Increased Ventilation Has Limited Effect on New Carpet Emissions

The common wisdom has been that homeowners and building managers should increase ventilation following carpet installation to hasten the emission of irritating compounds from the new carpet. The Carpet and Rug Institute (CRI) has recommended increasing ventilation for 72 hours. However, a recent research project shows that after the first 30 hours, increased ventilation and/or turbulence has no or little effect on carpet emissions of target chemicals.

J. Michele Low of Nortel (Ottawa, Ontario) conducted the research along with colleagues from the National Research Council Canada and Carleton University (also in Ottawa). The researchers reported the findings at the ASHRAE annual meeting, which was held in late June in Toronto, Ontario.

The purpose of the study was to measure the effects of increased ventilation and turbulence on emissions from a carpet-adhesive-concrete substrate assembly, which is typical for office buildings. The intent was to see how the conditions affected such things as total volatile organic compounds (TVOC), nonane, decane, and 4-phenylcyclohexane (4-PC), which has been linked with irritation from new carpets.

The researchers had hoped to find out how to balance IAQ against the energy penalty from increasing ventilation. They wanted to determine whether increasing air velocity and turbulence in the early stages of the emission process — before the occupants returned — would mean lower emission rates later in the process.

Materials

To construct the carpet assembly, the researchers used a 28-ounce, level-loop nylon carpet with a synthetic jute textured back. Both the carpet and the adhesives were donated by their respective manufacturers. The researchers kept the carpet in Mylar bags from the time of manufacture until the time of the experiment.

The adhesive was a synthetic latex base with a 3% mineral spirit content. The concrete slab used as a substrate measured 250 x 500 x 40 millimeters. To determine headspace measurements, the researchers took vapor samples from the Mylar bags that contained the carpet. For the adhesive, they placed a small amount in a glass vial and sampled the vapor above the adhesive after 72 hours. They placed the substrate slab in a static chamber and measured the TVOC after 24 hours. The carpet had a TVOC concentration of 4.45 milligrams per cubic meter (mg/m^3), while the adhesive had a concentration of 1,661 mg/m^3. The TVOC from the concrete substrate was 0.43 mg/m^3.

Methodology

To monitor carpet assembly emissions, the researchers used a 1.0 x 0.8 x 0.5-meter stainless steel chamber, which had an axial fan to circulate the air. The fan's DC motor was located outside the chamber to prevent contamination.

The researchers conducted seven tests. Before each test, they purged the chamber with clean air for eight hours and then prepared the carpet assemblies for the experiment. They removed the carpet from the Mylar bag, cut a suitable piece, spread adhesive onto the substrate, and then waited about 20 minutes before applying the carpet. They weighed and measured the carpet mass, carpet area, and the adhesive mass for each sample.

The researchers then placed the assembly in the chamber and selected the test parameters. The test continued for seven days, while the researchers monitored and recorded both the TVOCs and the chamber conditions, which included:

- Air velocity
- Turbulence data
- Air temperature
- Relative humidity (RH)
- Chamber pressure
- Airflow rate

Table 3 shows the test parameters for each of the seven tests. The tests designated 6r1 and 6r2 were replications of test 6 to see if they would show similar results with similar parameters. All tests were run at 23 ± 1.3°C and 45.5 ± 3% RH.

Results

The researchers report that higher air velocities during the first 30 hours resulted in

Table 3 — Carpet Test Parameters

Test	Carpet Area (m^2)	Carpet Mass (g)	Adhesive Mass (g)	Airflow (lpm)	Average Velocity (m/s)	Average Turbulence (k/u^2)
4	0.124	29.7	59.10	6.67	0.04	0.003
5	0.124	301.5	55.20	6.67	0.10	0.004
6	0.123	300.0	51.35	6.65	0.22	0.008
6r1	0.124	328.3	50.60	6.65	0.26	0.008
6r2	0.123	300.8	55.00	6.65	0.26	0.008
7	0.124	299.5	59.00	6.65	<0.04	0.077
8	0.122	299.2	58.00	6.67	0.26	0.212

Source: Low, et al.

increased TVOC emission rates. However, subsequent emissions appeared to be unaffected by increasing air velocity or turbulence. This would seem to indicate there was little benefit to be gained in increasing the velocity in the earlier stages. When air velocity was reduced, according to the researchers, turbulence had a greater impact on emission rates.

4-PC concentrations were very low, compared to the other compounds. However, the researchers note, 4-PC became detectable only after about 50 hours. The researchers conclude that this would indicate that 4-PC, emitted from the carpet, is of less concern than the VOCs emitted from the adhesive, at least during the first several hundred hours after installation (the time frame for the experiment).

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Researcher Calls for Airlines to Increase Outside Air for Passengers

One of the persistent complaints about the indoor environment from the general public concerns the air quality in commercial aircraft. In fact, ASHRAE currently has a group working on a standard for aircraft cabin air quality, a process that is in its early stages. Now, a researcher from the University of Victoria (Victoria, British Columbia) contends that airlines could reduce disease transmission and bring about "system saving" by either eliminating air recirculation or using HEPA filters. Martin B. Hocking reports his conclusions in the *American Industrial Hygiene Journal* (Vol. 59, 1998, pp. 446-454).

Hocking bases much of his argument on measured and predicted carbon dioxide concentrations in aircraft. He starts by showing that the time to any given CO_2 concentration in an enclosed space is very closely related to the volume. While this is probably intuitive, Hocking provides calculations showing that as the volume decreases, the time it takes to reach the acceptable limit drops off sharply. For example, in a 25,000-liter space with one resting person — assuming an initial CO_2 concentration of 357 parts per million (ppm) — it would take nearly an hour to reach the commonly accepted limit of 1,000 ppm. However, if that space were reduced to 1,000 liters, it would take only 2.3 minutes. Current commercial aircraft, Hocking notes, allow between 1,000 and 2,000 liters of air space per passenger.

Hocking says that as available space declines, systems become less resilient or tolerant of periods of nonventilation. Therefore, he says, to maintain a set CO_2 concentration, small spaces require more air exchange than would be theoretically predicted.

Aircraft Design

Aircraft have several characteristics that make them different than office buildings or other ground-based structures when it comes to ventilation and air quality. The foremost problem faced by aircraft is the need to control the pressure within the cabin when flying at high altitudes. Usually, commercial aircraft maintain cabin pressure equivalent to 8,000 to 10,000 feet above sea level.

According to Hocking, a single-pass ventilation system brings air to a passenger's face and then to the floor, where it exhausts to the outside. In this scenario, an infected person might be a danger to his or her seatmates and a few other surrounding people due to air turbulence within the cabin. A recirculation system, however, takes the air, perhaps containing viruses or bacteria, from near the floor, mixes it with outside air, and recirculates it to the entire cabin.

Table 5 — Calculated and Measured CO_2 Concentrations (ppm)

	Measured Concentrations			Calculated Concentrations
	1989 Flights (92)		1994 Flights (158)	
	Smoking	Non-smoking		
Mean	1,562 ± 685	1,765 ± 660	785	1,145
Minimum	597	766	464	771
Maximum	4,943	3,157	1,552	1,682
Distribution (%)				
<1,000	13	13	75	28
1,000-1,500	34.5	30.5	25	64
1,500-2,000	34	17		8
2,000-2,000	18	26		0
>2,500	3	13		0

Source: M.B. Hocking

Hocking suggests that if airlines are to use recirculation, they should also install and maintain HEPA filters to remove potentially infectious particles. Finally, Hocking recommends that the fresh air supply be kept at 15 cubic feet per minute per person during taxiing, ascent, and descent.

He supports his recommendations with an economic analysis that shows airlines save $60,000 per aircraft per year with recirculation systems. While this seems like a large sum, it works out to about $1 per passenger trip, based on a 200-seat aircraft that makes 300 trips per year. The figures would be different for larger or smaller aircraft and for longer flights. He contends that passengers have an interest in avoiding illness and therefore might be willing to pay the extra average cost of $1.

While the airlines claim large savings, Hocking argues that this is a "one-stakeholder saving" and not a "system saving." The passengers who become ill, as well as their families and employers, must bear the cost of the illness caused by the airline saving money.

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Case Study

[In each issue, **IEQS** *presents a case study on an indoor air investigation in a particular building. The information in the cases comes from various sources, including published material, reports in the public record, and, in some cases, reports supplied by the consultants involved in the case.* **IEQS** *presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply* **IEQS***'s endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case.* **IEQS** *invites readers to submit comments, suggestions, and questions concerning the case. At the discretion of the editors, correspondence may be presented in a future issue.]*

Investigators Link Building IEQ and Environmental Illness

This case involves a hospital complex, where IEQ problems went on for more than six years and affected hundreds of workers, causing what physicians described as environmentally induced dysfunction (EID). Despite the correction of the problems that caused the illnesses, 85 workers from the hospital still suffer from adverse health effects, keeping them out of work on long-term disability.

The case focuses on the illnesses suffered by the workers and the correlation of the syndrome to the building conditions. Roy A. Fox, M.D., a physician at the hospital, reports on

Another phenomenon was that some patients began to exhibit reactions to foods — not discrete food allergies, such as some people have to seafood or peanuts, but rather reactions to foods they had previously eaten regularly. Patients also reacted to exposure to electromagnetic fields and were unable to be near computer terminals, television sets, and other electrical appliances.

Environmental conditions affected some patients. These persons were unable to tolerate changes in temperature and were affected by light, both natural and artificial, and by noise. The investigators detected multiple reactions, some of which were synergistic and brought on other reactions. The environmental irritants rarely acted alone. The symptoms of these reactions to irritants ranged from mild to disabling. One characteristic of the syndrome was fatigue, which was universally present. Some patients became extremely tired after exercise and suffered myalgia. They also required a long time to recover from the exercise-induced fatigue. Some patients reported mood swings, and others developed depressions and anxiety.

The investigators report that patients sometimes had a yellowish cast to the skin. Other skin disorders included adult-onset acne, edema, petechiae, livedo reticularis, follicular hyperkeratosis, and dark circles under the eyes. Fox says some patients had a positive Romberg's test and others exhibited peripheral neuropathy.

Investigators conducted laboratory tests that confirmed the dysfunction and supported the EID presumption. Some patients had abnormal pulmonary function tests, a positive methacholine challenge test, and abnormal neuropsychological tests. Blood tests revealed leucopenia, elevated liver enzymes, and abnormal lymphocyte subsets. These findings were similar to abnormalities reported in cases of MCS.

Building Problems

Fox tells ***IEQS*** that the investigators began to focus on the various buildings in the complex and factors that might be common to the three buildings involved, other than the fact many workers visited the cafeteria in the VMB.

Looking at the HVAC systems in the two mechanically ventilated buildings, investigators determined that the system in the new building, the VMB, had never been commissioned, resulting in poor balancing. Also, there was significant reentrainment of exhaust, and an underground passageway had insufficient ventilation. Air monitoring showed elevated levels of phenol and formaldehyde in the building.

The AJL building, which was 25 years old at the time of the outbreak, had mechanical ventilation, but the system hadn't been maintained properly and, according to Fox, had probably never been cleaned. Workers removed considerable dirt and debris from the ducts within the building. Also, for energy conservation, workers had closed the O/A dampers, meaning that the building had no O/A supply.

However, neither of these situations was common to all three buildings, still leaving investigators with a puzzle. The one thing that was common to all three buildings was that they shared a steam heating system, and steam from the boiler was used in a common humidification system. According to Fox, the complex used anticorrosives in the boiler water that was eventually used for humidification. Instead of adding the anticorrosives in a steady feed, workers would add them in batches, often 5-10 times above the recommended levels. Investigators were able to recover amines from the anticorrosives in condensation in the ductwork.

Because of the condensate in the ductwork, mold and fungal contamination could have been a problem at the facility. Fox says that investigators looked at this and reported no significant mold contamination.

Acting on the recommendations from investigators, officials spent considerable money to upgrade and balance the ventilation systems. They also replaced the humidification system, installing one that uses a totally separate water supply without the anticorrosives.

As a result, reports of new illnesses have ceased. Many of the workers who were out sick from the initial outbreak have returned to work, although, according to Fox, about 85 are still out on long-term disability and are being treated for EID.

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