDERATIONS

16 Assuming that indoor contaminants are properly controlled at their source, the ability of the air handling system to flush the remaining contaminants out of the building is the major IAQ difference between one system and another. Figure 16 summarizes some system choices that make good IAQ more certain.

Constant-volume systems are simpler to design and analyze than VAV systems. Special design procedures and automatic controls for VAV systems are necessary to overcome the reduced flushing that is inherent to VAV systems. The design and commissioning of these elements must be properly executed if a VAV system is to be successful with respect to IAQ.

Many IAQ problems are related to high building humidity. Large central systems, especially those served from chilled water systems, can be designed to handle large percentages of outdoor air for ventilation or exhaust air makeup, and to control the building humidity under both design load and part-load conditions. Because these systems are customdesigned for the specific project, the cooling coils can be custom-sized for proper dehumidification. Control strategies such as face and bypass damper cooling coil control and/or reheat can be employed to maintain a cold coil surface for proper dehumidification under almost all operating conditions. Small, direct expansion factory-packaged systems usually have a single compressor, which is cycled on and off to control the room temperature. The cooling coil warms up during the compressor "off" cycle, with evaporation of the moisture on the coil fins back into the supply air to the room and loss of dehumidification until the compressor is restarted and the coil surface becomes cold again. Oversizing such systems only aggravates this problem in humid climates. Larger directexpansion equipment with multiple compressors, unloaders, compressor speed control, hot gas bypass, and face split cooling coils provides better humidity control, but will still require face and bypass or reheat for good humidity control under severe conditions. Some local codes may restrict the use of reheat control strategies. Check your local code.

The location of equipment is significant. Many IAQ problems are the result of poor maintenance, which is often related to the unit location. Air handling equipment located in mechanical rooms is most convenient for proper service when it is required. Floor-mounted equipment is much more convenient than equipment suspended from the ceiling. Equipment located in ceiling plenums is generally less

- **Constant-Volume Easiest to Design and Control**
- **Humidity Control Easiest with Built-Up System**
- **Floor-Mount, Equipment Room AHU Facilitates Necessary Maintenance**
- **Fewer, Central AHUs Facilitate Necessary Maintenance**
- **Select AHU with Adequate Filters and Fan(s)**

16. HVAC System Choices for Good IAQ

convenient than other ceiling-mounted equipment, because of difficult access to the ceiling space and disturbance to building occupants in the immediate area. Equipment located on roofs is more difficult to service if there is no elevator access to the roof level.

Equipment that is located indoors, protected from the heat and weather, is more likely to be maintained properly. Maintenance work can be performed better and quicker if the outdoor weather is not involved.

Usually, multiplicity of equipment is a factor in maintenance. A single, large central air handling system is easier to maintain than ten smaller units with the same total capacity. The smaller units may not be arranged as conveniently for maintenance, and the same maintenance procedure must be repeated many times.

HVAC EQUIPMENT DESIGN CONSIDERATIONS

HVAC equipment is designed to serve specific market segments. The design features that relate to superior IAQ performance include the provisions for high-efficiency filtration/air treatment, automatic controls, and equipment cleanliness. These items are generally not emphasized in the design of a specific product unless they are identified as necessary for the intended market.

Air Filtration and Fans

17 The type of air filter influences the physical size of the air handling equipment, and the air pressure drop that the fan must overcome. The fans in residential equipment and small chilled water and packaged direct-expansion units are not suitable for the high pressure drops that are associated with medium or high efficiency media-type filters. Retrofitting them with these filters will compromise the air delivery, efficiency, and life expectancy of these products. On the other hand, electronic air cleaners have a low pressure drop which is relatively independent of dirt loading, making them suitable for use with the fans of any type of equipment. Some electronic air cleaners include a media-type filter downstream of the electronic collector cells, making this type of filter subject to the same limitations as media-type filters.

Systems designed to deliver constant volume, which use forwardcurved fans, usually experience a significant reduction in airflow as the filters become loaded with dirt. The first column in the tabulation in Figure 17 shows the pressure drop that will occur at design airflow with a wet coil and dirty filters. This is the fan selection point. The air handler must deliver a total of 2.3 in. w.g. static pressure at 10,000 CFM to offset the friction loss of the system when the filters are loaded and the cooling coil is wet. The next column illustrates how much less static pressure is required at design airflow when the filters are clean and the cooling coil is dry. The system resistance is only 1.29 in. w.g., a 44% reduction from the design estimate. As a result, the fan brake horsepower (BHP) is only 4.40, down 37% from the design estimate of 7.0 BHP.

When a constant-volume system is designed, installed, and set to offset the resistance of the system with a wet coil and dirty filters (column 1), the CFM will climb when the filters are clean and the cooling coil is dry. The third column demonstrates this result for a forward-curved fan. The CFM is now 12,500, 125% of design. The fan rpm is assumed to be constant.

AIR SYSTEM PRESSURE DROPS (in. w.g.)

	1 DESIGN 10,000 CFM WET COIL DIRTY FILTERS	2 WINTER 10,000 CFM DRY COIL CLEAN FILTERS	3 12,500 CFM DRY COIL CLEAN FILTERS
FILTERS	1.00"	0.24"	0.38"
SUPPLY & RETURN SYSTEMS	0.60"	0.60"	0.94"
HEATING COIL	0.10"	0.10"	0.16"
COOLING COIL	0.60"	0.35"	0.55"
TOTAL STATIC PRESSURE	2.30"	1.29"	2.03"
BHP	7.00 BHP	4.40 BHP	8.60 BHP

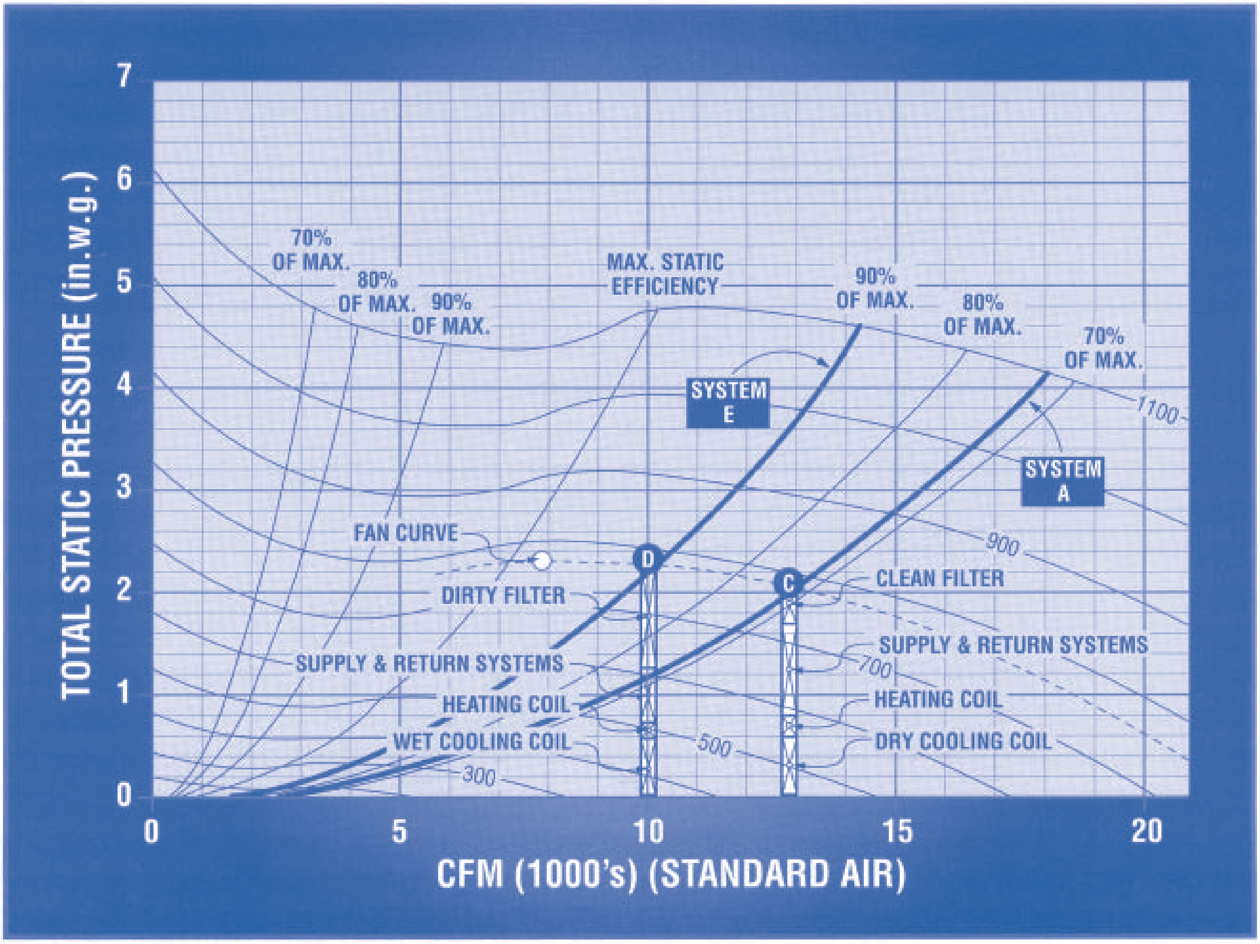
17. Air Filtration and Fans

The resulting total static pressure is 2,03 in. w.g., up substantially from the pressure loss at design airflow (1.29 in. w.g.). Most notable is the jump in fan brake horsepower. At 8.6, it is almost double the horsepower for the same air system conditions at 10,000 CFM (4.40 BHP), and even higher than the design estimate with wet coil and dirty filters (7.0 BHP).

Even though the system static pressure makes this example best suited to a forward-curved fan, let's compare the results of column 3 for a backward-curved or airfoil fan. The CFM increase for a backward-curved or airfoil fan is substantially lower than that for our forward-curved example. Furthermore, since the backward-curved or airfoil fan is "non-overloading," the brake horsepower will be relatively constant, regardless of filter or coil conditions. This makes it less sensitive to air system pressure fluctuations than a forward-curved fan.

18 The air system design point, identified in column 1 of Figure 17, is represented on the fan curve, shown in Figure 18, as point D (for "design" or "dirty"). The condition identified in column 3 of Figure 17 is represented on the fan curve as point C (for "clean"). The air system resistance contributed by each component is shown at each condition, which illustrates the component values in columns 1 and 3 of Figure 17.

DIRTY VS. CLEAN FILTERS



18. Fan Airflow Change

The fan selection point (point D) identifies the fan performance curve at a constant speed, shown in Figure 18 at about 770 RPM. The estimated system resistance curve is labeled as curve E. Plotting the system resistance curve with dry coil and clean filters (curve A) identifies the intersection of the clean/dry system curve with the fan curve, showing a 25% increase in airflow due to the changes in filter and cooling coil pressure drops.

Systems in which the pressure variation between clean and dirty filters is large in proportion to the total system pressure can be provided with pressure control dampers or variable speed drives to compensate for the change in ffiter pressure drop. On large systems, the savings in fan energy may justify a fan pressure control.

Where gaseous treatment is provided, the pressure drop of the treatment media must also be overcome by the air handling equipment fan. Pressure drop for gaseous treatment media is significantly higher than standard media filters, but is usually relatively constant if an adequate particulate filter is installed upstream. Combination particulate and gaseous treatment medias are available, which impose the same pressure drop limitations as media-type particulate ffiters.

Assuming that the air handling equipment fan is suitable for the air pressure drop through the filters, sufficient space must be available for filter installation and servicing/ replacement. With media-type ffiters, the life cycle cost of filtration will generally be lower if the ffiter area is increased so that the airflow is at the low end of the published range. A typical 24" x 24" panel filter bank rated for use between 1,200 and 2,000 CFM per filter will be more economical at less than 1,500 CFM per filter. Therefore, in the best interest of both IAQ and operating cost, filter sections should be generously sized and adequate servicing space must be provided for routine ffiter changes.

Where high-efficiency filtration is provided, the filters must be installed in properly sealed frames to prevent bypass of air through cracks between or around the filters. A system with individual gasketed frames for each filter, in which the ffiters are installed and replaced from a plenum on the upstream side of the filter bank, will provide the best longterm performance. Side access filter sections can be provided with gaskets above, below, and between ffiters, but the gaskets must be maintained and replaced when necessary to prevent air bypass.

With conventional draw-through fan arrangements, dirt-laden air can leak into the air handling equipment through improperly sealed casing joints, access doors, coil piping penetrations, and other openings downstream of the filters, especially if the equipment is at a large negative pressure with respect to the surrounding areas. Where filtration effectiveness is critical, such as pharmaceutical or computer chip manufacturing clean rooms, all areas downstream of the filters should be kept at a positive pressure by the use of blow-through fan arrangements.

Packaged air handling equipment may be limited to offering a 2" track to accommodate a certain number and size of ffiters. With such units, the IAQ potential is limited to identifying the best performing filter that will fit the available tracks. Central station air handlers and other equipment intended for more sophisticated markets will generally have a choice of several accessory filter options, including medium-efficiency cartridge and bag-type media ffiters from 6" to 24" in airway length. Customfabricated equipment may be engineered to accommodate any desired filtration/ gaseous treatment device.

Where the desired filtration provision is not available as part of the factory-manufactured air handling equipment, the filtration equipment can be field-engineered and assembled to mate with the inlet (and outlet, if downstream) of the air handling equipment. This is a common approach with ultra highefficiency filtration systems for clean rooms and laboratories, and is also the most popular arrangement for residential systems with electronic air cleaners.

Automatic Controls

For humidity control, the air handling equipment may require special arrangements or accessories such as face and bypass dampers, hot gas, or reheat coils. Provision must be made for field installations where factory-installed items are not available.

Automatic control systems are an integral part of the factory-engineered equipment on many projects. These controls work very well on applications for which they are intended, but may be very difficult to modify for unusual humidity or ventilation air control requirements. However, as direct digital control products become more versatile, modification may be as simple as reconfiguring the controls through a local interface device.

Equipment Cleanliness

The design of factory-fabricated air handling equipment varies considerably with respect to cleanability and access for general maintenance. The arrangement and construction of the condensate drain pan is significant in preventing the growth of microorganisms in water left standing within the unit. The drain pan should be sufficiently sloped to provide positive and complete drainage. The preferred construction is easily cleanable, non-corrosive material, such as stainless steel or plastic. The height of the condensate drain pan connection must be sufficient to permit drainage from the pan and to install the necessary trap in the condensate drainage piping.

The exterior casing of most air handling units is insulated to prevent heat transmission and moisture condensation, and to minimize sound transmission from the fan. Exposed insulation in areas where internal equipment components must be serviced should be protected against damage by the servicing workers. In theory, dirt accumulation should never be a problem on insulation that is downstream of a proper filter bank; but where exposed fibrous insulation is used, the lining materials should be selected for durability and cleanability. Many duct lining materials are available with factory-applied biocidal treatment to inhibit the growth of organisms. Exposed casing insulation must be prevented from becoming wet from moisture leaking or being blown from the cooling coils or drain pans, and should be protected from dirt accumulation.

Foil-faced foam insulation minimizes the potential for dirt and moisture accumulation, and can be cleaned more easily than fibrous insulation. Encapsulation of foam or fibrous insulation between the inner and outer metal layers of double-wall construction provides the best insulation protection, but eliminates sound absorption benefits. An extreme example of providing sound absorption and cleanability is to provide air handling equipment with solid inner casing liner, acoustical plenums at the inlet and outlet of the air handling unit and externally insulated metal air distribution systems with clean out doors. The acoustical plenums should also be arranged with access so that the acoustical lining material can be easily inspected, and cleaned or replaced when necessary.

SUGGESTED IAQ DESIGN SEQUENCE

A comprehensive set of checklists and master specifications is invaluable for design engineers, especially where the design work may be done at different times by different individuals, and where some of the individuals may not be as experienced as others. The following checklist is therefore suggested for designers who have not established their own IAQ design procedures. The "Section" and "Table" references in this text are from ASHRAE 62-1989.

19 Figure 19 shows a typical use of the checklist for a simple office building project.

Step 1: Begin documentation at the start of the project.

Step 2: Identify the project expectations and budgetary limitations.

IAQ DESIGN CHECKLIST

Project: ABC Office Building **Engineer:** WSO

Date	Design Element and Action Taken
10/2/96	IAQ level of expectations for project: Class A Rental Building
10/2/96	Outdoor air based on (ventilation rate or indoor air quality) procedure
10/14/96	Outdoor air quality verified: OK — '92 DNR Monitoring
10/14/96	Ventilation rates established per ASHRAE 62, Table 2: Yes
10/14/96	Areas with special ventilation rates: Conference rooms Cannot be identified until tenant work. Training rooms Cannot be identified until tenant work. Other No
10/14/96	Spaces requiring special exhaust: Tenant work
10/14/96	Type of filtration: 65% dust spot — 12" cartridge
10/14/96	Gaseous treatment necessary? No
10/14/96	Ventilation rate corrected for: Multiple spaces on common system: Yes VAV minimum airflow: Yes — 40% minimum Ventilation/diffusion effectiveness: Yes — 90% efficiency
11/12/96	Air intake/exhaust location to minimize contamination? OK
11/12/96	Outdoor air sufficient to pressurize building? OK
11/12/96	Proper system type/controls for normal operating conditions? Standard VAV System and control OK.
12/10/96	Ventilation flow measurement/control specified? Yes
12/10/96	Building contaminant levels measurement/control specified? No
10/14/96	Adequate space/access for equipment maintenance? Fan room space OK; AHU spec. with service plenums and access doors.
12/10/96	Appropriate commissioning procedures specified? Standard spec.
12/10/96	Appropriate operating/maintenance information specified? Standard spec.
12/10/96	IAQ design and documentation complete? OK for building shell design. Must check for special vent areas under tenant design contract.

19. Typical IAQ Checklist

20 The project criteria may justify exceeding the minimum requirements. If so, identify the level of performance that is expected. A simple approach is to initiate a form letter as shown in Figure 20 to the project director andlor client, stating the assumptions that will be made unless additional requirements are inade known.

SAMPLE DESIGN CRITERIA LETTER

To: ___________________________, Project Manager

Re: Indoor Air Quality Requirements

Our design services for this product include items related to Indoor Air Quality that are the responsibility of the HVAC system designer. Unless you direct otherwise, our design and the project HVAC budget will include the recommended ventilation air quantity and other requirements of ASHRAE Standard 62-1989, in addition to the codes that are applicable to this project.

Your assistance with the following specific items will minimize the possibility of IAQ problems that might be time consuming and expensive to correct.

1. The intended usage of the individual spaces must be properly identified before the HVAC systems are designed. Spaces such as conference and training rooms require additional ventilation. Spacfjs with odors or significant contaminants, such as food preparation areas, photographic labs, or other areas using chemicals must be provided with exhaust systems. Spaces that are not properly identified may have to be redesigned later at additional expense and delay.

2. HVAC equipment must be located where it can be properly maintained, and adequate space must be provided for maintenance. We will recommend equipment locations with recommendations regarding maintenance and access requirements, as soon as the equipment sizes are identified.

3. Ventilation air inlets must be located to minimize contamination of the ventilation air by exhaust air discharges, cooling towers, and boiler and incinerator flues. We will work with you to coordinate these items.

4. Building materials, carpets, and furnishings can be significant sources of chemical vapors. We recommend that your specifications limit contamination from these items.

5. The project construction schedule must allow time for the HVAC systems to be commissioned and adequate time for the building to be cleaned and flushed of contaminants before occupancy. Special precautions are necessary to prevent the spread of contaminants from construction areas to occupied areas, if the building is to be partially occupied before all construction work is complete.

Your cooperation regrading these IAQ items will be greatly appreciated.

20. Sample Design Letter

Step 3: Verify the outdoor air quality.

Follow the procedure described in Section 6.1.1. If the outdoor air quality is unacceptable, identify the treatment that will be used to reduce the contamination to acceptable levels.

Step 4: Identify the general building ventilating requirements.

The proposed general use of the building must be identified. Table 2 of ASHRAE 62-1989 provides recommended minimum requirements for the various areas.

Step 5: Identify spaces with special ventilation requirements.

Areas to look for include auditoriums, conference rooms, and training rooms that will have higher density occupancy for periods of more than a few hours. Section 6.1.3.4 provides guidance for intermittent or shortterm occupancy.

Step 6: Identify spaces that justify local exhaust systems or contaminant control.

Look for food preparation and service areas, and smoking lounges. The release of fumes, such as from electric welding equipment; chemicals, such as from photographic developing equipment; or infectious biological agents, such as in hospital isolation rooms, must also be prevented from contaminating other areas.

This is done by capturing the contaminants at the point of generation with hoods and exhaust systems, or by enclosing the contaminated area and maintaining it at a negative pressure with respect to the surrounding uncontaminated areas. Depending upon the effectiveness of local hoods and exhaust systems, air from these areas should not be returned to a central system serving uncontaminated areas.

Step 7: Select the type and efficiency of particulate filters or the gaseous treatment device that will be used to remove the contaminants which are likely to exist in the outdoor and return air. Identify whether separate or common systems will be used to remove contaminants from the outdoor air and the return air.

Step 8: Identify the spaces that will be served by common air handling systems. If the spaces identified in item 5 are not served by separate systems, or if variable air volume (VAV) systems are being used to serve multiple spaces, use Section 6.1.3.1 to calculate the minimum % ventilation air that must be provided in the supply air to ensure adequate ventilation in each of the spaces.

Step 9: Use Section 6.1.3.3 to evaluate the type and location of the air supply and return outlets to determine the effectiveness of the air distribution devices in delivering the ventilation air to the occupants of the spaces. The airflow pattern must not permit the supply air to bypass the breathing zone as it flows from the supply outlets to the return/exhaust grilles during either the cooling or heating mode. A moderate reduction in the ventilation effectiveness factor can be offset by further increasing the proportion of ventilation air in the supply air stream.

Step 10: Size the air intake and exhaust openings. Coordinate the location of these openings so that the ventilation air will not be contaminated by nearby exhausts, bacteria from standing water in cooling towers or evaporative condensers, traffic fumes or other combustion engine exhausts, or other sources of contamination which can be avoided.

Step 11: Evaluate the building pressurization, using the preliminary outdoor air and exhaust airflows. Increase the outdoor airflow as necessary to maintain positive pressurization of the general building spaces with respect to the outdoors. Make sure that all spaces that are expected to be contaminated are maintained at a negative pressure with respect to the cleaner spaces.

Step 12: Evaluate the need for special humidity control precautions. Identify the most difficult operating conditions which are likely to occur for a prolonged period, and the relative humidity which will occur in the building with the type of equipment and controls that have been selected. Modify the design if necessary to prevent unacceptable relative humidity, usually limited to 60% RH maximum and, on some jobs, about 30% RH minimum.

Step 13: Determine the automatic controls and devices which will be used to control and measure the ventilation airflows. Determine whether continuous measurement of building contaminant levels is warranted.

Step 14: Coordinate the space requirements, access and other provisions that are necessary for adequate inspection and maintenance of the air handling equipment.

Step 15: Specify the commissioning procedures which will be used to ensure that the IAQ will be acceptable before the building is occupied. Transmit the design information which is necessary to commission the HVAC system.

Step 16: Specify the information which the contractor is to provide regarding the proper operation and maintenance of the HVAC system.

Step 17: Review the IAQ design documentation for completeness, and maintain the file for a period of at least five years after occupancy of the building, in order to provide necessary proof of correct design intent within the statute of limitations.

CONCLUSION

Indoor air quality has truly entered into the spotlight of design concerns, as well it should. On the horizon are a growing number of code regulations targeted to reduce and confine indoor contaminants and to limit their concentrations to safe and acceptable limits. Air qualities that were previously considered optional will become mandatory as increasing effort is exerted to prevent the growth of microbes that pose a threat to human health. The air conditioning system designer who is well positioned for the future will pay careful attention to the changes now underway concerning ventilation regulations, filtration, gaseous treatment devices, and humidity control. As ASHRAE releases their new standard for acceptable indoor air quality (Standard 62), designers must understand its implications for design strategies. The topics covered in this guide are designed to facilitate such an understanding and to make our time of transition a bit easier.