CONTROLLING AIR QUALITY IN OFFICE BUILDINGS

BY PRESTON E. MCNALL

SINCE THE ENERGY CRISIS OF THE 1970S, A NUMBER OF FACTORS HAVE adversely affected the quality or perceived quality of air indoors, particularly in office buildings. In brief, they are 1) purposely lower ventilation rates used to conserve energy, 2) tighter sealing of envelopes against outside air infiltration, 3) new construction and maintenance materials, 4) new types of office machines, 5) increased use of nonvented combustion appliances (in residences), 6) increased health research which has made years-old problems suddenly well known, and 7) new occupant behavior patterns that reduce ventilation.

Options for improving the quality of air indoors are isolating contaminants, keeping contaminants out of buildings in the first place, diluting contaminated air with clean air, removing contaminants with special equipment or filtration, and using special designs such as local exhaust or pressure-differential systems, which can keep contaminants within specified areas.

Ventilation, which dilutes contaminated air with cleaner air, has long been considered a highly effective way to provide adequate air quality in office buildings, and it will continue to be the primary strategy—implemented and controlled by HVAC systems. Many building codes, however, modified with energy in mind, permit ventilation rates that are too low in light of recent research. The current revision of ASHRAE Standard 62-1981, Ventilation for Acceptable Indoor Air Quality, specifies a *minimum* of 15 cubic feet of outdoor air per person per minute. Because of the frequency of complaints, practitioners and owners may wish to use the higher ventilation rates specified in tables in the existing standard and its revision. Both are available from ASHRAE headquarters in Atlanta.

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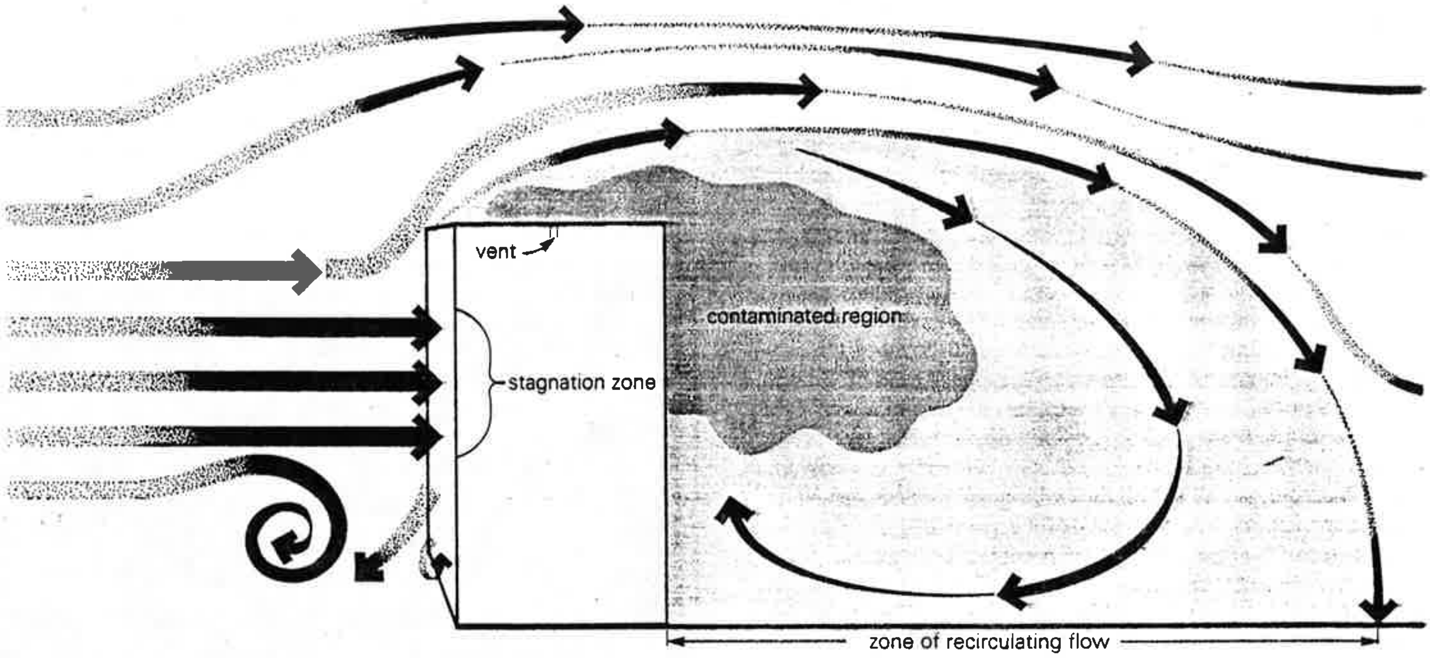
HVAC SYSTEMS CAN CLEAN OR FOUL AIR

Ventilation systems are necessary and vital for controlling indoor air quality. However, it's more than an irony that ventilation systems can also breed contaminants that may make people ill and circulate those contaminants throughout a building. Ventilation systems can introduce biological material, including pathogens, allergens (mold and insect parts, for instance), and other particles and gases. Even the best-designed system can run afoul if it does not receive proper installation, commissioning, testing and balancing, and maintenance.

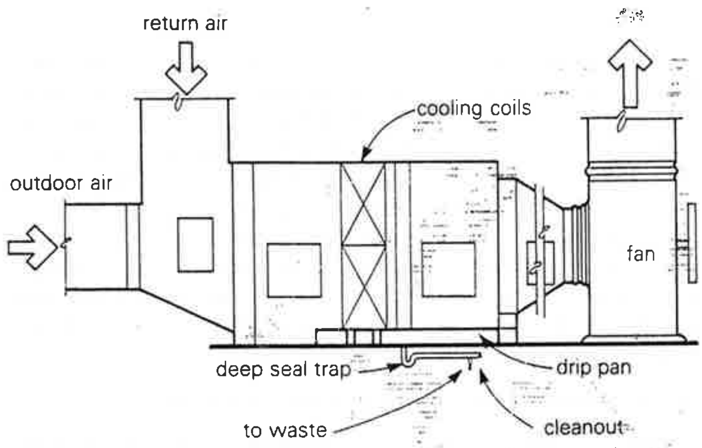
One aspect of HVAC-system design that could easily be improved is placement of exhaust and intake vents to minimize entrance of pol-



Airflow around buildings.

The airflow over and around a building is difficult to predict, much less control. In areas where there is a predominant wind direction, a zone of recirculating air is likely to be entrained. This zone is not a good place to locate outdoor-air intakes or exhausts.

Ventilation effectiveness is a fertile area for improvement



Typical arrangement of cooling coils in a central system.

To prevent dirt, insects, and foreign matter from accumulating on cooling coils, ASHRAE recommends in its Equipment Handbook *that all supply air be filtered. Cooling coils and some humidifiers (when used) must be fitted with a drip pan to catch condensate formed during the cooling cycle, and also excess water from the humidifier. The pan should pitch to the drain connection to prevent water from standing there. The connection between the drain and the drip pan should be located on the downstream side of the coils and should discharge to an indirect waste or storm sewer so that there will be no possibility of sewer gas entering the system. The pipe connection should be of ample size and be fitted with accessible ports for cleaning and a deep-trap seal. Furthermore, adequate maintenance must be provided to ensure that the drain pan remains clean and drains freely.*

lutants from traffic and other possible local outside sources. In hospitals, for instance, rooftop fresh-air intakes located downwind of emergency diesel generators, which must be run periodically to meet codes, can sometimes entrain the diesel exhaust plume. Numerous buildings have outdoor-air intakes located adjacent to or above loading docks, where trucks congregate with engines running and where garbage bins are located.

A second area fertile for improvement is ventilation effectiveness—a variable dependent upon the degree to which supply air mixes with air already in a space. Many studies have demonstrated, directly or by implication, that some typical placements of supply- and return-air diffusers result in *short-circuiting*—some supply air is drawn directly into return air vents (both usually located in the ceiling) without ever mixing in the space. In a study that Public Works Canada performed on a typical open-plan office building served by supply-air (and return-air) vents located in the ceiling, it was demonstrated that little supply air reached workers seated at their desks—where partitions approximately five feet high divided the area into small workplaces. Experimentation showed that raising partitions four inches above the floor improved mixing 50 percent. Certainly, some approaches to ventilating office spaces work better than others. Many of the strategies called for by clients on tight budgets, or used simply by convention, are minimally effective.

An ASHRAE standards project committee is now working to develop methods to measure ventilation effectiveness (Standard Project Committee 129P). A preliminary definition of ventilation effectiveness (used by this author) is: "The measure of the ability of the ventilation air to produce a contaminant level in the occupied zone of a space *divided into* the contaminant level produced by a similar amount of ventilation air with *perfect mixing* in the space." Using this definition, the drawings on page 32 show a range of stylized cases in which the ventilation effectiveness can vary from zero to infinity.

Rest rooms and laboratories have long been equipped with dedicated local exhaust systems. Spaces that house print shops, copying machines, or other office machines that off-gas chemicals also may benefit from local exhaust.

Clean rooms and hospitals often control airflow and air quality by utilizing differential-pressure control. These principles may have their place in the office, too, particularly when contamination levels in certain zones can be anticipated.

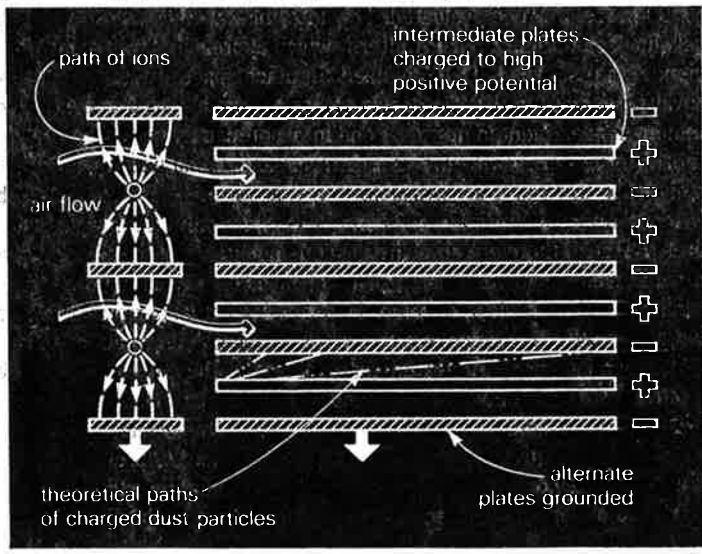
Particulate and gaseous filters

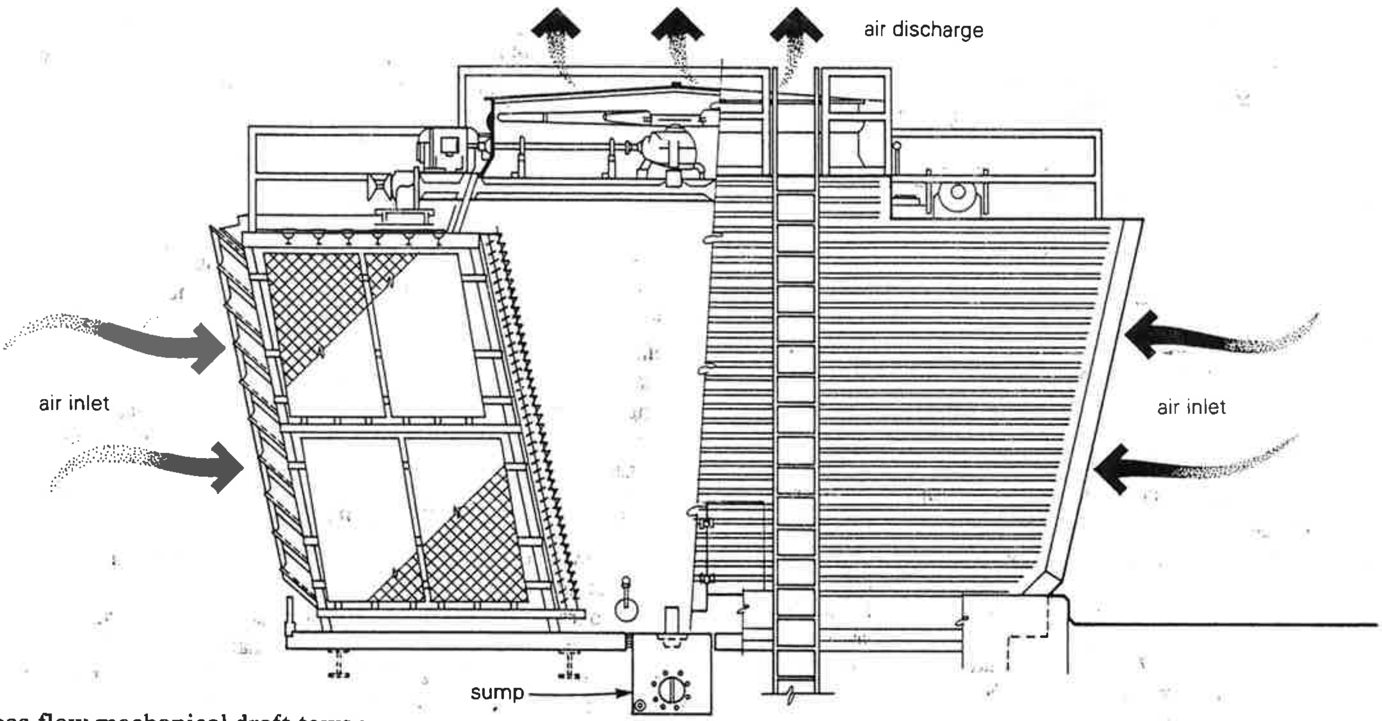
Studies show that office buildings typically harbor concentrations of many pollutants far in excess of levels outdoors, but in many locations, of course, outdoor air contains objectionable pollutants as well. This situation, together with the fact that it is more economical to recirculate air than to heat or cool outside air, gives filtration systems interesting possibilities.

The performance of the most common filtering equipment, particulate filters, can be measured using ASHRAE Standard 52-76, which specifies procedures for atmospheric-dust removal (called the "dust-spot method") and coarse-particle removal (called the "weight-arres-

Diagrammatic section of ionizing electronic air cleaner.

One of several types of electronic air cleaners produced for commercial service, the ionizing-type air cleaner charges dust particles in the airstream with positive ions that are generated when the air passes over a high-voltage wire. Particulates are subsequently driven to plates having a negative charge, where they remain until washed off. Good cleaning and maintenance procedures are vital.





Cross-flow mechanical draft tower.

Outdoor cooling towers of various types are commonly used to cool water and reject the heat of air conditioners. The cooling water in open-type towers is cooled by evaporating a small percentage of the water. If the sumps in these towers are not maintained well, many organisms in the outdoor air can be collected in the water and can incubate. "Drift" (small droplets of water) can be blown from the tower and reentrained into building air inlets. This was the probable cause of the famous Legionnaires' disease outbreak at the 1976 American Legion convention in Philadelphia.

tance method"). The arrestance method is used to measure the performance of filters whose main function is to keep HVAC systems from fouling. The arrestance method, however, does not measure the respirable fraction of particles (those between 0.1 and 10 micrometers), which most affect health and comfort. For measuring these particles, the dust-spot method is used—and efficiencies above 90 percent can be evaluated. For determining efficiencies of so-called absolute filters (HEPA filters, which approach 100 percent efficiency), a test called "DOP" is used. In office spaces, dust-removal efficiencies in the 90-percent range require a considerable incremental investment in first cost and in maintenance, and often are not considered. However, both electronic and media filters with efficiencies in that range are available in a wide variety.

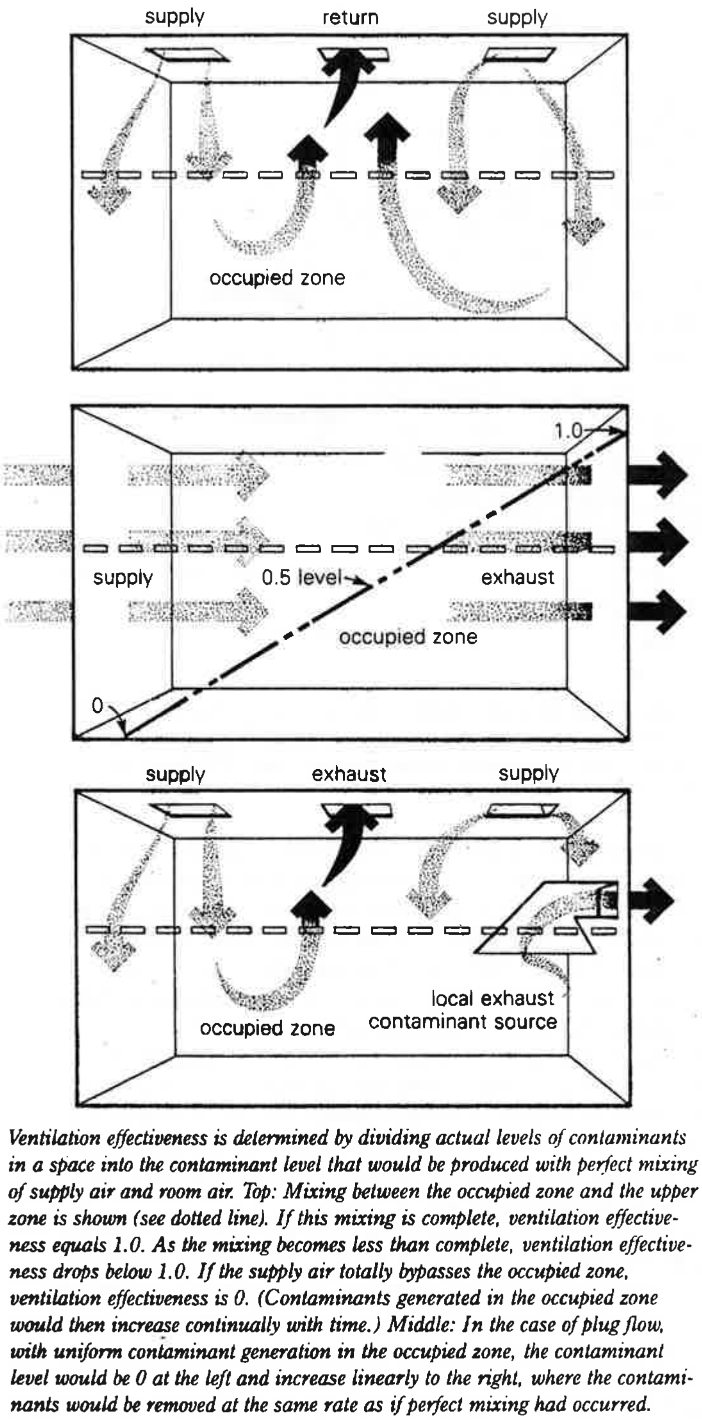
Gaseous-removal filters are a second, less commonly used, type of filter. Because there are so many gaseous pollutants in the air, each with unique characteristics, good standards for evaluating the filters have been difficult to develop. Determining actual performance requires architects and engineers to rely on suppliers' information and their own judgment. Activated-charcoal filters, the most common of the gaseous-removal filters, tend to absorb materials with high molecular weights and let materials with lower molecular weights pass through. When the filters become loaded, to prevent off-gassing of previously absorbed materials, they must be either regenerated or replaced. A second class of gaseous-removal filters utilizes porous pellets impregnated with active chemicals, such as potassium permanganate. The chemicals react with contaminants and remove them or render them less annoying or harmful. Maintenance consists of regenerating or replacing the filters. In general, inexpensive, desk-top filters are ineffective other than for the air movement they create, which occupants may find comforting. Some higher-quality filters can be effective, however.

Air washers have been used primarily for special applications, such as controlling bacteria growth and humidity. Because there are no standards for evaluating this equipment's general performance in controlling contaminants, maintenance is essential. Untreated water sumps or drain pans can quickly become environmental niches where harmful biomatter can multiply.

Air ionization, usually negative ionization, has been experimented with extensively over the past two decades. It was first intended to add a perceivable "freshness" to the air, and also to improve thermal comfort. In the 1960s, an ASHRAE technical committee that studied air ionizers concluded, "If ionization has an effect, it is too small to be of engineering importance for freshness, well being, or thermal-comfort effects."

On the other hand, air ionization, either positive or negative, has since been recognized as an effective method of cleaning air. When passed through the energized fields of an ionizer, dust particles and even some gases collect on surfaces that have an opposite charge.

Ventilation effectiveness.



Ventilation effectiveness is determined by dividing actual levels of contaminants in a space into the contaminant level that would be produced with perfect mixing of supply air and room air. Top: Mixing between the occupied zone and the upper zone is shown (see dotted line). If this mixing is complete, ventilation effectiveness equals 1.0. As the mixing becomes less than complete, ventilation effectiveness drops below 1.0. If the supply air totally bypasses the occupied zone, ventilation effectiveness is 0. (Contaminants generated in the occupied zone would then increase continually with time.) Middle: In the case of plug flow, with uniform contaminant generation in the occupied zone, the contaminant level would be 0 at the left and increase linearly to the right, where the contaminants would be removed at the same rate as if perfect mixing had occurred. However, the average contaminant level in the occupied zone would be 0.5, hence ventilation effectiveness would equal 2.0. Bottom: If the local exhaust system removes all of the contaminants from the source shown, the concentration in the balance of the occupied zone would be 0, resulting in a ventilation effectiveness of infinity.

Because people could themselves be collectors and because of a number of unanswered questions, such as whether or not ozone generated by some ionizers is harmful, air ionization is still considered experimental.

Commissioning an HVAC system

Commissioning an HVAC system involves the initial operation of the system as installed so that it can be properly tested and balanced to meet design goals. After commissioning, the system should be tested and balanced using field adjustments to provide the designed airflow rates. ASHRAE publishes a number of technical documents familiar to those acquainted with proper HVAC design. The organization also is working on its first guideline (Guideline Project Committee 1P) for commissioning HVAC systems. Standard Project Committee 111P is developing a new standard for proper testing and balancing of systems.

HVAC systems will undoubtedly contribute to healthier indoor environments as knowledge and perception about indoor air increases—prompted in part by better codes and standards that embody this knowledge. In the meantime, systems already in place, and those being designed, can yield better air quality through proper installation, maintenance, and adherence to basic design principles listed here. Architects and engineers who can deliver this advice to their clients, through actual designs and recommendations for maintenance and operation, will be offering a valuable service indeed.

Do these things if nothing else:

- Use ASHRAE Standard 62-1981 and Standard 62-1981P to determine the most appropriate outdoor air quantities for dilution of contaminants. Employ engineering judgment as appropriate. Consult local building codes, but consider that larger outdoor quantities will often be appropriate.
- Design for the *minimum* outdoor air quantity now in the ASHRAE Standard 62-1981P draft of 15 cubic feet per person per minute.
- Use engineering judgment to increase outdoor flow rates if ventilation effectiveness is thought to be much less than 1.0.
- Provide system designs that eliminate or minimize standing water, which can incubate biomatter, and allow easy access for system cleaning and maintenance.
- Design systems that permit easy access for instruments used in testing and balancing—to ensure that systems can operate as designed.
- Design to eliminate or minimize the recycling of exhaust air into intakes.
- Position intakes to minimize entrainment of pollutants from traffic and other local outside sources.
- Use ASHRAE Standard 52-76 as a guide to evaluate the efficiency of particulate-removal equipment. Standards for evaluating the effectiveness of equipment designed to remove gases from recirculated air are lacking. Consequently, this equipment must be evaluated and selected with extra care.
- Consider heat-reclamation equipment and other strategies to conserve energy.
- Consider local exhaust and differential pressure control. ■