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Indoor Air Quality Update™

A Guide to the Practical Control of Indoor Air Problems, from Cutter Information Corp.

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Ventilation and IAQ in Telephone Switching Offices

In the May 1990 *IAQU* (Vol. 3, No. 5), we described the work of Charles Weschler and his colleagues at Bell Communications Research (Bellcore) in Red Bank, New Jersey, on indoor ozone. Weschler has also studied the control of fine particles that can cause failures in telephone company switching equipment housed in dedicated buildings. He has discussed with *IAQU* the costs of controlling volatile organic compounds (VOC) and their effects on telephone switching equipment (as well as office electronic devices). This month we will look at some of Weschler's recently reported work related to the impacts of ventilation and IAQ on electronic equipment.

Part of Weschler's analysis, the effects of particles on telephone switching equipment, will appear in the kick-off (sample) issue of the new journal, *Indoor Air*, to be distributed at Indoor Air '90 in Toronto later this month. Much of it was part of a presentation he gave at the ventilation workshop sponsored by EPRI and the Solar Energy Research Institute in Golden, Colorado, last November.

Weschler's Study

Weschler and his colleague at Bellcore, Helen Shields, have analyzed how ventilation and IAQ affect electronic equipment. Their concerns are primarily with failures in telephone switching systems. However, their work is also applicable to computers and other electronic devices. Their studies have looked at three types of contaminants: VOC, particulate matter, and ozone.

Indoor Pollution Effects on Electronic Equipment

According to the authors, VOC can contribute to frictional polymerization, promote arcing, and increase sticking coefficients on read/write heads (leading to crashes in high-speed disk drives).

Airborne particles containing water-soluble salts that absorb moisture at high relative humidities can become conductive, causing current leakage and shorts. Insulating particles (nonconductive) cause high resistance in electrical contacts and "opens." Abrasive particles accelerate wear on connectors and moving parts. Currently, the gap between the head and the disk surface in high-speed disk drives is only 0.3 microns. Therefore, they are extremely sensitive to fine particles. Typically the manufacturers protect the heads with HEPA filters, and most failures result from particles produced downstream from the HEPA filters. But occasionally particles in the ambient environment can cause failures.

Ozone can cause oxidation of rubber O-rings and seals, plastics, and other insulating materials used in electrical wiring. Other inorganic gases can induce corrosion. Acidic gases can attack metallic components.

VOC

The sources of VOC in telephone switching offices are primarily electronic equipment and the building itself. Managerial controls limit the use of VOC-containing maintenance products and prohibit tobacco smoking in the switchrooms. Nonetheless, the measured indoor VOC concentrations at the

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telephone switching offices are "significantly larger than the corresponding outdoor concentrations." Thus, the greater the ventilation rate, the lower the indoor VOC concentration. However, the authors point out, the relationship is not linear.

They have calculated VOC concentrations as a function of ventilation rate using a simple one-box, mass-balance equation. The calculations were validated in previously published studies with data from a building located in Sheboygan Falls.

The authors assumed an internal volume of 14,200 ft^3 (400 m^3); a ventilation fan moving 1,600 cfm (750 L^3/sec); the outside air varying from 0 to 100% [0 to 6.75 air changes per hour (ach)]; a hypothetical VOC internal generation rate of 40 µg/min; and a VOC concentration outdoors equal to zero.

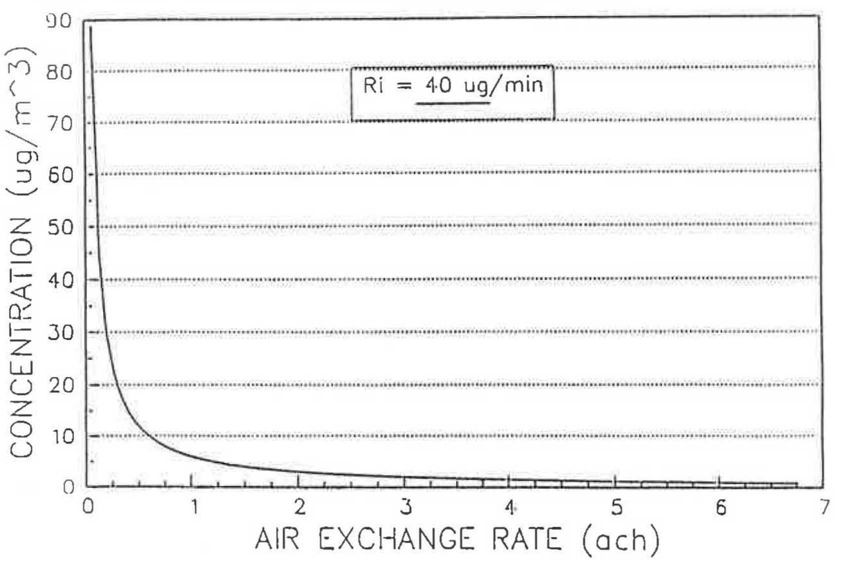

Figure 1 — Indoor concentrations of a hypothetical VOC vs. air exchange rates.

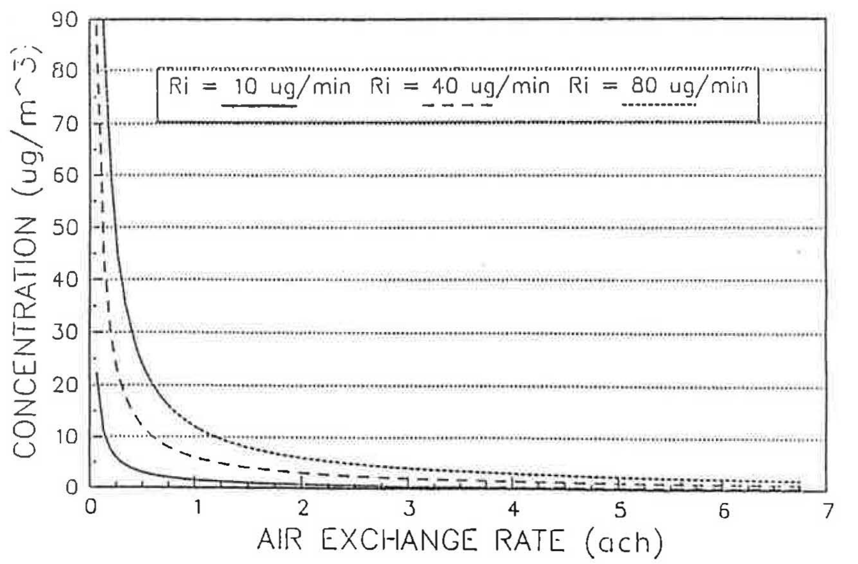

Figure 2 — Indoor concentrations of a hypothetical VOC vs. air exchange rates.

Ventilation Rate

Figure 1 shows the relationship between VOC concentration and ventilation that we have described previously (See *IAQU*, June 1990; June 1989; May 1989.) In this case, as the ventilation rate is decreased from 6.75 to 1.0 ach the curve climbs gradually from about 1 µg/m^3 to about 6 µg/m^3. But, when air exchange falls below 0.6 ach, the curve climbs steeply to about 60 µg/m^3 at 0.1 ach.

Thus, below 0.6 ach small reductions in air exchange result in large increases in VOC concentrations. Building on our own presentation at the Denver ventilation conference, Weschler and Shields point out that it is important to keep ventilation rates in the region where the slope of the curve is fairly small. This requires knowing where the slope starts to change rapidly; we pointed out that where this occurs depends on the characteristic VOC source strength for the building or space being ventilated.

Hours of Ventilation

Figure 2 shows three curves calculated for different VOC source strengths. As the hypothetical source strength increases, the amount of ventilation required to maintain a "safe" steady-state VOC concentration increases from 0.3 to 0.6 to 0.8 ach. This, the Weschler report says, is a strong argument for controlling indoor sources of VOC as well as for providing adequate ventilation.

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Extending the concepts presented by Larry Palmiter at the Denver ventilation conference, Weschler points out that the VOC concentration is inversely proportional to the hourly air exchange rate, while the energy cost of ventilation is roughly proportional to the arithmetic average of the air exchange rate. Thus, buildings where fans are periodically turned off have an effective air exchange rate for VOC control that is lower than the air exchange rate reflected in energy cost. [If the fans are turned off at night, and if the source strength of VOC is assumed constant throughout the daily cycle, then the energy cost will be even lower in areas where electric costs are lower at night.]

To clarify the point of the difference between harmonic average and arithmetic average, Weschler described a simple example. Assume a hypothetical VOC with no outdoor sources and an emission rate that results in a steady-state concentration of 10 $\mu g/m^3$ at one ach. If the fans are operated at 2.5 ach for 130 hours per week and there are 0.2 ach (from leakage) with the fans off for 38 hours per week, the average concentration would be 14.4 $\mu g/m^3$ for the week. This is seen by the calculation below:

$$\frac{130(10/2.5) + 38(10/0.2)}{168} = 14.4 \text{ mg/m3}$$

This same average concentration could be achieved with the fans operating at only 0.7 ach continuously.

Implications

VOC sources and their effects are not as constant in buildings with intermittent occupancy as they are in the telephone switching offices where equipment works 24 hours per day. However, elevated VOC concentrations are adsorbed on building surfaces and released later, especially when air moves across the surfaces on which they are adsorbed. Thus, the hours of fan operation should be carefully evaluated in the control of indoor source VOC.

Particulate Matter

Weschler's studies focused on fine particles [smaller than 2.5 microns (μm) in diameter]. This is because typical building ventilation filters do a fairly good job of removing coarse particles (larger than 2.5 μm diameter). According to the authors, fine and coarse particles tend to have different sources and, therefore, different chemical compositions and physical properties.

Fine particles are a greater threat to electronic equipment because they are more difficult to filter from air; they accumulate on both horizontal and vertical surfaces; their movements are influenced by air currents, thermal gradients, and electrical fields; and their chemical composition is potentially more harmful to the equipment than that of coarse particles.

Fine-particle concentrations indoors are strongly influenced by ventilation strategies. The sources of fine particles indoors are primarily in outdoor air unless there are combustion sources indoors (such as tobacco smoking, fossil-fuel appliances, and wood stoves and fireplaces). Unlike VOC, fine-particle concentrations indoors at telephone switching offices are substantially lower than outdoors.

Concentration levels reflect the air quality in the surrounding environment. The researchers have found significantly different levels depending on whether the study building was located in a rural, suburban, or urban area. There are, not surprisingly, lower outdoor air contaminant concentrations in the rural areas.

Figures 3 and 4 show plots of calculated values (based on extensive field measurements) of indoor concentrations of fine-mode sulfate particles (particularly harmful to electronic equipment) versus air exchange rate with 85% and 30% (ASHRAE dust spot rate) filters. More specifically, the calculations plotted in Figure 3 are based on the assumption that the 85% filter removes 74% of the 0.5-0.6 μm diameter sulfate particles. The calculations in Figure 4 are based on the assumption that the 30% filters remove 10% of the 0.5-0.6 μm diameter sulfate particles. These calculations are also based on an assumption that there are no indoor sources of fine particulates.

The graphs show clearly that increasing ventilation results in increased indoor concentrations of outdoor contaminants. When outside air is contaminated, effective air cleaning and filtration are required to protect equipment (and people) indoors.

Note the contrast between the solid lines (fans on 100% of the time) in Figures 3 and 4. In Figure 3 (85% filters), the line increases almost linearly and rather gradually as air exchange increases from almost zero to 2.6 ach. In Figure 4 (30% filters), the solid line increases in a strongly nonlinear fashion and the rate of growth is steep in the region from 0.3 to 0.9 ach.

Comparing the four lines in Figure 3, we see that particle concentrations increase as the amount of time the fans are on decreases. This is because the *percentage* of air coming into the building

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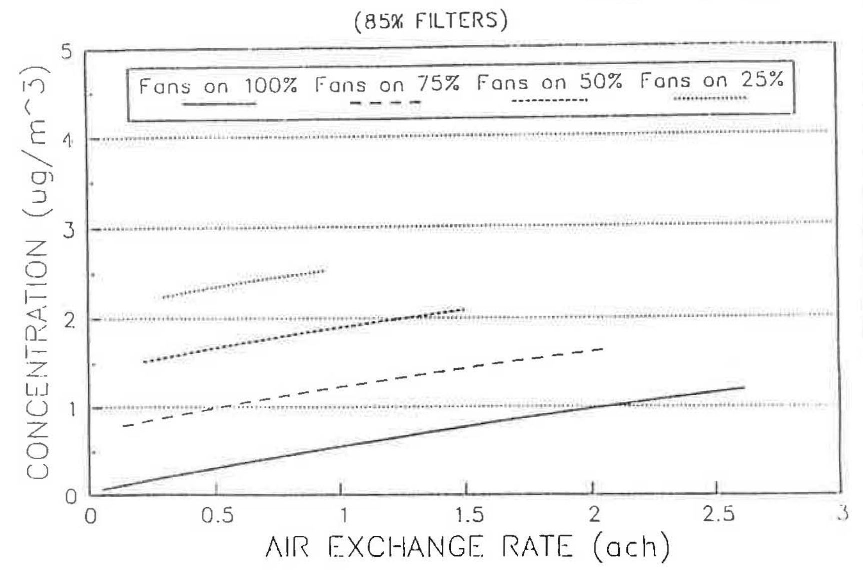

Figure 3 — Indoor concentrations of fine mode sulfate particles vs. air exchange rates.

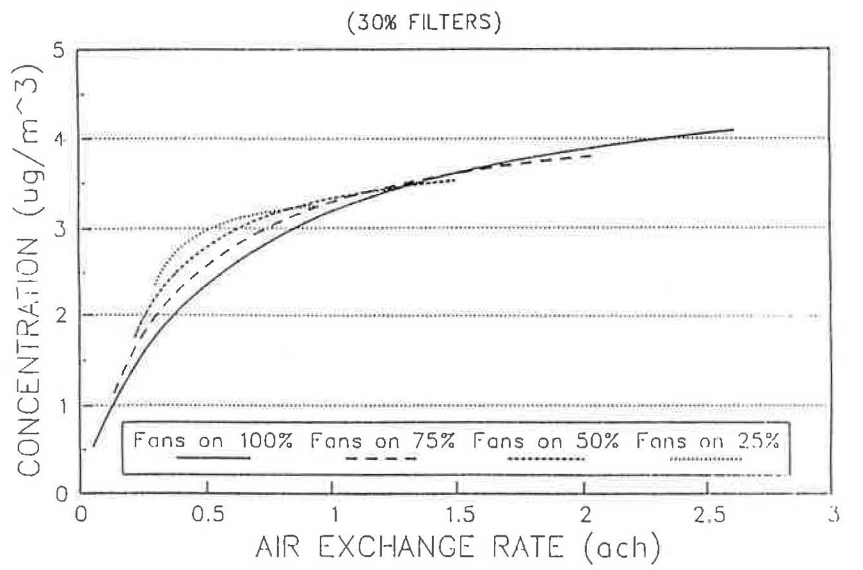

Figure 4 — Indoor concentrations of fine mode sulfate particles vs. air exchange rates.

through leakage without passing through the filters increases as the time the fans are on decreases.

In this hypothetical case, the increase in particle concentrations from running the fans less of the time is far greater than the penalty for using more outside air when the fans are run a larger fraction of the time. Thus, the more the fans are off, the less control there is over the pollution in the ventilation air. This effect is not as dramatic in Figure 4 because the filters are so inefficient in removing fine-mode sulfate particles.

Ozone

While many inorganic gases, especially acidic gases, can damage equipment, Weschler focused on only one, ozone, in his recent work. We described that work in great detail in the May *IAQU* (Vol. 5, No. 3). We plotted a curve similar to Weschler's based on his work.

Summarized simply, Weschler's calculations show that as the air exchange rate is varied from 0 to 10 ach, the indoor/outdoor ozone concentration ratio increases from about zero to just above 0.7. This means that when outdoor ozone levels exceed the federal standard of 120 ppb, indoor concentrations can reach levels known to cause harm to humans. Over half the U.S. population lives in areas that failed to meet the federal standard in 1988.

Switching offices are concentrated in population centers. And the available guidance suggests that 100 ppb ozone can be harmful to switching equipment. In locations that frequently experience extremely high outdoor ozone concentrations, even low ventilation rates still result in a significant exposure of equipment (and people) to ozone. Fortunately, properly designed charcoal filters have been demonstrated to be effective for ozone mitigation.

Guidelines

Weschler has suggested some guidelines for HVAC in telephone switching offices. They are certainly relevant to buildings for human occupancy in order to protect people as well as electronic equipment.

1. Ventilation rates should be no less than 0.25 ach.

This comes from Figures 1 and 2. Note that the source strengths in Weschler's analysis are fairly low. It is clear that when indoor VOC source strengths are large due to activities and especially new con-

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struction materials, furnishings, or maintenance operations (such as floor waxing or furniture polishing), the ventilation rate should be increased.

2. *The environment for digital switches should be maintained at positive pressure relative to the external environment (approx. 0.02 to 0.05 inches of water).*

This guideline is intended to reduce infiltration of outdoor air. Infiltration air has normally bypassed building HVAC system filters as well as thermal- and humidity-control devices. "The more air that leaks into a building, the less control one has over the indoor environment."

However, Weschler cautions, when outdoor air temperatures are extremely low, it may not be advisable to maintain positive pressure. Water contained in the indoor air may condense on cold structural surfaces and cause damage. This condition does not prevail for most of the year in most of the U.S., according to Weschler.

3. *Filters should have ASHRAE dust spot ratings no less than 85%.*

Figures 3 and 4 show why this recommendation is made. For a typical telephone building with continuous fan operation, the difference between air concentrations of fine sulfates with 30% and 85% filters is an eightfold decrease.

4. *The HVAC fan should be operated continuously.*

Each of the previous three guidelines supports this fourth one. Also, thermal shock to the electronic equipment is more likely during fan cycling. With continuous HVAC operation, continuous air movement reduces the probability of thermal shock.

Conclusion

Weschler and his colleagues have done careful research, produced clever analyses, and made some valuable contributions to our IAQ knowledge base. Next month we will look at their calculations of the economic impacts of various ventilation strategies. We hope to learn some lessons about building operation in general and about office environmental impacts on worker productivity.

For More Information:

Weschler, C.J. and H.C. Shields, "The Impact of Ventilation and Indoor Air Quality on Electronic Equipment." *Proceedings: Ventilation Workshop (Nov. 13-15, 1989, Golden, Colorado), Appendix D,* Research Project 2034-34, Electric Power Research Institute, Palo Alto, California. pp. 18-34. Available from the Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94304.

Charles J. Weschler "Predictions of Benefits and Costs Derived from Improving Indoor Air Quality in Telephone Switching Offices." *Indoor Air.* Volume 0, No. 0 (Sample issue) in press.

Feature

"TLVs: They Aren't Thresholds After All"

In the April 1990 *IAQU* (Vol. 3, No. 4), we wrote about disagreements over the applicability of industrial exposure limits to nonindustrial workplaces and other environments ("Is Certification of IAQ Practitioners Coming?"). In particular, we were concerned with reliance on adopted Threshold Limit Values (TLVs, established for industrial workplaces) for interpretations of environmental monitoring or other exposure assessment in nonindustrial settings. We wrote that an American Industrial Hygiene Association (AIHA) representative attending a meeting in Washington asserted that TLVs were appropriate standards for indoor air evaluations and that using lower levels was practicing "environmental terrorism."

In last month's *IAQU* (Vol. 3, No. 6), we published a letter from Richard Gammage, a past chairman of the AIHA's Indoor Environmental Quality (IEQ) Committee, in which Dr. Gammage pointed out that not all AIHA members agree with some of the organization's representatives. Gammage indicated that the IEQ Committee and other AIHA members "have followed an evolving course of recognizing the often distinctly different protective needs of workers in the manufacturing and service sectors."

There and elsewhere in his letter Gammage implied that many industrial hygienists recognize the limited applicability of TLVs in nonindustrial settings. We wrote that we have also received comments from other industrial hygienists, mostly members of AIHA, strongly disagreeing with the position of the representatives at the Washington meeting.

What Are TLVs?

TLVs are established by the American Conference of Governmental Industrial Hygienists (ACGIH), an organization of occupational health and safety professionals in government and educational institutions.

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