Indoor Air Quality Update™

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

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In This Issue

ASHRAE Ventilation Standard Close to Adoption

The draft Standard 62-1981R, "Ventilation for Acceptable Indoor Air Quality," cleared a major hurdle and moved one giant step closer to adoption at ASHRAE's Winter Meeting in Chicago last month. The new standard will have a very significant impact on nearly everyone and everything concerned with indoor air quality. (We describe those implications in the feature article of this issue.)

The ASHRAE Standards Committee approved the committee draft with only minor changes, in response to one of the six appeals it considered. Lawrence Spielvogel, an independent consulting engineer, had submitted an enormous appeal; it was the only one resulting in modifications to the draft standard.

Spielvogel raised scores of objections, many of them on procedural grounds, and the Standards Committee's actions were primarily on procedural matters relating to the standards adoption process. The changes required by the Standards Committee's action will not seriously affect the important provisions of the standard.

What's Next?

Now the draft standard will undergo minor revisions and move through ASHRAE's adoption process. The ASHRAE Board of Directors is likely to adopt the draft standard when they hear it in the next few months. Spielvogel told us he intends to appeal again when the board considers the draft in its last step before adoption. However, based on comments Spielvogel made during the Standards Committee hearing as well as privately to us, we would not be surprised if he filed a lawsuit as well, perhaps after final adoption by the ASHRAE Board of Directors.

Implications of the New Standard

Since the ASHRAE Standard 62, "Ventilation for Acceptable Indoor Air Quality," is really the only game in town (or on this continent, for that matter), it has tremendous significance. Many state building codes incorporate it by reference. Recent legislation in some states mandates its implementation, either within the code process or apart from it.

Design professionals (who are already increasingly concerned about liability and lawsuits) are way out on a limb if they do not use it. The provisions of the existing Standard 62-1981 are often used as a basis for evaluating performance for indoor air quality investigations and for legal actions that often follow such investigations. After all, it is the best effort of professionals and researchers with considerable knowledge and wisdom about ventilation and indoor air quality, and it was several years in the making.

Promulgation of the new standard will significantly increase attention to several aspects of HVAC system design and operation:

- Outside air delivery to the occupants.
- Maintainable HVAC systems.
- Filtration and cleaning of air that doesn't meet federal ambient air quality standards, and of recirculated indoor air.
- Thorough documentation of design criteria and system characteristics.

See page 3 for more details. ♦

HVAC Commissioning Guidance from ASHRAE

An important and often neglected part of building construction is the "commissioning" process.

The high cost of money and the sense of urgency it breeds frequently mean that newly constructed buildings are occupied before they are ready. A classic example is the Gregory Bateson State Office Building in Sacramento, which put indoor air quality on the California public agenda in 1981. That much-touted, innovative, energy-conserving office building was occupied a year before some of its important environmental control system components were fully operational. Complaints, claims, and even lawsuits followed.

Now, engineers, contractors, and building owners alike are seeing the importance of making sure that a building is operating correctly before it is occupied and the contractor walks away, final payment in hand. Authorities we spoke to claim it is cost effective and just plain good sense to include a formal, comprehensive HVAC system commissioning process in the construction contract. If it is clearly spelled out at the outset, they told us, it actually won't cost any more and it will save a lot of trouble.

An ASHRAE committee is developing guidelines for HVAC system commissioning. A "Public Review Draft for Commissioning HVAC Systems" was released last June after almost a dozen committee meetings. Insiders expect formal adoption by ASHRAE's Board of Directors at the June meeting in Vancouver.

Several papers presented at ASHRAE's Winter Meeting in Chicago provided a preview of what the committee chair and other members believe will be in the final guidelines. Details are described in the Tools and Techniques article, "HVAC System Commissioning Guidelines," on page 10. ♦

EPA Considering SEIU Asbestos Petition

Last month we wrote about the Service Employees International Union (SEIU) submitting an asbestos rulemaking petition to EPA. SEIU petitioned to have EPA initiate rulemaking about the inspection and abatement of asbestos in public and commercial buildings. The law required a response from EPA by February 7th.

On January 30, SEIU representatives met with EPA asbestos staff and counsel, who told the union that if a decision were rendered on February 7, it would be a denial. If that had happened, SEIU was prepared to go to court, as it has done in the past, to seek the basic protections it believes are required by TSCA (Toxic Substances Control Act). In 1986 SEIU obtained a summary judgment order in federal court that an earlier rulemaking be initiated. Recognizing the facts discovered in SEIU's lawsuit, Congress enacted the Asbestos Hazard Emergency Response Act, AHERA, mandating the issuance of rules on remediation of asbestos hazards in schools.

SEIU's Bill Borwegen told us that the union was encouraged by the tone of the January 30 meeting, in which EPA's representatives appeared more open than in the past to the union's arguments. Those arguments are essentially that EPA's own data and related rules (school asbestos inspection and abatement) contain persuasive evidence of the need to extend the protection of maintenance workers and building occupants to non-school buildings. EPA had previously indicated that a shortage of resources, and not lack of merit, would drive the decision toward petition denial.

On February 3, SEIU President John Sweeney wrote to the new EPA administrator, William Reilly, saying that the union will not file a suit now, to "avoid the delay and expense of litigation" in the hope that the Agency will assert its "leadership role" and commence "such rulemaking and promulgation of rules as the record may show to be required."

EPA has until early April to act, before SEIU's time to file a legal action on the current petition expires. SEIU is prepared to file a lawsuit, but it is clearly in the interest of all parties that such a suit be avoided. Sooner or later, one way or another, asbestos hazards must and will be addressed in nonschool public access buildings. As Sweeney pointed out in his letter, "in the absence of regulatory controls, real estate market pressures appear to be causing actions that, because they are not adequately controlled, are causing unnecessary risk to life and waste of money." ♦

Table 1. Key Features of ASHRAE Draft Standard 62-1981R.

1. Design documentation is required.
2. Maintainability of HVAC systems is required.
3. Outside air used for ventilation must meet federal standards.
4. The required outside air quantities must be delivered to the occupants' breathing zone.
5. Control of indoor air pollutant sources is mandated.
6. Minimum outside air is 15 cfm/p; in most cases it is 20 cfm/p or more.
7. HVAC design and operation must respond to IAQ loads, not just thermal loads.

Feature

The Revolutionary New ASHRAE Ventilation Standard

The draft revised ASHRAE standard, "Ventilation for Acceptable Indoor Air Quality," is a virtual outline for a guide to preventing indoor air quality problems. Implementation of the standard will result in radical changes in design practice; in equipment selection, operation, and maintenance; and in evaluation of problem buildings. In fact, in the words of one practicing ventilation engineer, the standard implies "a whole new way of practicing engineering."

The feature of the draft standard that has received most public attention is the set of recommended minimum outside air ventilation rates. A base minimum is established at 15 cubic feet per minute per person (cfm/p), replacing the existing minimum of 5 cfm/p (smoking not allowed) and 20 cfm/p (smoking permitted). For general office space the recommended minimum is 20 cfm/p, and the rates vary according to the type of occupancy: for meeting rooms it is 35 cfm/p and for smoking lounges it is 60 cfm/p.

The required minimums in the new standard may impact many existing buildings, which were designed to provide only 5 cfm/p under many typical operational conditions. This is especially true of buildings built since Standard 62-73 was adopted in 1973. Standard 62-73 revised required minimum outside air quantities downward to 5 cfm/p. Some 1975 to 1988 buildings do not have equipment capable of delivering any more than that minimum during much of the year. When investigations or complaints result in recommendations for increased outside air flow, many existing buildings will simply be unable to supply it.

We believe that most engineers and others consider the ASHRAE ventilation standard important to establish outside air ventilation requirements and little else. The detailed requirements of the existing standard have not necessarily been followed. In fact, both the existing and the emerging standards go far beyond simply prescribing outside air ventilation rates.

Important Features of the New Standard

The features of the new standard that we think will most influence design and operation of buildings in the future are shown in Table 1.

Some of these features are more or less requirements of the current standard. But designers have been ignoring most of them. The new standard will emerge in an environment in which indoor air is receiving far greater attention from designers, their clients, regulators, and the public. We expect promulgation of Standard 62-1989 (as it will be called) to generate much attention in the professional, trade, and popular press.

We think all these features are worth implementing immediately, regardless of the legal status of the ASHRAE standard. In some cases, they simply reflect good professional or business practice. In others, the rationale is so obvious in terms of avoiding IAQ problems that to ignore them is to run a great risk. We are currently advising clients — designers, owners, and tenants — to adopt these practices now.

In the remainder of this article we discuss each of these seven features and their implications for indoor air quality.

1. Design Documentation

Investigators of problem buildings have frequently found that the buildings were simply not being operated as designed. In some cases, they have identified load changes from increasing occupant density or changing use patterns and activities as exceeding design capacity or operationally determined capacity. In other cases, changes in operating procedures to conserve energy have violated design assumptions. Requiring design documentation can prevent or mitigate many of these and other problems.

Among the major causes of indoor air quality problems are changes in building loads without appropriate modification of ventilation system equipment or operation, and changes in building system operation to conserve energy without regard for the indoor air quality impacts of the changes.

Building loads change with increased occupant density or the initiation of new activities which generate pollutants. Often the load or use changes are made without regard for ventilation system capacity to control or remove contaminants or to handle thermal loads. The impacts of the load changes may overwhelm the HVAC system, which responds to thermal but not air quality loads.

The draft standard does not delineate required details of design documentation. It makes it clear that the designers must identify their design assumptions regarding ventilation rates and air distribution. Adequate documentation of these assumptions could be revolutionary by itself. If the documentation spells out what we think is necessary, it will include the items in Table 2.

Transmitting the Design Documentation

The draft standard does not specify how the design documentation is transmitted from designer to owner, operator, or future designer. This will be worked out in practice. In order to protect themselves from liability, everyone in the process will need to identify and define their own roles and responsibilities in creating, maintaining, and transmitting the documentation. And, of course, everyone will be expected to consult it when its contents might inform their activities or decisions.

Copies should be kept by the design engineers, the architects, the building owner (developer or subsequent purchaser), and the building management (operator).

Assumptions made in the design will be incorporated into leasing agreements and building rules. In speculative office buildings or even in owner-occupied buildings, the characteristics of occupancy are often unknown when the design assumptions are made and even when the building is built. Designers rarely know the details of the eventual occupancy.

Under the new standard's requirements, the assumptions which drive the design will be documented and available when actual occupancy conditions or intentions become known. It will then befall the responsible parties (owners, tenant improvement designers, mechanical contractors, code officials, or others) to evaluate the actual plans in light of the design assumptions. Where the original (or other previous) design assumptions turn out to be invalid, redesign or modification of the system or its operation will have to be considered.

Building operators will also be expected to receive a copy of the design documentation. If they choose to deviate from the assumptions about operation, they will need to perform the necessary analysis to justify any changes. This may involve retaining the original design engineer or another engineer to perform the analysis. In concept, the assumptions made and analysis performed here will also have to be documented.

When major (or even minor) remodel projects are designed, the original design assumptions will be available to the remodel design team. Knowledge of the design assumptions will be useful in evaluating the capacity of the system to handle the changes. Necessary modifications should reflect the designed capacity of the system in place or the modifications necessary to provide acceptable indoor air quality.

Design Documentation Will Improve IAQ

Creating the design documentation and the process of making it available to building operators, future designers, investigators, and even potential tenants has the potential to eliminate many (but certainly not all) of the sources of indoor air quality problems. This is a neces-

Table 2. Suggested Elements of Design Documentation

A. Design Criteria:

1. Indoor design conditions (all seasons): Temperature, relative humidity.
2. Outdoor design conditions (all seasons): Temperature, humidity, wind direction and velocity, location and timing of outdoor sources of air pollutants.
3. Assumed or anticipated occupant densities, activities, and use patterns for each space or type of space in the building.
4. Assumed electrical load for light and power.
5. Any special loads which might exist.
6. Outside air supply rates under various operating conditions and loads.
7. Assumed ventilation effectiveness for each type of space under HVAC system modes of operation which result in differing supply design conditions. Assumed distribution characteristics for each ventilation or air circulation condition including conditions of minimal air circulation and of upper and lower supply air temperature limits.
8. Definition of building envelope, including type and characteristics of materials and assumed infiltration.
9. Air quality design criteria.
10. Code requirements.
11. Noise criteria.
12. Fire and safety requirements.
13. Energy efficiency and projected operating cost.

B. HVAC System Description:

1. Basic system types.
2. Major components.
3. Capacity and sizing requirements.
4. Redundancy provisions.
5. Intended operation in each seasonal mode, including designed changeover conditions.
6. Changeover procedures.
7. Part-load operational strategies for each season.
8. Occupied/unoccupied modes of operation for each season.
9. Design setpoints for control system, including permissible lists of adjustments.
10. Operation of system components in life safety modes.
11. Energy conservation procedures.
12. Any other engineered operational mode of the system.

sary and valuable part of the proposed standard.

Design documentation resembling that suggested in Table 2 is necessary for commissioning the HVAC system, and its preparation is likely to occur in that connection if not in response to the new ventilation standard.

2. HVAC System Maintainability

Building investigators have traced many indoor air quality problems to inadequate, inappropriate, or nonexistent maintenance. Making HVAC systems maintainable is a requirement of the new standard, in response to the frequent finding of poor maintenance in problem buildings.

The identified maintenance problems range from dirty filters to gobs of microbial slime growing in drip pans under condenser coils or in cooling towers. Dirt and debris accumulated in HVAC systems directly contaminate indoor air or nourish microbial growth that eventually contaminates indoor air. In many cases, simple periodic inspection and cleaning are lacking, but their absence is sufficient to cause significant indoor air quality problems.

Many HVAC systems, particulary small "packaged" units such as rooftop air handlers or room fan coil units, are inaccessible for routine or special maintenance. The new standard implicitly forbids inaccessible components by requiring that all components be easily inspected and cleaned. This will have a revolutionary impact on many manufactured products and on those who design, operate, and maintain HVAC systems.

Some Basic Maintenance Requirements

The draft standard does not spell out specific maintenance requirements. Our experience suggests that the design should support the following broad categories of maintenance:

- Periodic, routine inspection, cleaning, adjustment, and replacement of such HVAC components as filters, air cleaners, cooling and heating coils, humidifiers, drip pans, and motor drive belts.
- Checking and adjustment of thermostats, time clocks, sensors, and other components of the HVAC controls at least once a year.
- Special inspections and cleaning at least once a year for all major HVAC components, including surfaces exposed to the flow of air. Particular attention to fibrous insulation materials, return air plenums, and other concealed surfaces.
- Seasonal modifications in equipment usage accompanied by specific maintenance operations, including checking out performance of equipment that has been off-line, decontaminating cooling towers in the spring, and cleaning heat exchange surfaces (heating or cooling coils) periodically.

3. Outside Air Must Meet Federal Standards

The draft standard requires that outside air used for ventilation meet the EPA's National Primary Ambient Air Quality Standards. This provision is in the existing standard, 62-1981. However, it has been ignored.

We are not aware of any building design that explicitly controls IAQ ventilation by monitoring and cleaning outside air specifically to meet federal standards (see Table 3). When we try to apply the ASHRAE standards (existing or revised) we see no way to avoid compliance with this provision. Its application varies greatly from one part of the country to another and is particularly important in heavily urbanized areas where air quality is worst.

The contaminants of concern will vary from one locale to another, and in some areas there will be little to worry about. But in most major metropolitan areas in the United States, ambient air quality fails to meet at least some of the six criteria pollutant standards some of the time.

The most frequently violated standards are those for carbon monoxide and ozone. In a small number of locations and at infrequent intervals the particulate mat-

Table 3: National Primary Ambient Air Quality Standards

	LONG TERM			SHORT TERM		
	Concentration		Averaging	Concentration		Averaging
CONTAMINANT	µg/m³	ppm	time	µg/m³	ppm	time
Sulfur dioxide	80	0.03	1 year	365[a]	0.14[a]	24 hours
Particulate matter (PM10)	50[b]		1 year	150		24 hours
Carbon monoxide				40,000	35	1 hour
Carbon monoxide				10,000[a]	9[a]	8 hours
Oxidants (ozone)				235[c]	0.12[c]	1 hour
Nitrogen dioxide	100	0.055	1 year			
Lead	1.5		3 months[d]			

a) May be exceeded only once per year

b) Arithmetic mean

c) Standard is attained when expected number of days per calendar year with maximal hourly average concentrations above 0.12 ppm (235 µg/m³) is equal to or less than 1, as determined by Appendix H to sub chapter C, 40 CFR 50

d) 3-month period is calendar quarter.

ter concentrations exceed federal standards.

Most major metropolitan areas have elevated levels of carbon monoxide (CO) at least a few days each year, and many areas violate the CO standard 10 to 30 days a year. Similarly, many areas violate the ozone standard a few days a year, and a few areas exceed it more than ten times a year. In the greater Los Angeles area, the federal standard for ozone is exceeded almost half the days of the year (nearly all summer long) and at times it is exceeded by a factor of two. And the LA area violates the CO standard more than fifty days a year.

Controlling Contaminant Levels

Ozone can be practically and effectively removed by activated carbon filtration. The question is whether buildings will need banks of charcoal filters to control ozone when it is elevated outdoors. Will they use sensors to monitor outdoor ozone and input data to a computer, which is programmed to determine the best ratio of filtered outside air and filtered recirculated air? That would be permissible under the air quality procedure of the existing and the draft revised standard, but it would require sensors to monitor key indoor air pollutants; or it would require air cleaning capable of controlling them to below the guideline levels.

Carbon monoxide can be controlled with hopcalite, a mixture of oxides of copper, cobalt, manganese, and silver that serves as a catalyst to convert CO to carbon dioxide. Questions arise about the magnitude of the resulting levels of CO_2 and about the economics of using large quantities of hopcalite.

The draft standard requires that where available, the best demonstrated and proven technology must be used. Where such technology is not available, outside air quantities may be reduced during periods of high contaminant levels.

Will additional sensors be employed inside to measure various contaminant levels and determine the air cleaning requirements for recirculation air? What are the economic tradeoffs between cleaning and recirculating indoor air and cleaning and conditioning outdoor air? These are some of the new and challenging questions for design engineers, architects, and building owners to address in the coming years.

The Air Cleaning Business Will Fluorish

Whether the air quality procedure or the ventilation rate procedure is used, many areas of the country will require filtration. This will entail significant differences from present practice; most public access buildings use media filters to capture larger particles and do not control gaseous contaminants.

Filter and air cleaning equipment manufacturers are headed for boom times. New products that are more cost effective may also appear on the market.

4. Outside Air Delivered to the Breathing Zone

The draft standard's outside air requirements were based on an implicit assumption about ventilation effectiveness. While the standard may consider a modest shortfall of required outside air to be acceptable, systems will need to supply additional quantities to compensate for significant inefficiency or shortfall of outside air delivered in the breathing zone.

Definition of "acceptable inefficiency" will probably be an important issue of lawsuits until the appropriate professional or regulatory groups clearly establish it. In an illuminating response to Mr. Spielvogel's appeal (see first page, News and Analysis), project committee chairman John Jannsen said that the required outside air ventilation rates allow for some loss of efficiency, although he did not say how much.

This is a critical point, since the majority of the attention given to the standard revision by the engineering and indoor air quality communities is focused on the minimum outside air requirements.

The draft standard spells out the outside air requirements for various specific building types and uses, and states that values assume well-mixed conditions (where ventilation effectiveness approaches 100%).

If ventilation effectiveness is typically in the 50 to 80% range, as reported by such authorities as John Jannsen and James Woods, then 125% to 200% as much outside air as required in the standard will need to be cleaned, conditioned, and distributed by the air handling components. This could substantially increase costs for equipment capacity, energy consumption, and maintenance requirements. Jannsen has investigated and written about ventilation effectiveness since the mid-1970s. One of his papers is referenced in the draft standard (and at the end of this article).

There is still disagreement about ventilation effectiveness and its measurement, and the first designers to apply the new standard will have to resolve the issues in practice.

Ventilation Effectiveness Controversy

Ventilation effectiveness is the fraction of the outdoor air delivered to the space that reaches the breathing zone. The intended or actual occupants and their activities define the breathing zone. Generally, the breathing zone in an office is from 42 to 72 inches above the floor. A sleeping room would have a lower bottom limit.

Authorities disagree about whether supply air mixes well after entering the room from supply diffusers. Some argue that horizontal stratification of room air occurs, which means that supply air does not mix well with room air and fewer contaminants are removed. Some investigators argue that supply air short-circuiting back to return inlets reduces the delivery of outside air to the breathing zone.

Other researchers argue that their very careful measurements do not indicate poor or incomplete mixing within spaces. They do find differences in contaminant removal rates or supply air distribution rates (depending on how one interprets their data) among different rooms or areas within a building.

The ventilation effectiveness question is an important one. It appears that different measurement systems and methods used by the various authorities produce different data and conclusions.

No field work has been done that convincingly demonstrates which view is correct. It is possible that both groups' findings are valid for the cases they have investigated; or, it is possible that there are implicit assumptions in the methodologies which are producing consistent results for each side.

The imminent adoption of the new ventilation standard makes the resolution of this issue important. We hope that those who fund IAQ research will recognize the significance of this question and stimulate research on ventilation effectiveness.

5. Control Indoor Air Pollutants at the Source

This feature of the standard requires that HVAC systems collect contaminants from local sources close to the source and exhaust them to the outside. Many activities that occur in offices, schools, shops, libraries, and other public access buildings produce indoor air contaminants.

An important example is the office photocopier or computer printer. These devices emit particulate matter and either volatile organic chemicals or ozone or both, depending upon the printing technology employed. As these devices proliferate in modern offices, so do their emissions.

Modifications of the devices, maintenance and cleaning, and the use of filters on their exhaust can provide effective control. Placing them away from densely occupied areas and adjacent to exhaust inlets can reduce their impact on indoor air quality. But exhausting their emissions directly to the outside, without recirculating them, may be necessary under the new standard, especially for larger, more heavily used copiers and printers.

This will be a difficult requirement to meet because copiers and printers are frequently added to existing space. Providing stub-outs for exhaust systems and making them accessible throughout a space will challenge designers and builders alike. It is far easier to run the power supply to a new location for a copier than to run an exhaust duct that will vent to the outside. Designers should consider systems which will allow such exhaust to be installed where and when required.

Machines, building materials, and furnishings all emit indoor air pollutants which HVAC systems must control. Designers and builders will focus increasingly on eliminating the sources of pollutants rather than on controlling them through ventilation.

This is the real wave of the future, because it can be done at little or no extra cost and it is a long-term solution without on-going costs. Researchers and product manufacturers alike are currently developing and using materials emissions testing. Designers and regulators have begun to seriously examine its potential and a few are already applying it. (See *IAQU*, December 1988.)

A number of specific building locations, such as humidifiers, drip pans, fibrous insulations, and moistened carpeting, are sources of bioaerosols — molds, mildew, fungi. Controlling humidity can reduce the amplification of these organisms. A narrower range of allowable humidity, 30% to 60%, is called for by the draft standard and will improve the chances of controlling bioaerosol sources.

6. Minimum Outside Air Requirements

While this requirement of the draft standard generally receives the most attention, its implementation and verification have not been the subject of much discussion.

Apart from making certain design assumptions based on outside air requirements, designers will have to model (either mathematically or physically) the performance of HVAC systems to confirm that the designed flows will be achieved. And they will have to show this for part loads and full loads under the various designed modes of operation. If designers do not perform such modeling, then they will have to oversize the systems to allow adjustment during commissioning to meet requirements in the actual building.

Building owners will be looking for evidence that the design requirements have been met. Management firms taking responsibility for operating buildings will want evidence of the building's performance. And tenants will also want to see such evidence. This is likely to take the form of additional measurements at the time of air balancing or commissioning.

Whole new areas of professional responsibility will develop and evolve as this requirement of the new standard is implemented.

7. HVAC Design for IAQ

HVAC design and operation must respond to indoor air quality as well as to thermal loads. For the past three decades or more, HVAC designers have considered indoor air quality simply by assuming certain outside air supply rates. From there on, most of the design concerned thermal and, sometimes, humidity control.

Indoor air quality became an invisible, implicit but neglected, consideration. And the HVAC systems technology and design evolved to control temperature. As energy costs became more important, design incorporated and even was dominated by conservation, often at the cost of indoor air quality.

We believe all this is changing and that the new standard will catalyze an acceleration of the change process. Law suits and problem buildings have already contributed substantially to modest changes. But the new standard will be the subject of intense attention, as engineers try to determine how it will affect their practices.

Our own clients have already begun to ask for assistance in meeting the requirements of the new standard, in order to assure themselves that their buildings will be comfortable and legally problem free.

For More Information

ASHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality." Atlanta: ASHRAE, Inc. 1981. ASHRAE Standard 62-1981R, Public Review Draft, "Ventilation for Acceptable Indoor Air Quality." Atlanta: ASHRAE, Inc. 1986.

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On the Horizon

ASTM Balloting Measurement Methods for Nicotine and VOC

ASTM Subcommittee D22.05 on Indoor Air is currently balloting two indoor air sampling methods of considerable importance. They are for nicotine and for volatile organic compounds (VOC) respectively.

1. New Standard Test Method for Nicotine in Indoor Air.

This method collects nicotine using personal or area active sampling at one L/min into a tube containing XAD-4 resin adsorbent. This method is for the collection of nicotine in the vapor phase, which studies have shown to comprise 90% of nicotine in indoor air. Since low concentrations of nicotine (as low as 1.8 $\mu g/m^3$) have been found in indoor air, sophisticated analytical procedures and equipment are necessary.

The sample is solvent desorbed and an aliquot is injected into a gas chromatograph equipped with a thermionic specific (nitrogen-phosphorous) detector. Limits of detection and quantitation (in $\mu g/m^3$) at the one L/min sampling rate for one hour are 0.17 and 1.7 respectively and for 8 hours are 0.02 and 0.2 respectively. Both the LOD and LOQ can be reduced by increasing the sensitivity of the thermionic specific detector.

2. New Standard Test Method for Determination of Volatile Organic Compounds in Indoor Air Using Multibed Adsorbent Tubes and Gas Chromatography/Mass Spectrometry (GC/MS).

This method uses a multibed adsorbent tube containing graphitized carbon blacks and a carbon molecular sieve and determination by thermal desorption and GC/MS techniques. The method eliminates some of the quantitation limits involved with traditional activated carbon sampling with solvent extraction. By using nitrogen desorption in a cold trap and injection into the front section of the GC held at very low temperatures, the entire sample can be used for analysis, and lower detection and quantification limits can be achieved.

As with other activated carbon collection, only nonpolar organic compounds are collected by this method.

ASTM Process

ASTM is an open membership organization. Membership is not required to participate, although only members can vote. Comments from all interested parties are considered during the standards development process.

Subcommittee D22.05 on Indoor Air develops sampling and analytical methods for determination of indoor air. The subcommittee has also developed protocols for investigations, selection of sampling methods, and other related matters. The next meeting of the Subcommittee will be June 6-8 in Philadelphia. For copies of the draft standards or information on participation, contact George Luciw, Staff Manager, Subcommittee D22.05, ASTM, 1916 Race Street, Philadelphia, PA 19103; (215)299-5571. ♦

Business Council on Indoor Air Formed

A group of chemical manufacturers, ventilation companies, and consumer products companies, have joined to form a new Washington, DC-based indoor air organization. The Business Council on Indoor Air (BCIA) will try to increase understanding of indoor air and ensure that sound science is used to assess exposure to indoor air contaminants.

BCIA intends to advise federal and state officials in the development of reasonable goals for indoor air quality to protect human health and of methods to achieve these goals. This is the usual agenda for industry groups facing possible or imminent government regulation. Its formation is another sign of the growing attention indoor air quality is receiving.

For more information, contact: BCIA, 1225 19th Street, N.W., Suite 300, Washington, DC 20036; (202)775-5887. ♦

Tools and Techniques

HVAC System Commissioning Guidelines

Commissioning HVAC systems according to ASHRAE's draft guideline can identify and correct equipment and operational problems before they affect indoor air quality and occupant health and comfort. And it can do so at little or no extra initial cost.

According to one ASHRAE committee member, Cedric Trueman of the British Columbia Buildings Corporation (BCBC), it is cost effective to employ comprehensive commissioning procedures.

Trueman has estimated the costs involved in implementing an effective commissioning process and compared them with the estimated costs avoided when commissioning is not properly completed. His estimates, based on the BCBC process and data, appear in Table 4. While he emphasizes that many of the numbers are merely guesstimates, his organization is thoroughly convinced that proper commissioning is cost effective.

The results show that it is clearly cost effective to plan and execute a complete and proper HVAC system commissioning process, at least for BCBC. So we asked another committee member, Harvey Brickman, senior vice president of the Tishman Construction Corporation in New York, what his experience was with commissioning. His answers corroborated Trueman's. In fact, Brickman told us that, if clearly documented in the construction contract and followed during implementation, HVAC system commissioning would not cost any more at all.

Committee Chairman Doug Stone of Douglas T. Stone, P.E. & Associates, Engineering Consultants in Dallas, Texas, said that the concept of HVAC commissioning has been used effectively in Europe and Canada for a long time.

What is HVAC System Commissioning?

The major components of an HVAC system commissioning program are described in Table 5. They involve comprehensive planning, documentation, and implementation. Another way of thinking about it is that proper commissioning is merely doing it right and making sure that it is done right.

Some of our clients are already asking for assistance in commissioning HVAC systems. We see this as an essential part of all major construction contracts in the future. It is in everyone's interest to do it right. The question that occurs to us is whether HVAC system commissioning will be expanded to cover all components and systems in new buildings in the near future. We think the answer is "yes"! ♦

Controlling ETS with Electrical Fields

Using electrical fields in ducts may alleviate the discomfort caused by environmental tobacco smoke (ETS). According to Allen Frey, a researcher at Randomline, Inc. of Huntingdon Valley, Pennsylvania, electrical fields in ducts reduced the airborne concentrations of ETS to levels that

Table 4: Economics of HVAC Commissioning
(Estimates from British Columbia Buildings Corporation)

ITEM	$/SQ FT BASED ON HVAC	COMMENT
A. COSTS FOR COMMISSIONING		
Designer	$0.02 - 0.10	Additional time spent on site to witness and verify functional performance testing.
Contractor	$0.10 - 0.20	Direct commissioning activities. If documented at beginning, results in no additional costs for construction and avoids call-backs.
Owner	$0.025 - 0.10	Additional involvement of operational staff during construction: familiarization with systems.
SUBTOTAL	$0.145 - 0.40	
B. AVOIDED COSTS		
Energy	$0.13 - 0.26[a]	Shortens usual 3 year period for building operators to learn optimal energy operation.
Maintenance	$0.15[b]	Estimated reduction due to proper initial functioning of equipment and training of operational staff; present value for 5 years' savings.
Construction	$0.07	Correction of construction problems defects by contractor prior to occupancy and at no cost to owner.
Satisfied	$0.25[d]	Avoiding meetings to resolve tenants problems, avoiding absence due to illness.
SUBTOTAL	$0.60 - 0.73	
C. NET RESULT:	**$0.20 - 0.515 / SQ FT**	**SAVINGS OVER FIRST FIVE YEARS.**

a. Present value calculation
b. Estimated from actual cost data
c. Based on studies of 5 buildings, 2 had serious problems, costs averaged over 5 buildings.
d. Based on the following assumptions:
Every fifth person in meetings 30 min./mo. = $0.10/yr/sq ft
Owner meetings and direct costs = $0.05/yr/sq ft
Every fifth person out of work (illness) 2 days/year = $0.25/yr/sq ft

other researchers believe may not cause discomfort.

The alternative, providing very high air exchange rates to reduce airborne levels of ETS, could be prohibitively expensive. But Frey's data indicate that electrical fields are extremely effective. ETS consists of both gaseous and particle fractions, and the gases appear to be most involved in the reported discomfort.

Before recommending this approach, we would like to know if there are any potentially harmful effects of introducing electrical fields within building HVAC ducts.

We are also interested in what ultimately happens to the ETS treated by the electrical field. Presumably the particulate matter coagulates and smaller particles or charged particles plate out on all available surfaces, while heavier particles fall onto horizontal surfaces.

Thus, the removal is of short-term value, but the space is loaded over time with particulate matter containing the condensed or particulate phase components of ETS. And the particulate matter provides a large surface area for condensation of gases from the vapor phase. Many of the low vapor pressure chemicals in ETS are known to be toxic or carcinogenic. They would be most likely to adsorb or condense onto particle surfaces.

Presumably, electrical fields in duct work are being advocated for ETS (and other) airborne contaminant control. Will this technique be effectively commercialized and achieve widespread use? The answer in the short run will have as much to do with the perceived need as it will with the effectiveness of the approach.

For more information contact Allen Frey, 1334 Orcap Way, Southampton, PA 18966; (215)355-8265. ♦

Table 5: HVAC System Commissioning Process

Design phase (by architect/engineer)

- Establishment of clear design criteria
- Documentation of HVAC design criteria and systems description (see Table 2, page 5)
- Preparation of a commissioning plan
- Describe verification procedures
- Define documentation requirements for commissioning process including all reports, submittals, drawings, schematics, checklists, operating data, maintenance data, and as-built documentation.

Construction phase

- Pre-commissioning contractor preparation for start-up
  - Personnel selection
  - Pre-commissioning meeting of designer, owner, and contractor representatives
- Actual system start-up: initial operation of all equipment
- Final start-up — complete performance inspection
  - Temperature control system
  - Facility automation system
  - Testing and balancing
  - Equipment documentation

Final commissioning

- Meeting of all relevant parties to discuss system and answer any questions about system sequences, set points, operation; review all final documentation for submittal to owner.
- Assemble all documents for submittal to owner
- Train operational personnel in the following:
  - System philosophy
  - System familiarization
  - System sequence
  - System maintenance
  - System diagnosis
  - Facility automation system

Model for Predicting Fate of ETS

Researchers and investigators now have another modeling tool at their disposal, this one for predicting the fate of environmental tobacco smoke (ETS). The model is a sophisticated and complex one, like those that preceded it from this pair of prolific scientists, Bill Nazaroff (formerly of Cal Tech and now at the University of California at Berkeley) and Glen

Cass of California Institute of Technology (Cal Tech).

The model accounts for the effects of ventilation, filtration, deposition onto surfaces, direct emission, and coagulation. The mathematical model was tested against data from field studies, and the model performed pretty well, the researchers said.

The model may be applied to other environmental problems including the soiling of surfaces due to deposition of airborne particles and human exposure to ETS. It might also be useful in improving our understanding of the risk associated with human exposure to radon decay products.

For more information: Nazaroff, W. and G. Cass, "Mathematical Modeling of Indoor Aerosol Dynamics." ***Environmental Science & Technology***, Vol. 23, No. 2, pp. 157-166.

Contact: William Nazaroff, Department of Civil Engineering, University of California, Berkeley; (415)642-3261. ♦

Passive Smoking, Health, and the Law

An article in the February 1989 issue of the ***American Journal of Public Health*** (AJPH) summarizes the health effects and legislative status of environmental tobacco smoke. It describes the known health effects of exposure to ETS, the strength of the evidence available, and the trends in lawsuits stemming from exposure.

The article is a comprehensive guide to the subject and a valuable resource if you are concerned with indoor air quality, smoking policy development in buildings, or the health effects from exposure to ETS.

For more information: James C. Byrd, Robyn S. Shapiro, and David L Schiedermayer, 1989. "Passive Smoking: A Review of Medical and Legal Issues." ***AJPH*** February 1989, Vol. 79, No. 2, pp. 209-215.

For reprints, contact James C. Byrd, MD, MPH, Associate Chief of Staff for Ambulatory Care, Clement J. Zablocki, VA Medical Center, 5000 West National Avenue, Milwaukee, WI 53295-1000; (414) 384-2000. ♦

Expanded Mass Spectrometry Database for PCs

NIST (National Institute of Standards and Technology, formerly the National Bureau of Standards) has issued a revised and expanded version of NIST/EPA/MSD Mass Spectral Data Base, and it is now available. It contains about 50,000 compounds and the structures for more than 40,000 of them. The database is available on magnetic tape or in a new PC version, which sells for $975. Upgrades from Version 1.0 cost $225.

The database will allow more rapid identification of chemical substances, particularly useful for volatile organic compounds in indoor air. The PC version will allow wider dissemination of the information and make it accessible to more laboratories. The result should be an increase in services available to indoor air investigators and researchers alike.

For more information contact Office of Standard Reference Data, A320 Physics Building, NIST, Gaithersburg, MD 20899; (301)975-2208. ♦

Practical Research Briefs

Radon Mitigation: Ventilation and Energy

It is far more effective and energy efficient to control radon entry into a building than to remove it once it gets in. David Harrje of Princeton University told us this conclusion results from investigations at several homes where researchers measured air flows, radon levels, and the effects of various radon mitigation strategies.

Harrje's main point, presented in a paper at ASHRAE's Winter Meeting, was that there are additional energy costs of virtually all of the radon control techniques. Radon mitigation systems can exhaust large quantities of conditioned air in residences. Measurements by Harrje and his co-investigators indicate that a typical value for exhaust rates of interior air is about 30 cfm (about 0.1 to 0.2 air changes per hour in a typical home). Besides their impact on energy costs, such radon control measures could also result in prevention of combustion products flowing up stacks, resulting in unsafe contamination of the home's interior.

Air-to-air heat exchangers minimize heat losses, but they do not eliminate them, and there is an energy cost to operating them — just as there is to any of the air pollution control technologies that involve moving air.

Subslab ventilation seems to have the least impact on energy consumption. It is even conceivable that it has some positive effects, as it may help reduce the impacts of the stack effect and circulate more warm air to lower portions of the building. This would be particularly important in an occupied basement area.

Space conditioning systems themselves can alter the pressures within the building, and that could interfere with the mitigation system. In the case of subslab depressurization, HVAC systems which depressurize basements or crawl spaces decrease the relative depressurization of the subslab. These considerations suggest that those involved in designing and installing mitigation systems need to consider the total structure as a system and analyze potential interactions between radon control and HVAC.

For more information: D.T. Harrje et al, "The Effect of Radon Mitigation Systems on Ventilation in Buildings," to be published in ***ASHRAE Transactions***, 1989, Vol. 95, part 1. Atlanta: ASHRAE, Inc.

Contact: David Harrje, Center for Energy and Environmental Studies, EQUAD, Princeton University, Princeton, NJ 08544; (201)452-5445. ♦

Removing Airborne Radon and Dose

According to Professor Dade Moeller of Harvard University's School of Public Health, most methods of flow-through air treatment for radon, such as filtration and electrostatic precipitation, are effective in reducing potential alpha energy concentrations (PAECs). But they subsequently result in a larger concentration of unattached particles when more radon gas decay products are formed. Professor Dade estimates that this results in a much larger dose to the bronchial tissues of people breathing the treated air.

Combining a portable fan with a positive ion generator unit, however, removes 75% to 90% of the total PAECs without increasing the radon decay products dose to bronchial tissues.

Since reducing dose to the bronchial tissues is the goal of controlling indoor radon and its decay products, the analysis of any air cleaning or other radon control method needs to include its impacts on dose. Dr. Moeller has correctly made this connection. And his device, the positive ion generator with a portable fan, works well, according to his measurements and analysis.

Some questions remain about the potential health effects of the increased positive ion concentrations. Research on the subject of air ions and health produces lots of controversy and does not seem to clearly point one way or another yet. Furthermore, the dose model used by Moeller is not the most current, according to sources at Batelle Pacific Northwest Laboratory, where considerable radon health effects research is conducted.

Nonetheless, Moeller's work is provocative. We hope he does the necessary calculations to update the dose analysis. As to the effects of positive ions, we do not anticipate that anyone soon will resolve the controversy and ambiguity that emerge from the research reported to date.

Moeller's device is commercially available, although we have no information on the product itself.

For more information: D.W. Moeller, E. F. Maher, and S. N. Rudnick, "Removal of Airborne Radon Decay Products," to be published in ***ASHRAE Transactions***, 1989, Vol. 95, Part 1. Atlanta: ASHRAE, Inc.

Contact: Professor Dade W. Moeller, School of Public Health, Harvard University, 677 Huntington Ave., Boston, MA 02115; (617)732-1000. ♦

Conferences

IAQ 89, the One Not to Miss

If there is one conference you should not miss, it is ASHRAE's annual IAQ conference. The theme of this year's conference is "The Human Equation: Health and Comfort," and it will be co-sponsored by the Society for Occupational and Environmental Health. IAQ 89 will take place in San Diego, April 17 - 20. Concurrently, the conference this year will feature a Manufacturers' Product and Services Session. Included in the session will be the following:

- Air purification technology.
- Radon analysis and reduction.
- Asbestos removal.
- Health effects of indoor air pollution.
- Filtration/controls.
- Products or services that aid in promoting health, comfort and clean air quality.

IAQ 89 continues the series of annual symposia that began with IAQ 86. Each year the conference has published the papers, and these are among the most useful and accessible publications for those interested in IAQ.

The emphasis on human health and comfort this year is an indication of possible future directions for ASHRAE, as well as for the design and regulatory communities. There has been some criticism of ASHRAE's ventilation standard because it is primarily a comfort standard with an attempt at protecting health. As more information emerges on the health effects of indoor pollutants, increased emphasis on health will be more practical and more popular.

For registration information, contact the meetings department, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329; (404)636-8400. ♦

Call for Papers

Papers are invited for Roomvent '90, Second International Conference on "Engineering Aero- and Thermodynamics of Ventilated Rooms," to be held in Oslo, Norway, in June 1990. Topics include the following:

- Methods for predicting air flow patterns, heat and mass transfer distribution of temperature, velocity and contaminant concentration in ventilated premises.
- Principles and technology for measuring room air velocities, temperature and contaminants.
- Principles and technology for measuring ventilation effectiveness and air exchange effectiveness.
- Characterization of heat sources and sources of contamination.
- Case studies.

Abstracts are due June 15, 1989, with notification of authors September 1989, and manuscripts are due January 15, 1990.

Contact: Room Vent, c/o Norsk VVS Teknisk Forening, P. O. Box 5042, Maj N-0301 Oslo, Norway. ♦

From Our Readers

Jean Mateson's IAQ Experience

Jean Mateson of Mateson Chemical Corporation wrote in with a correction on our article "Jean Mateson's IAQ Experience" (*IAQU*, January 1989, page 6):

"Page 6: Column 2, Paragraph 2: 'Mildew and bacteria strains ...' — 'Formaldehyde' should be 'organic particulate condensates,' i.e. Formaldehyde = Urea Formaldehyde Resin, where formaldehyde, itself, inhibits germ growth if free. Note: U-F Resins do disintegrate over time, especially if catalysts remain, where the urea fraction decomposes into amine derivatives, which in turn could smell and could be biodegradable — if the formaldehyde fraction off-gases. I am sure some of your readers will catch this and I wanted to make this correction first."

Yours very truly,
Jean F. Mateson,
President
Mateson Chemical Corporation

Editor's Reply:

We appreciate Mr. Mateson's letter and correction. Readers are encouraged to communicate with our office on any item which appears incorrect or inaccurate. We also welcome comments and suggestions as well as questions from our readers. ♦

Lead Abatement

A couple of our esteemed colleagues recently pointed out that lead paint is not a new indoor pollutant (*IAQU*, November 1988) and we agree. The point of our article was that removing lead paint, if not properly done, can result in a secondary problem, perhaps worse than the one it attempts to abate.

Certain methods of paint removal were found to seriously contaminate indoor air, perhaps worsening an already problematic situation. In this sense, the problem is similar to that created by improper or unnecessary asbestos removal. And parallels exist regarding the need to protect abatement workers and contain contaminants within a defined work area. We were particularly interested in the model program developed by the City of Baltimore and in the U. S. Dept. of Housing and Community Development's rules requiring testing of vacant dwellings in HUD-assisted projects.

We are anxious to hear your questions and your comments on this issue. Please write to our Editorial Office in Santa Cruz (address on back page of this issue). ♦

Calendar

Through March (schedule and locations listed below), **Reducing Indoor Radon**, New York State Energy Office. February 6-8: Central Valley, February 27- March 1: Binghamton, Mar. 13-15: Saratoga Springs, Mar. 27-29: Kingston. Contact: New York State Energy Office, Two Rockefeller Plaza, 8th Floor, Albany, NY 12202; (518)473-7243.

March 6-10, 1989. **Indoor Air Quality Diagnostics**, Honeywell, Golden Valley, MN. Contact: Honeywell IAQD MN10-1451. 1985 Douglas Drive North Golden Valley, MN 55422-3992; (612) 542-6488 or (800)232-4637.

March 7. **Radon: An Awareness Seminar: What It Is And What Can Be Done About It.** Atlanta, Georgia. Contact Education Extension -R, Georgia Tech Research Institute, Atlanta, GA 30332-0385; (404)894-2400, (800)325-5007.

March 8-10. **Combustion and the Environment**, Air and Waste Management Association (formerly APCA). Seattle, Washington. Contact: Meetings Department, Air and Waste Management Association, P. O. Box 2861, Pittsburgh, PA 15230; (412)232-3444.

April 17-18. **Air Change Rate and Air Tightness in Buildings ASTM Committee E6 on Performance of Building Constructions.** Atlanta, Georgia. Contact: Meetings Department, ASTM, 1916 Race Street, Philadelphia, PA 19103; (215)299-5400.

April 17-20. **IAQ 89: The Human Equation: Health and Comfort.** San Diego, California. Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329; (404)636-8400.

May 2-5. **EPA/APCA International Symposium on Measurement of Toxic and Related Air Pollutants.** Raleigh, North Carolina. Contact: Seymour Hocheiser, Environmental Monitoring Systems Laboratory. U.S. EPA, Research Triangle Park, NC 27711.

May 15-19. **Indoor Air Quality Diagnostics.** Honeywell, Golden Valley, Minnesota. Contact: See information above for March 6-10.

June 6-8, 1989. **ASTM Subcommittee D22.05 on Indoor Air.** Philadelphia, Pennsylvania. Contact: George Luciw, Staff Manager, ASTM, 1916 Race St., Philadelphia, PA 19103; (215)299-5571.

June 20-24. **ASHRAE Annual Meeting.** Vancouver, British Columbia. Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E. Atlanta, GA 30329; (404)636-8400.

June 25-30, 1989. **Air and Waste Management Association** (formerly APCA). 82nd Annual Meeting and Exhibition, Anaheim, CA. Contact: Meetings Department, Air and Waste Management Association, P. O. Box 2861, Pittsburgh, PA 15230; (412)232-3444.

July 16-19. **Symposium on Biological Contaminants in Indoor Environments.** ASTM Subcommittee D22.05 on Indoor Air, Boulder, Colorado. Contact: George Luciw, Staff Manager, Subcommittee D22.05 on Indoor Air. ASTM, 1916 Race Street, Philadelphia, PA 19103; (215)299-5571.

September 11-15. **Indoor Air Quality Diagnostics.** Honeywell, Golden Valley, Minnesota. Contact: See information above for March 6-10.

October 11-13. **Blueprint for a Healthy House Conference.** Cleveland, Ohio. Contact: Housing Resource Center, 1820 W. 49 St., Cleveland, OH 44102; (216)636-8400.

November 13-17. **Indoor Air Quality Diagnostics.** Honeywell, Golden Valley, Minnesota. Contact: See information above for March 6-10.

INTERNATIONAL

June 19-22. **11th International Congress on Quality for Building Research Users, Council for Building Research, Studies and Documentation (CIB).** Paris, France. Contact: Jean-Louis Feliz, Centre Scientifique et Technique du Batiment, Relations Exteriereurs, 4 avenue du Recteur-Poincare 75782 Paris, Cedex 16, France. Phone (1) 45 24 43 02.

June 23-24. **Building Simulation '89: Technology Improving the Energy Use, Comfort, and Economics of Buildings Worldwide.** International Building Performance Simulation Association, Vancouver, British Columbia, Canada. Contact Dr. Marianne McCarthy Scott, MCC Systems Canada Inc., 30 Wellington Street East, #202, Toronto, Ontario, Canada, M5E 1S3; (416)368-2959.

September 1. **CLIMA 2000**, the Second World Congress, Sarajevo, Yugoslavia. Contact: CLIMA 2000, Massinski Fakultet, Prof. Dr. EMin Kulic, 71000 Sarajevo, Omladinsko Setaliste bb, Yugoslavia.

October 16-20. **The Sick Building Syndrome.** Nordic Institute of Advanced Occupational Environment Studies (NIVA), Copenhagen, Schafergarden. Contact: NIVA, c/o Institute of Occupational Health, Topeliuksenkatu 41 a A SF-00250 Helsinki, Finland; tel: +358-0-47471.

June 13-15, 1990. **Roomvent '90,** Second International Conference on "Engineering Aero- and Thermodynamics of Ventilated Room" Oslo, Norway. Contact: Room Vent, c/o Norsk VVS Teknisk Forening, P. O. Box 5042, Maj N-0301 Oslo, Norway.

July 29 - August 3, 1990. **5th International Conference on Indoor Air Quality and Climate.** Toronto, Canada. Contact: Dr. Douglas S. Walkinshaw, Centre for Indoor Air Quality Research, University of Toronto, 223 College Street, Toronto, Canada M5T 1R4.

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