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IAQ, Productivity, and Occupant Control

Can indoor air quality affect productivity? Most IAQ consultants and many researchers and engineers think so. They argue that small changes in productivity rates can be worth far more than the costs of changes in building construction or operation; thus, improving the building environment is often worthwhile if productivity can be increased even slightly.

Typically, energy costs for operating office buildings run around $1 to $2 per sq. ft. per year. Assuming an average employee cost (salary, insurance, and benefits) of $40,000 per year and an average 200 sq. ft. per employee, energy cost is between 0.5 and 1% of employee cost. Reducing ventilation rates to save money can raise contaminant levels; if impaired IAQ lowers productivity, it's a false economy. In fact, doubling energy expenditures ($2-400) would be cost-effective if it could provide a mere 1% improvement in productivity (adding $400 value).

Now we'll factor in other operating and capital costs. Total operating cost is about $7 per square foot per year, and the annualized capital cost is in the neighborhood of $10 to $15 per square foot; total building costs are thus in the range of $17-22 per year. Rounding off to $20 a sq. ft., an employee's workspace costs $4000 per year. A 1% improvement in an employee's productivity would justify a 10% investment in improving their work space.

We don't advocate using more energy; you can reduce consumption by improving efficiency. For example, minimizing waste heat from lighting reduces cooling requirements. Also, capital investments in energy efficiency pay for themselves very quickly.

In any case, far more is spent on employees than on buildings. Slight improvement of employee productivity will easily pay for the small increments in building costs. For example, we calculated the amortized additional cost of installing 200 sq. ft. of polyurethane-backed (rather than SBR-latex-backed) carpet that would not emit 4-PC as equivalent to the salary cost for about one employee's coffee break. Increasing the quality of the ventilation system, or spending slightly more to operate or maintain it, can easily be paid for if employees are healthier, absent less and, therefore, more productive.

The difficulty with relating environmental quality and productivity is that we don't know how to measure non-industrial productivity directly other than, for instance, clerical work that involves repetitive actions such as key strokes. It is difficult to measure for other types of office work, for students in school, and for many other types of indoor activity. We can easily equate employee or student absentee rates with reduced productivity; an absent worker or student is simply not productive. But how does one analyze the less clear-cut impact of SBS symptoms on productivity?

Some studies have asked workers to estimate the impact of environmental stressors on their own productivity. The results are predictable: people who perceive problems with the building environment generally report that the environment adversely affects their ability to work. Similarly, those who report SBS symptoms usually say they could be more productive if the building environment were better. Although these self-reported estimates are biased and are not measures of actual productivity,

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they suggest that environmental factors are probably important determinants of productivity.

David Wyon on Productivity

David Wyon of the Swedish Building Research Institute has studied the effects of buildings on productivity for twenty-five years. He shared some of his findings at a recent conference in Montreal, and last September he lectured at ASHRAE IAQ '91 — Healthy Buildings. Much of what follows comes from his talks and published work. References noted in the text are provided at the end of the article.

How can buildings affect productivity? Wyon says it is obvious that if a building environment causes death or disabling injury, an affected worker becomes absent; productivity is decreased 100%. Wyon says there is evidence that people stay home because of SBS symptoms or because they don't like the work environment; their productivity is also decreased 100%.

Wyon says, "There is good reason to believe that decreases of 20, 30, and even 50% are produced by people feeling the symptoms of sick building syndrome." He suggests that we "consider how we feel when we are coming down with a cold. We may be able to get our work done, but it just is not up to usual standards. Therefore, if a building makes you feel as though you are just about to get a cold, then it would be worthwhile doing something about it." SBS can also lower productivity by reducing vigilance, alertness, the ability to concentrate, mental and manual dexterity, and comfort.

Thermal Environment and Productivity

When he started, according to Wyon, most productivity studies looked at the effects of thermal comfort rather than IAQ. Wyon told the audience in Montreal: "Temperature does affect productivity directly, and it does affect sick building syndrome." In fact, many studies show or suggest significant decrements in productivity due to poor control of the thermal environment.

Wyon believes that the human body's heat balance system was developed to cope with the outdoor climate. Outdoors we generally match clothing to activity and climate. Sweating or shivering are our bodies' ways of compensating for poor matches. But indoors, Wyon says, "quite small deviations from the individual optimum temperature can have powerful negative effects on efficiency."

In 1982, Wyon showed that even within the subjective comfort zone, "moderate cold can reduce manual speed, sensitivity, and dexterity by up to 20%." And, in several studies dating from 1969, 1974, 1979, and 1986, he showed that "moderate heat can reduce reading speed, typewriting, and the kind of logical thinking required for mathematics by up to 30%, in comparison with individual thermoneutrality." The theory is that there is "a natural, instinctive tendency to lower levels of arousal in order to reduce body heat production and maintain thermal comfort without sweating."

Over an extended period of time, people do about 30% less work at 24 °C than at 20 °C, according to Wyon's re-analysis of studies conducted in the United States and published in the journal *Ergonomics* (Wyon, 1974). Drivers were less vigilant for potentially dangerous signals at 27 °C compared to 21 °C. After a half hour, the rate of signals missed was approximately doubled at the higher temperature. Wyon's solution is to provide people with individual control over their thermal environment, and he cites his own and many other investigators' work to support his opinion.

Humidity and Thermal Effects on SBS

In the winter, people commonly complain that the air feels dry. But, Wyon says, laboratory researchers concluded that humans are ill-equipped to accurately detect humidity. For example, he says, people often report a decrease in humidity when an increase has been imposed, and vice versa.

However, not everyone agrees with this observation; work by Berglund and Cain (1989) at Yale University contradicts it. They found that their study subjects' "judgments about humidity were consistent with actual conditions, though compressed in comparison to the humidities explored." In a stüdy at three dry-bulb temperatures, three wet-bulb temperatures, and three activity levels, Berglund and Cain held air quality constant and asked participants their perceptions of the environment. Each subject was studied at each of the three by three by three matrix test conditions (27 total) for one hour, and asked their perceptions at the beginning and each fifteen minutes thereafter.

Ambient temperature had only a minor influence on humidity assessments while activity level had a greater effect. The researchers hypothesized that this was due to increased perspiration and wettedness at higher activity levels. As activity level increased, study subjects judged the air more humid.

Berglund and Cain found that, overall, temperature had a more pronounced effect on perceived air quality than did humidity. They asked about air freshness, stuffiness, and acceptability. The responses correlated well for all three questions about air quality. The results indicated that a 1 °F change in air temperature had the same effect on subjects' perceived "staleness" of the air as a 6 °F change in dew point temperature. This translates to about 0.56 °C dry bulb having about the same effect as a change of 3.36 °C wet bulb. Also. increases from low humidities (20 to 30% RH) to moderate humidities (38 to 52% RH) were less significant than increases from moderate humidities to high humidities (68 to 90% RH).

Figures 1, 2, and 3 show the acceptance of air quality at three activity levels defined as 1, 2, and 3 met. ASHRAE defines the met as a unit of metabolic rate of people. One met is defined as 18.4 Btu/h-ft^2 (58.2 W/m^2). One met is the energy produced per unit surface area of a seated person at rest. The surface area of an average man is about 19 ft^2 (1.8 m^2). Three met is produced by a person continuously walking. In the study, two met was achieved by a repetitive routine of five minutes of walking and five minutes of standing.

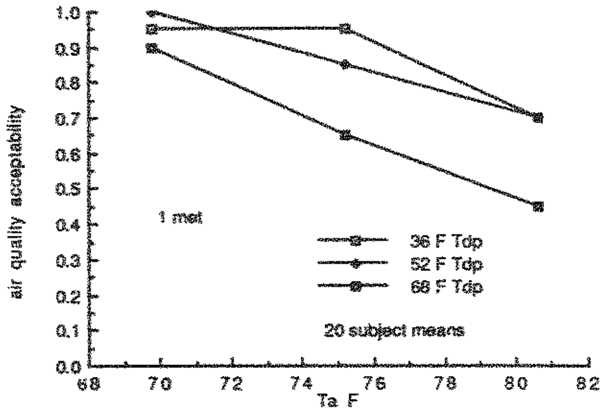

Figure 1 - Acceptance of Air Quality at 1 met.
(Berglund and Cain, 1989)

It is clear from Figures 1-3 that people find air quality considerably less acceptable as temperature climbs through and above the traditional indoor comfort range of 20 to 26 °C. It may be that temperatures of 25 to 26 °C (77 to 78 °F) are simply not acceptable when we consider IAQ and the total indoor environment relative to occupant comfort, health, and satisfaction.

In fact, it appears that temperatures in excess of 24 °C (75.2 °F) will nearly always increase dissatisfaction with IAQ and are likely to increase SBS symptoms due to thermal discomfort as well as the secondary effects of elevated temperature. There are many correlates of increased temperature that exacerbate environmental factors associated with elevated SBS symptom prevalence rates. These correlates include elevated VOC emissions and increased microbial growth. (Levin, 1989).

To support his contention, Wyon described one study that showed that people are not distressed even at humidities as low as 10% for 78 hours. However, he said, these studies do not mean that humidity is unimportant. It is expensive and difficult to install and properly operate humidification without causing health problems, for instance, due to condensation on poorly insulated outer walls or in HVAC systems due to mold growth.

In a large field study in Swedish office buildings described by Wyon, researchers showed that a 2 °C reduction in room air temperatures from 23 to 21 °C dramatically reduced complaints of dry air. In the same study, raising humidities from 20% to 40% halved complaints of dry air but caused a large increase in complaints

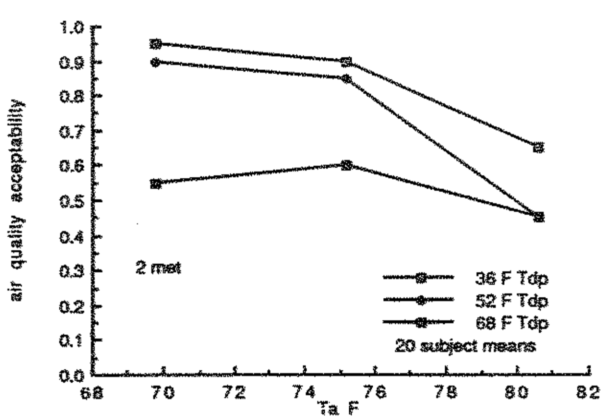

Figure 2 - Acceptance of Air Quality at 2 met.
(Berglund and Cain, 1989)

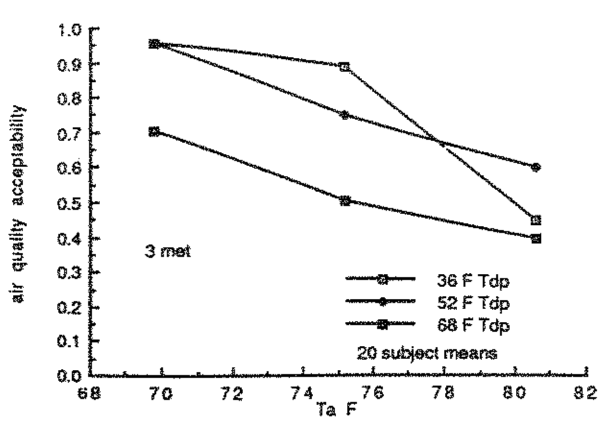

Figure 3 - Acceptance of Air Quality at 3 met.
(Berglund and Cain, 1989)

that the air was too humid, and the total proportion of occupants dissatisfied with the humidity was unchanged.

According to Wyon, the laboratory studies he mentioned above involved very clean air. He says "...the very different results obtained in offices suggest that the distress associated with dry air is caused by the inability of the mucous membranes in the nose, throat, and eyes to deal with airborne dust, at least for some individuals...." Wyon believes that the "drying associated with low winter humidity is greatly increased by room air temperatures at the upper end of the conventional range of thermal comfort, 20-24 °C."

Jaakola, Heinonen, and Seppanen (1990) studied 2150 office building occupants' SBS symptoms, sensations of dryness, and thermal comfort in relation to room temperature. Their study showed that in the traditional thermal comfort region of 20 to 24 °C there was a very powerful effect of room air temperature on the sensation that the air is dry as temperature rises. According to Wyon, the warmer it is, the drier it feels. SBS symptoms increased with temperature in that region as well. Menzies (1990) in Canada also found that SBS symptoms increased with higher temperatures in a four-way crossover study in two Montreal office buildings.

Wyon reported that a recent study showed "a very marked effect of thermal conditions on SBS" experienced by 100 Volvo workers in a computerized office at various imposed temperatures from 20 to 24 °C. In this study, temperatures were changed once a week and maintained constant during the remainder of the week. Virtually all SBS symptoms increased with temperature from a minimum of 20 to 21 °C. The effect was widespread, according to Wyon, and not just confined to a few sensitive individuals. For example, the proportion reporting headaches increased from 10% to 60% when temperature was raised from 20-21 °C to 24.5 °C. Complaints of other SBS symptoms, including skin problems, increased similarly, Wyon said.

Temperature and Negative-Ion Generators

Wyon studied SBS symptom prevalence in a hospital ward by lowering room air temperature only 1.5 °C. The result was that symptom intensity was lowered. The reduction in SBS symptoms was even greater when negative-ion generators were used. These devices presumably increased airborne dust particle mobility and deposition velocities. Wyon described the experiment as a sequential three-week single-blind use of ion generators with placebo ion generators in reference wards. Installing "convincing replicas of ionizers did not reduce SBS symptoms, although the subjects fully believed them to be in operation and protested when they were removed."

Individual Environmental Control

At Indoor Air '90 in Toronto, British and Dutch researchers separately reported that in the office worker populations they studied, people felt they were working more productively in proportion to their ability to control their own environment. A study of 5000 Dutch office workers in 61 office buildings by Preller et al. (1990) estimated the relative importance of different factors for absenteeism. The researchers suggested that discomfort or adverse health effects create a considerable loss in productivity and increase in absenteeism.

Working more than four hours per day at VDTs increased the number of lost workdays due to SBS by 20%; females missed 1.8 times as many days as males; smokers were absent 1.4 times more days than were non-smokers; and those with allergy missed 1.8 times more days than those without allergies. People in buildings with spray humidification reported 1.4 times as many days of sick leave due to SBS symptoms and 1.25 as many days of sick leave due to general illness. Workers in buildings with steam humidification did not experience more general illness sick leave but did miss 1.45 times more days of work due to SBS symptoms.

Temperature Controls

A 34% reduction in sickness due to SBS occurred in offices where people could individually control the temperature. Wyon says: "This is because people are very different, we ourselves are very different from day to day depending on our state of health, fatigue, and how much sleep we have had. If we can control our heat balance we stay well; if we can't, we get sick. It's as simple as that. And this is losing everybody a great deal of money."

Openable Windows

In sharp contrast to what many might assume based on the case of temperature control, those who had openable windows in their offices were in fact 25% more likely to lose work days due to SBS symptoms than those who did not have openable windows. We see at least two possible reasons for this. One, although the windows were technically openable, they may not have been openable by occupants. Second, opening windows may have caused other unforeseen adverse changes in the environment. Contaminated outside air could have infiltrated or the changed ventilation could have caused the mechanical ventilation system to function improperly.

British Studies

British studies by Ray, Roy, and Leaman (1990) showed that if people can control temperature, humidity or lighting, self-estimates of productivity increase dramatically. They also showed that the number of SBS

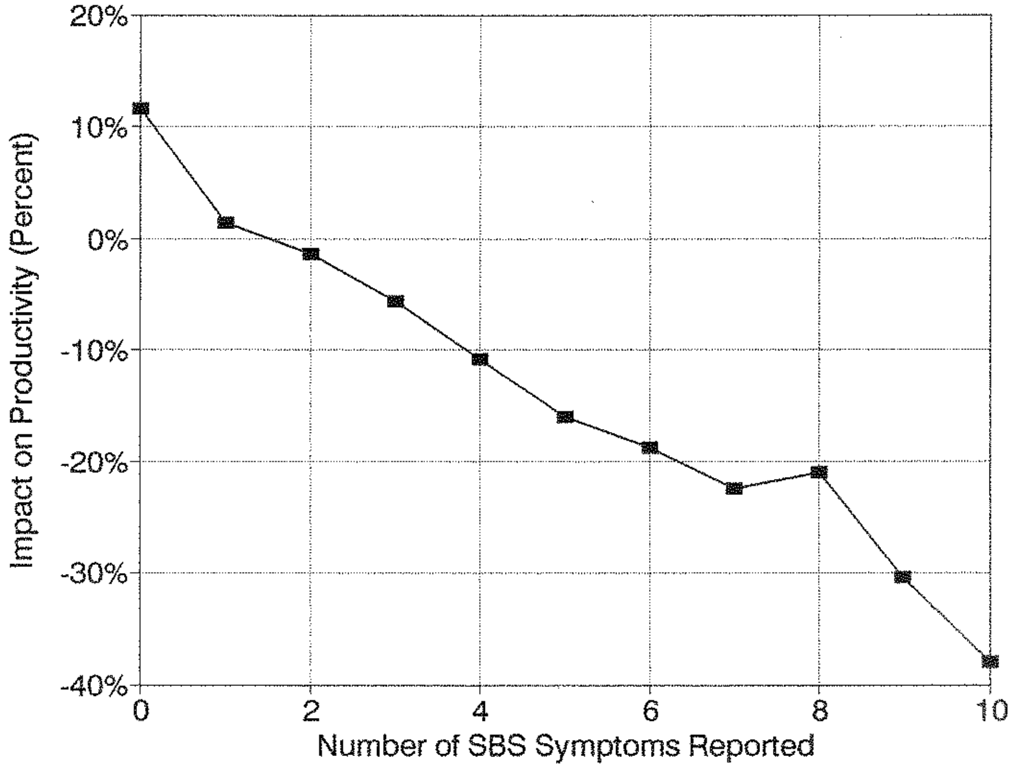

Figure 4 - Productivity and SBS Symptoms Reported (Ray, Roy, and Leaman, 1990)

symptoms people reported correlated with a sharp decrease in self-reported productivity. Figure 4 shows a sharp decrease in self-reported productivity associated with SBS symptom prevalence as reported by the researchers. A baseline average of two SBS symptoms was reported; note that the absence of reported SBS symptoms accompanied an increase in self-reported productivity.

Conclusion

A substantial amount of research shows that the thermal environment profoundly influences people's reactions - whether they be health, comfort, satisfaction, or productivity responses. Furthermore, SBS symptoms appear to influence productivity, although it is not clear exactly how much. This, in part, is because not all SBS symptoms are likely to have a similar influence on productivity given the very diverse nature of the symptoms. It is partly due to the difficulty in measuring productivity in the non-industrial workplace.

Wyon advocates increasing occupants' personal control over their environment. People believe they are more productive when they have personal control, and Wyon agrees. The challenge to architects, building owners, and employers is to find economic and practical means to provide such individual control while maintaining overall cost and environmental control.

There are several devices on the market that begin to address this need, but all of them are deficient in some significant measure. Next month we will discuss the various approaches to individual environmental control, some of the available devices, and directions for future research and product development. Your comments and suggestions are invited.

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Radon

Science Editor Attacks EPA Radon Policy

By continuing to assert that radon is a major cause of lung cancer, the EPA is creating a financially and emotionally costly radon program with negligible public health benefits, according to Philip H. Abelson, editor of *Science* magazine. Abelson's attack on EPA's radon policy appeared in the editorial article of the November 8, 1991, issue of *Science*, the respected journal of the American Association for the Advancement of Science (AAAS).

Abelson asserts that there is abundant evidence that exposures to 4 picocuries per liter (pCi/L) of radon do not cause lung cancer in either smokers or non-smokers. He says EPA has "no solid evidence that exposures to 4 pCi/L of radon cause lung cancer...." He writes that the evidence is actually to the contrary: residents of states "...with high levels of radon ... have less lung cancer than those in states with low levels."

Abelson says the EPA justifies its claim on 381 lung cancers — 356 in cigarette smokers and 25 in nonsmoking men exposed to "huge amounts of radon, mineral dusts, and other lung irritants in uranium mines on the Colorado Plateau." Even the non-smokers were unable to avoid heavy passive smoking. Abelson cites several sources for his information that the exposures occurred when the Atomic Energy Commission urgently needed large-scale domestic supplies of uranium. Miners generally worked without respirators in poorly ventilated mines called "dog holes" that contained radon levels as high as 15,000 pCi/L. Additionally, dog hole air contained excessive levels of lung irritants, especially silicon dioxide (SiO_2).

Among the many criticisms of the basis for EPA's policy, Abelson says that the entire risk assessment process is based on only a few separate, sporadic measurements in the mines. From these, EPA has extrapolated to the home by assuming 170 hours per week spent at home versus only 40 hours per week in the mines. In fact, Abelson says, the assumption that the miners spent only 40 hours per week in the mines "...may be valid for miners working for wages, but not for dog-hole operators, whose income depended on the amounts of uranium mined."

EPA has also extrapolated the risk of radon exposure from the miners' high doses to low doses in the home on the assumption that there is no threshold involved. This implies "that humans have no remediation mechanism for alpha particle damages." In fact, Abelson says, there is evidence to the contrary.

A second questionable assumption is that the heavy exposure to silica dust in the mines had no effect on the miners' lung cancers. Again, there is evidence to the contrary. Studies have shown that silica dust causes lung cancer in animals. Others have shown that exposure to silica has an enhancing effect on the incidence of lung cancer in cigarette smokers. Abelson says: "EPA is on shaky ground when it attempts to frighten the public about radon using as a basis a large extrapolation of data obtained from mines laden with mineral dusts."

Finally, Abelson says: "EPA has no solid evidence that exposures to 4 pCi/L of radon causes lung cancer." Apparently, Abelson based much of his editorial on a recent publication from the National Research Council, *Comparative Dosimetry of Radon in Mines and Homes*. That book is published as a "companion" to the (previous) landmark publication, *Health Risks of Radon and Other Internally Deposited Alpha-Emitters, BEIR IV*. The report was requested (and funded) by EPA. Sources inside EPA indicate that the agency is preparing a response to Abelson's editorial.

Previous Radon Policy Questions Unanswered

In June of 1990, William Nazaroff of the University of California, Berkeley, and Kevin Y. Teichman of EPA's Office of Research and Development questioned the current federal policy encouraging testing of all homes rather than targeting those homes with the highest levels of radon. When their article was published in *Environmental Science and Technology* (*ES&T*), Nazaroff and Teichman questioned what federal policy should be in light of the factors contributing to the estimates of excess lung cancers attributable to radon exposure. Furthermore, they questioned the process by which federal policy was being set: without the same sort of scientific and public review normally accompanying such important federal policy decisions.

At that time, EPA was reviewing comments on a draft revision of its *Citizen's Guide to Radon*, the major public information document the agency had developed about radon. That was June of 1991. EPA was roundly criticized by a diverse and large number of scientists and others when the draft was issued for comment. At this writing, EPA still has not released the document.

More Radon-Like Policies

Recently, Congressional initiatives were rumored that would take the entire radon program approach and apply it wholesale to the problem of lead in homes. Here, too, caution is needed to develop an effective means for abating lead hazards. Recently published research reveals that lead-abatement projects can increase in-home exposure to lead rather than reducing it.

Somehow, radon control efforts of EPA received a positive "spin" from the media and much of the larger community. Perhaps, in comparison to asbestos, it appeared that EPA was handling the radon policy in a reasonable fashion. More likely, this is simply the difference between the reaction to mandatory problems that require businesses to spend millions of dollars compared to a "voluntary" program that tries to motivate individual homeowners to spend thousands.

References:

Philip H. Abelson, *Science*, November 8, 1991.

National Research Council, *Comparative Dosimetry of Radon in Mines and Homes.* Washington, D.C.: National Academy Press. 1991. 244 pages. Available from National Academy Press, 2101 Constitution Avenue, NW, P. O. Box 285, Washington, DC 20055. $29.95 per copy.

Carbon Dioxide

Using CO_2 Measurements to Evaluate IAQ

Carbon dioxide (CO_2) measurements are used widely to evaluate indoor air quality. In particular, CO_2 concentrations indicate the adequacy of ventilation. Exhaled breath contains CO_2 at very high concentrations. CO_2 outdoor air concentrations are usually around 325 to 350 ppm. (They averaged under 300 ppm before the industrial revolution and appear to have risen sharply during the 20th Century - a major factor, scientists believe, in global warming.)

By measuring CO_2 in indoor air, many building investigators make a preliminary assessment of the adequacy of ventilation in relation to human occupant loads. ASHRAE has used a maximum indoor air CO_2 concentration of 1000 ppm as the basis for establishing minimum outdoor air supply requirements in its ventilation standard, Standard 62-1989.

Under steady state or equilibrium conditions, an outside air supply rate of about 15 cubic feet per minute per person (cfm/p) will maintain the CO_2 concentration about 650 ppm above the supply air concentration. Presumably, changes in CO_2 concentrations reflect other metabolic gas concentrations, and acceptability of IAQ depends partly on controlling human body odor.

Contaminant Sensors for Ventilation Control

Some companies now offer contaminant sensors for ventilation systems control. Some of these sensors are available at fairly reasonable prices, and wider use will bring the price well below $100 per unit. CO_2 is frequently the substance their sensors monitor. Some have sensors that measure volatile organic compounds (VOCs). Depending on the sensor technology, many possibilities exist for monitoring single compounds or for monitoring total VOC concentrations calibrated to some specific compound or mixture.

In theory, when CO_2 (or VOC) concentrations exceed a certain set-point, the outside air supply would be increased. This type of system appeals to those looking for a single signal to control ventilation rates. However, maintaining IAQ is far more complicated than that.

Accurate CO_2 measurements alone do not often reasonably indicate the relationship between occupant metabolism generated loads and outside air ventilation. Also, CO_2 is not the only substance of concern. Therefore, many authorities are critical of excessively relying on CO_2 as an indicator of IAQ.

CO_2 Measurement is Controversial

The importance of CO_2 measurements in IAQ evaluation is exceeded only by the controversies that exist regarding measurement methods, technology, and data interpretation. These factors led organizers to hold a forum at the January ASHRAE meeting in Anaheim, California. Much of what follows is based on opinions offered during the forum. ASHRAE policy prohibits attribution of comments to individual speakers, but we know most of those who commented to be knowledgeable authorities in the IAQ field. Many of them have published results of their studies using CO_2 measurements.

Problems with Relying on CO_2 Measurements

One problem is that CO_2 concentrations do not indicate building- or occupant-activity-generated loads. Activities that generate pollutants other than CO_2 include such things as food preparation, floor waxing, computer printer or photocopier use, craft, hobby, manufacturing work, and tobacco smoking. These and other contaminant sources are relatively independent of CO_2 concentrations. Sources that are not from occupant metabolism or activities, such as building materials, furnishings, pesticides, and outdoor air, can be far more important sources and far stronger sources than building occupants.

CO_2 Measurements Vary

CO_2 measurements are often unreliable due to equipment problems, and it is diffucult to obtain occupancy conditions that favor using occupant-generated CO_2 as an indicator of ventilation. Several hypotheses explain some of the variability in interpreting CO_2 monitoring data.

Instruments are inaccurate. Many if not all of the instrument(s) commonly used fail accurately to measure CO_2. These include a variety of instantaneous, direct-reading instruments as well as length-of-stain detector tubes. Detector tubes are still widely used by many IAQ consultants, although their accuracy is frequently questioned and operator-exhaled breath is likely to influence their readings.

IAQ experts warn against incautiously using direct-reading instruments. Users with experience cite error sources including inadequate or inaccurate calibration, instrument instability, zero-drift, and non-linear responses. Good calibration is infrequent according to one authority who recommends re-calibration at least three times a day.

Air mixing. Another potential source of error is poorly mixed air. Unless a building's air is well-mixed, the values measured at a single location do not necessarily reflect the levels elsewhere. In most cases, they do not.

Lack of equilibrium conditions. CO_2 measurements are generally biased low because CO_2 is not at equilibrium when the measurements are made. It takes several hours for CO_2 concentrations to reach equilibrium, and that means the ventilation system and the building population must remain relatively constant for that period. In a well-mixed space a concentration approaching 80 to 90% of steady state is usually reached in about an hour.

Figure 5 shows calculated CO_2 concentrations during a day at various ventilation rates. Under normal conditions, most office buildings are at 0.5 to 1.5 ACH. With all outdoor-air economizers, the rate might be 3 to 6 ACH depending on the building. A school meeting ASHRAE's 15 cfm/person minimum ventilation rate would have around 5 to 8 ACH.

Figure 5 - Calculated Build-Up of Carbon Dioxide.
(Persily and Dols, 1990)

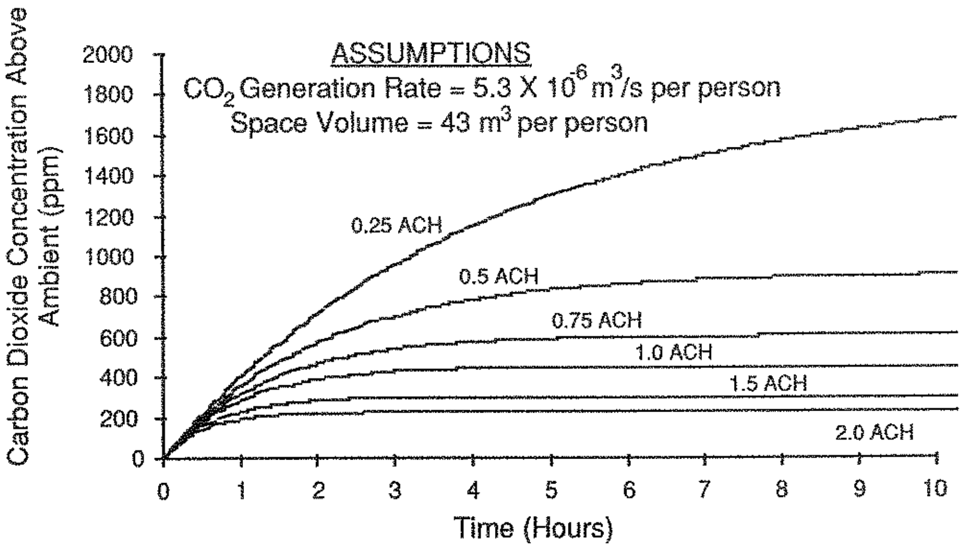

Figure 1 Calculated Build-Up of Carbon Dioxide

Stable occupant density. Occupant density must be fairly stable for a couple of hours and must be fairly uniform over the area being evaluated. This might occur a couple hours into the day in a school room. In a residence, if living room measurements are made while occupants are in the bedrooms, the measurements are likely to be quite low unless there is a high-turnover-rate ventilation system. For related reasons, bedroom measurements cannot accurately indicate living-room concentrations. In office buildings with large temporal and spatial variations in occupant density, there is a real problem deciding where to measure CO_2. A similar problem faces those trying to decide where to locate the CO_2 sensor(s) controlling the air supply.

Implications

Because of the increasing awareness of the importance of IAQ, there will be an increased demand for automatic ventilation controls. And, CO_2 sensors have become commercially viable with the introduction of a fairly low-priced, reasonably reliable sensor manufactured by Gaztech Corporation of Goleta, California. Honeywell is marketing the Gaztech device under its own name and was showing the device at the exhibition accompanying the ASHRAE meeting.

We have used the Gaztech meter incorporating the sensor, and we find it convenient to use. But the demonstration model sent to us by Gaztech had calibration problems, perhaps from rough handling during shipping. The problem occurred again when we sent it back for recalibration. Others we know who use the device calibrate it before use and speak highly of it. We worry about the unsophisticated user who might not recognize the calibration problem or be aware of the need to check it.

There is no consensus standard or guideline for interpreting CO_2 measurements, although many governmental organizations and professional groups (besides ASHRAE) have adopted a 1000 ppm value as a guideline value. We fear that this oversimplifies interpretation issues and should be used with caution. Certainly a value of 1000 ppm indicates that there may be insufficient ventilation, but a lower value is no assurance that IAQ is acceptable or good.

There is a need for useful sensor technology, but the CO_2 experience shows both the value and the danger of simple or narrow solutions. We need a consensus standard for interpreting indoor air CO_2 data. (ASTM Subcommittee D22.05 on Indoor Air is working on it.) Also, we should educate those responsible for investigating or maintaining IAQ about the virtues and pitfalls of CO_2 concentration measurement as an indicator of IAQ.

References:

Three valuable papers on CO_2 measurements are cited below. They contain additional references that will be of value to interested readers.

William A. Turner and David Bearg (1989) "Determining Delivered Quantities of Outside Air: CO_2, Tracer Gas, or Both? In *IAQ 89 - The Human Equation: Health and Comfort.* Proceedings of the ASHRAE/SOEH Conference IAQ '89, April 17-20, 1989, San Diego, California. Atlanta: ASHRAE, Inc. pp. 117-127.

Andrew Persily (1989) "Ventilation Rates in Office Buildings." In *IAQ 89 - The Human Equation: Health and Comfort.* pp. 128-136.

Andrew Persily and W. S. Dols (1990) "The Relation of CO_2 Concentration to Office Building Ventilation." In M.H.Sherman, (ed.), *Air Change Rate and Airtightness in Buildings, ASTM STP 1067,* Philadelphia: American Society for Testing and Materials, 1990, pp. 77-90.

Ventilation Guidelines

Nordic Committee Issues Building Regulations

The Nordic Committee on Building Regulations (NKB) has issued "Indoor Climate - Air Quality." The handsome, 36-page booklet contains a digest of the consensus knowledge obtained in the Nordic countries where IAQ has received considerable attention far longer than in most other parts of the world. The publication, dated June 1991, is a revision of a May 1981 publication.

The report contains two principal sections: one on pollution sources and one on ventilation. Each has its own set of requirements and of guidelines. The report's provisions are not law but constitute recommendations to the governing bodies in each of the Nordic countries. Compliance with the recommendations is voluntary on the part of each member country — Denmark, Finland, Iceland, Norway, and Sweden. Representatives of each country were on the indoor climate committee appointed by the Nordic Committee on Building Regulations.

Causes of IAQ Problems

The foreword outlines four major causes of building problems that create the need for the report. They are as follows:

- The use of materials, fixtures, fittings, and furniture that emit various pollutants.

- The use of materials and constructions sensitive to moisture without sufficient preventive measures to control moisture accumulation.
- Insufficient outdoor air provided by HVAC systems due to poor design, improper use, contamination of supply air by HVAC system components, or neglect of maintenance and cleaning.
- Unsatisfactory coordination (quality control) in the building process to maintain good indoor climate: unsatisfactory or incorrect construction, operation, cleaning, and maintenance.

Overall Objectives

The report briefly discusses various important indoor air contaminants, their occurrence indoors, and available guidance on acceptable concentrations. It concludes that "on the whole, knowledge is not available to lay down quantified criteria for risk assessments regarding the quality of indoor air." It refers the reader to the WHO *Air Quality Guidelines for Europe* (1987), then establishes the following overall objective:

"Buildings inclusive of their installations shall be planned, designed, constructed, maintained and operated so that satisfactory comfort is achieved with regard to air quality and so that danger to health does not arise when rooms are used in the way intended."

It goes on to define "satisfactory" air quality as follows: that the "great majority of visitors, on entry into the room, perceive the air as acceptable (do not express displeasure), if the air does not cause irritation to the skin, mucous membranes, or airways, not even in persons who are somewhat more sensitive than normal, if there is no risk of sensitization, and if the risk of health effects after long-term exposure is negligible." It also says that the IAQ must not cause disease.

The term "in the way intended" is defined operationally — anticipated activities such as smoking should be part of the design conditions. It calls for a margin for "short-term pollution loads" giving the example of openable windows as such a margin. In residences, normal hobbies, housekeeping, and cleaning activities should be able to be carried out without "causing inconvenience."

To assess buildings in operation, it says, "the experience and complaints of people can be used in judging the 'health' of the building."

Building Materials and Surface Finishes

The report says that the goal for materials is that they impose no need to provide ventilation to remove the gases they emit. But, it says, present knowledge is insufficient regarding the nature and significance of emissions. The first step, therefore, is to choose materials "which emit the smallest quantities of pollutants." [This is similar to the "pollution prevention" strategy adopted by the United States Congress and being implemented by the EPA.

The potential of materials "to act as storage areas for pollutants" (the sink effect) is also a significant factor in material selection. The report says the storage effect depends, among other factors, on the surface area of the material and can be both positive and negative. It says that fleecy surfaces have larger storage area than smooth ones.

The report also focuses on material handling during construction. It says that faulty handling that increases moisture load is a significant cause of sick buildings. It cites the use of chipboards and glued timber structures in the 1970s that emitted formaldehyde especially in connection with moisture. It also cites casein screeds (levelling compounds) used over insufficiently dried concrete before floor covering or carpet was laid. Other examples cited are acoustic tiles of loosely compacted mineral wool, certain paints, and adhesives.

Four factors cause emissions from materials: 1) solvent residues; 2) remnants of raw materials (e.g., monomers); 3) reaction and decomposition products from the manufacturing process; and, 4) additives. The first three are greatest in new materials and within one to six months decrease asymptotically to a level characteristic of the particular material and emission type.

Recommended Regulation

"Building materials and surface finishes shall have the lowest possible emission properties. They shall be manufactured, selected, handled, stored, and used so that emission to the room air is the least possible. The material shall be able to stand up to the intended use. The material shall not contain any genotoxic or neurotoxic substances, substances which cause sensitization or irritation of the mucous membranes or substances harmful in any other way, which pose a health hazard when used as intended in the building." A note following the recommendation says: "Intended use includes e.g., cleaning."

For more information:

Contact: Kristina Saarela, Technical Research Centre of Finland, PO Box 204, SF-02151, Espoo, Finland. Tel. 358 0 456 5292; fax 358 0 460 041.

WHO (1987). *Air Quality Guidelines for Europe*. Copenhagen: World Health Organization.

The Greening of Architecture

Nearly everyone who makes, owns, or uses buildings is thinking about "the environment." IAQ has become one of the many concerns for those interested in being "environmentally responsible." Other areas of concern include energy conservation (of course), but also recycling programs, water conservation, using materials from renewable resources, eliminating the use of ozone-destroying refrigerants, and a host of others.

Not all the interest in "green architecture" is out of concern for the environment. Some of it comes from a pragmatic business-management perspective. Consumers are expressing their concern about the environment, and green marketing is a major theme of today's retail sector.

Green Can Be Profitable

We met the CEO of a large building materials manufacturing corporation who described the greening of his company. In the early 1980s, company officials realized that their manufacturing process generated large amounts of waste that had to be hauled to a landfill. Replacing the waste required substantial amounts of additional raw materials. The management decided to investigate manufacturing methods that would generate no waste, and they succeeded. They then discovered that it was, in fact, a far more profitable production method.

Then, in the late 1980s, according to our CEO friend, it became very fashionable — very "environmentally responsible" — to minimize waste. His company suddenly was receiving high praise from environmental groups and government for their no-waste manufacturing process. They developed an "environmental manifesto" that the company began to promulgate as a declaration of their commitment to the environment.

Many other companies have discovered that there are markets for green products. During the early 1980s, concern about asbestos had crept out of the shipyards and into the building sector, primarily in schools. Certain underlayment products were advertised as containing no asbestos — and no formaldehyde. Awareness of formaldehyde hazards grew in the late 70s and early 80s around mobile homes and manufactured housing that used lots of pressed-wood products.

Now, low VOC content or emissions is used to market some paints and adhesives. Other companies market their products as based on natural ingredients, "all natural," or containing no synthetic organic chemicals. Many others are rushing to increase the recycled-material content of their products and promote them on that basis.

Green Labeling Programs

Groups are springing up in the United States and Europe to certify environmentally responsible products. These include Green Seal (Washington, D.C.), which is just about to issue its first label, and the Green Cross (Oakland, CA) program. Green Cross certifies to consumers that products are, indeed, what the manufacturer claims and that the improvements are state-of-the-art.

The oldest green label is the government sponsored *Umweltzeichen* (environmental label) program in Germany. The German program, begun in 1978, identifies more than 3,600 products in 64 product categories. A 1988 poll found nearly 80% of respondents recognized the label. The program is complex, operated by a combination of the federal government (Environmental Agency) and a non-profit (Institute for Quality Assurance and Labeling - RAL). Manufacturers pay a one-time application fee of 300-DM (US$190), an annual contract fee based on sales, and contribute to the advertising costs for the label program.

In 1988, Canada established the Environmental Choice labeling program modeled after the German program. The program is operated by the Ministry of Environment. Japan began its EcoMark label program in 1989.

AIA Environmental Resource Guide

The American Institute of Architects (AIA) established a Committee on the Environment (COTE) in 1990. Its first project is to publish an Environmental Resource Guide, and the first issue has just come off the press. The COTE is concerned about all the things architects do that might affect the environment. Among its task groups' concerns are tropical rain forests, global warming, waste management, energy, and building ecology.

Attitudinal Change

We have noticed a shift in attitude lately. We began researching indoor environmental health issues in 1978 and started consulting on IAQ problems in 1979. As recently as only a couple of years ago, when we said we researched and consulted on IAQ, many people would say: "Oh, you mean like asbestos and formaldehyde." People then started saying: "Oh, like sick building syndrome." But generally, there had been limited interest in actually doing anything to prevent IAQ problems.

Now people say: "We know we should be doing something about that," or, "We've been looking for help in doing something about that in our projects." Improbable clients are asking for help, and more and more building owners and occupants seem to agree that IAQ is an important aspect of *their* building environment.

Two of the major architectural journals (not, lamentably, including the AIA's *Architecture*) and many interior design and engineering journals have carried feature articles or even devoted issues to green architecture and green buildings. Products are rapidly being developed and marketed with lower emissions and without some well-known hazards.

The challenge is enormous, but things are looking up.

For more information:

Environmental Resource Guide, available from the AIA/ERG Project, 1735 New York Ave., NW, Wash. DC 20006, (202) 626-7331 or (800) 365-ARCH.

Ozone In Indoor Air

Southern California School IAQ Studied

In the November issue we described the California Air Resources Board's (CARB) recommendation for a new, lower formaldehyde level. This was CARB's first Indoor Air Quality Guideline, and it marks a new era in air pollution control activities in California. The formaldehyde report is a significant move by CARB into the indoor air field beyond the research and planning activities of the last few years. California's Department of Health Services has had a significant indoor air program since the early 1980s, but CARB has, until now, limited its indoor air activity to research.

We do not know if this portends a trend among air quality regulators to shift some of their attention to IAQ. (As we travel around the country, we often hear that California leads the nation in environmental consciousness and regulation.) It certainly is a shift that is long overdue. There is an obvious disparity between the funding available for indoor air research and that available for ambient air or other environmental hazards that are considerably less threatening to human health.

Another indication that this may be a trend is the initiation of an ozone study in schools by the South Coast Air Quality Management District (SCAQMD). SCAQMD is the largest air pollution control agency in the country with the toughest air quality problems; it regulates air pollution in Los Angeles, Orange, and the urbanized portions of Riverside and San Bernardino counties.

In the study, researchers will measure ozone concentrations in southern California schools during the next year. Traditionally, those who regulate and research outdoor air quality have assumed that ozone was not an indoor air concern. Recently published literature has reiterated the evidence that the assumption is invalid, but little has been done to date. SCAQMD is acknowledging the potential significance of indoor air and of ozone indoors by initiating the study. We expect they will find a wide distribution of indoor ozone concentrations due to the wide range of ventilation systems and operations in use and the wide range of outdoor concentrations.

Naturally ventilated schools are likely to have ozone concentrations approaching 70 to 80% of outdoor levels when windows and doors are open. In many southern California public schools built in the 50s and 60s, they are open when it is warm to induce maximum air flow by cross ventilation.

The extremely high ozone levels are usually reported when the weather is hot; that is, when occupants of non-air-conditioned buildings open their windows and doors to improve occupant comfort. Indoor ozone could approach 200 ppb under such conditions. The National Ambient Air Quality Standard (NAAQS) for ozone levels is 120 ppb; levels sometimes exceed 250 ppb in southern California.

The SCAQMD "Micro-environment study" dealing with public schools will measure ozone, CO, and 10 organics in a sample of schools in the SCAQMD territory. A southern California coroner recently reported that teenage homicide victims' lungs appeared as badly damaged as long-time cigarette-smoking adults'. Ozone may play a role in the deterioration of the lung tissue and may potentiate other lung tissue insults such as particulate matter from motor vehicle exhaust. We think the significance of ozone in indoor air is generally underestimated. The SCAQMD study may begin to provide data necessary to encourage more complete assessment of its role.

For more information:

If you would like to know more about the SCAQMD "Micro-environment study," write: Office of Planning and Rules, SCAQMD, 21865 East Copley Drive, PO Box 4939, Diamond Bar, CA 91765-0939; or, call Pierre Sycip, (714) 396-3095, or Ditas Shikaya, (714) 396-3060.

Sealants

New Products Will Have Lower Toxicity

Future developments in construction sealants will focus on lowering product toxicity, according to Donald Swanson, manager of the construction silicone division of Rhône-Poulenc, a Princeton, New Jersey sealant manufacturer. *Building Design & Construction* magazine reported Swanson's views in a September 1991 article on emerging technology.

According to Swanson, improved methanol-based sealants and the introduction of ethanol-based sealants are on the horizon. Swanson says these new product formulations will have low levels of VOC emissions. Toward the end of the decade, Swanson forecasts the introduction of water-based silicones that can be used for high-performance sealant needs.

Reference:

M. Bordenaro, "New Formulations Improve Sealant Performance." *Building Design & Construction*, September 1991, pp. 54-58.

Conference Announcement and Call for Papers

Indoor Air '93, Helsinki, Finland

"Indoor Air '93, The 6th International Conference on Indoor Air Quality and Climate" will be held July 4-8, 1993, in Helsinki, Finland. The Conference President, Professor Olli Seppänen from the University of Technology in Espoo, Finland, has issued the Call for Papers and Second Announcement.

Indoor Air 'XX Series Continues

Indoor Air '93 continues the series begun in Copenhagen in 1978 and continued in Amherst, Massachusetts, 1981; Stockholm, 1984; Berlin, 1987; and Toronto, 1990. This series is the principal international conference in this multi-disciplinary field. According to the conference announcement, "One of the major responsibilities of the conference is to ensure that the complex indoor air quality and climate issues are addressed on a scientific and technical level." The 1993 conference will continue the multi-disciplinary approach established by the previous assemblies.

Conference Program

The conference program will include several scientific symposia organized by topic, poster presentations, workshops, invited lectures, and social events. The four main themes are: 1) Health, Comfort and Performance; 2) Characterization, Measurement and Modeling of Indoor Environment; 3) Building Technology and Remedial Measures; and 4) Risks, Policies and Regulations. Abstracts are due October 1, 1992. (The official language of the conference is English.)

Many researchers we know plan their publications around the triennial conferences as they are a central focus of the indoor air community. Since the peer-review process for the conferences is generally not as rigorous as for scientific and professional journals, it is possible to present current work and work in progress. Many excellent papers at the last meeting in Toronto were just that. (Several were cited in this *BULLETIN*'s feature article.) Thus, the conference offers an excellent overview of the latest research in the indoor air field. It is also an unparalleled forum for exchanging ideas on an international level.

The conference itself will take place in Finlandia Hall in the heart of Helsinki. This building is a masterpiece of modern architecture by Finland's Alvar Aalto. The location and timing of the conference means that there will be almost 24 hours of daylight during the conference, likely a new experience for many conference participants.

Exhibition

The conference will also feature the Indoor Fair '93 exhibition. At past meetings, this has been a useful place to learn what new technologies and products are emerging in the indoor air field. Among the expected exhibitors, according to the announcement, are manufacturers of building products, materials and HVAC equipment; makers of scientific instruments and control devices; publishers of books, scientific journals, and computer programs; and international societies devoted to topics relevant to indoor air.

For more information:

Contact: Professor Olli Seppänen, President, Indoor Air '93, P. O. Box 87, SF-02151 Espoo, Finland. Phone +358-0-451 3595; Fax +358-0-451 3611.

Building Your IAQ Library

We are often asked to recommend more extensive IAQ reading. What follows is a selection of publications we think you'll find useful. Please give us your comments and suggestions, and we will revise this list accordingly for publication as a supplement for you and as a bonus to new subscribers.

1. National Environmental Health Association, *Introduction to Indoor Air Quality: A Self-Paced Learning Module.* (EPA/400/3-91/002) and *Introduction to Indoor Air Quality: A Reference Manual.* (EPA/400/3-91/003) July 1991. Available from the National Environmental Health Association, 720 South Colorado Boulevard, South Tower, Suite 970, Denver, CO 80222. Tel. 303-756-9090. Cost is $47.50 ($40 for members of NEHA).

This is a very useful publication. The reference manual is the most comprehensive collection of information available at present. The emphasis is on the residential environment, and there is very little attention on radon or asbestos because other publications dealing with these subjects are available.

2. Cone, J., and Hodgson, M., Preface, In Cone, J., and Hodgson, M., (Eds.) *Problem Buildings: Building Associated Illness and the Sick Building Syndrome.* Philadelphia: Hanley & Belfus, Inc. Vol. 4, No. 4, *Occupational Medicine: State of the Art Reviews.*

This work includes separate chapters written by professionals from various disciplines including chemistry, engineering, industrial hygiene, medicine, epidemiology, and architecture. We may be biased by the inclusion of our chapter on "Building Materials and IAQ," but material in this book is often cited in scientific and other publications. We think the chapter on "Social and Organizational Factors in Office Building Associated Illness" by Dean Baker is unique and particularly valuable. A hard-bound copy of the book is a bargain for only $32. Available from Hanley & Belfus, Inc., 210 South 13th Street, Philadelphia, PA 19107. Tel. 215-546-7293.

3. EPA, "Building Air Quality: Guide for Building Owners and Facility Managers." Reviewed in the November issue of the ***BULLETIN***. It will not turn you into an IAQ expert, but it will help you identify IAQ problems and oversee the work of staff and consultants.

Copies of the guide are available for $24.00 each ($30.00 to international customers) from the Superintendent of Documents (part of the Government Printing Office). A discount of 25% is available on orders of 100 copies or more. Include the publication number S/N 055-000-00390-4 with your order. Write to New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. You can fax your order to (202) 512-2250.

4. Berglund, B., and Lindvall, T. 1988 (Eds.). *Healthy Buildings '88*, volumes 1-4. Stockholm: Swedish Council for Building Research. Available from Svensk Byggtjänst, S-171 88, Solna, Sweden. The cost for a complete set is SEK 390, about US $64.

Unique among conferences, the "Healthy Buildings '88" proceedings are interesting and useful and somewhat different from the majority of other conference proceedings. We discussed these volumes in the August issue of the ***BULLETIN***.

5. Danish Building Research Institute, "Indoor Climate and Air Quality Problems, Investigations, and Remedies," (SBI Report 212) 1990. Danish Building Research Institute (Statens Byggeforskningsinstitut, SBI), P. O. Box 119, DK-2970 Hørsholm, Denmark.

This is a very valuable, concise, clearly written treatment of the subject.

6. Levin, H., 1991, "Critical Building Design Factors for Indoor Air Quality and Climate: Current Status and Predicted Trends," *Indoor Air: International Journal of Indoor Air Quality and Climate*, Vol. 1, No. 1. Copies and subscriptions available from MUNKSGAARD International Publishers, Ltd., Three Cambridge Center, Suite 208, Cambridge, MA 02142. In Europe, contact MUNKSGAARD, 35 Nørre Soøgade, Postbox 2148, DK-1016 Copenhagen, K, Denmark. Tel. 45 33 12 70 30. Fax +45 33 12 93 87. Subscriptions are US$152/yr, DKK 838/yr.

This article is our most complete contribution to the literature in the form of an overview of what architects, engineers, and interior designers should consider in their building design work. *Indoor Air* is the closest thing to a representation of the state-of-the-art in indoor air research and technology. The editorial board is comprised of chairpersons from the past five international indoor air conferences are held each three years starting in Copenhagen in 1978.

7. Norback, D., 1990, "Environmental Exposures and Personal Factors Related to Sick Building Syndrome," [Unpublished doctoral thesis] Uppsala University, Uppsala, Sweden. Copies are available for $25 from Norback at Department of Occupational Medicine, Uppsala University, S-751 85, Uppsala, Sweden.

The most comprehensive review of SBS as of about one year ago. It is thoroughly referenced and annotated, and will be a valuable reference to anyone wanting a reasonably complete literature review of the subject. In addition, Norback's findings from the five studies he conducted are provocative and somewhat different from those of most SBS studies.

8. ASHRAE Standard 62-1989 "Ventilation for Acceptable Indoor Air Quality." Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Contact ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA, 30329, (404) 636-8400.

If you are designing or operating buildings, consulting on or investigating indoor air complaints, or just more generally interested in indoor air, this is the essential document, at least in the United States today. The minimum outside air ventilation rates are widely quoted and used as the basis for building design. But many other aspects of the standard are important for achieving good indoor air quality but overlooked by those who only look at the ventilation rate tables.

9. ASHRAE has held a series of conferences on IAQ starting in 1986. The proceedings from those conferences contain many papers addressing the designers' concerns about IAQ. The volumes are from IAQ '86, IAQ '87, IAQ '88, IAQ '89, and '91. Each of the five conference reports contains many useful papers. We think that the 1991 Proceedings is by far the most useful. Contact ASHRAE for ordering information. Price is $87 per copy; $58 for ASHRAE members for *IAQ '91*. See ASHRAE contact information above.

10. EPA, "Report to Congress, Volume II, "Assessment and Control of Indoor Air Pollution," U.S. EPA, Office of Air and Radiation, 1989. Available from NTIS, Springfield, VA 22161, (703) 487-4650. It will help to give them the EPA publication number, EPA/400/1-89/001C.

This is the most recent, complete assessment of IAQ from the United States government. It has a great deal of useful basic information and should be a part of any IAQ consultant or researcher's collection.

11. National Academy of Sciences, 1981. *Indoor Pollutants.* Washington, D.C.: National Academy of Sciences. Available from Publications, National Academy Press, 2101 Constitution Avenue NW, Washington, DC, 20418, (202) 334-3113.

Although much of the technical information is slightly outdated now, this is still the most comprehensive single overview of the indoor air field available. Its 537 pages are packed full of valuable reviews of most of the major contaminants. There are also brief sections on lighting and noise.

Calendar

March 2-6, 1992. **"Improving Indoor Air Quality in Non-Industrial Buildings,"** Sponsored by EOHSI/CET, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School and Rutgers, The State University of New Jersey. Contact: Centers for Education and Training (CET), 45 Knightsbridge Rd., Piscataway, NJ 08854-3923. (908) 463-5064. Course fee is $750 for five days.

March 5-6, 1992. **"Diagnosing & Mitigating Indoor Air Quality Problems,"** Sheraton Century Center, Atlanta, GA. Sponsored by Association of Energy Engineers (AEE). Contact: AEE, 4025 Pleasantdale Road, Suite 420, Atlanta, GA 30340. (404) 447-5083, Fax (404) 446-3969. *Fee is $685 for AEE members, $785 for non-members.*

March 16-20, 1992. **Affordable Comfort VI Conference,** Pittsburgh, Pennsylvania. Contact: Linda Wigington, c/o Sara Crumm, Southwestern Pennsylvania Energy Center, Indiana University of Pennsylvania, Robertshaw Building, Indiana, Pennsylvania 15705-1087. Tel. (412) 357-7573, Fax (412) 357-2464.

March 23-24, 1992. **"How to Meet New Ventilation Standards: Indoor Air Quality and Energy Efficiency,"** San Jose Convention Center, San Jose, California. Sponsored by Association of Energy Engineers (AEE). Contact: Contact: see listings for March 5-6 above. *Fee is $685 for AEE Members, $785 for nonmembers.*

March 23-24, 1992. **"HVAC Systems: Improving Operation and Maintenance,"** San Jose Convention Center, San Jose, California. Sponsored by Association of Energy Engineers (AEE). Contact: see listings for March 5-6 above. *Fee is $685 for AEE Members, $785 for nonmembers.*

April 26-28, 1992. **Symposium on Modeling Indoor Air Quality and Exposure,** Sponsored by ASTM Subcommittee D22.05 on Indoor Air, Pittsburgh, Pennsylvania. Contact: George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103-1187, (215) 299-5571 Fax (215) 299-2630. *There will be a workshop on Sunday, April 26, with tutorials and hands-on demonstrations of models by many of the presenters at the symposium. Symposium papers will be on Monday and Tuesday. Registration fee is $100 before March 30, $125 after, and includes a copy of the proceedings. Fee for the workshop is included in the symposium registration fee and only a nominal charge when separate from the symposium.*

April 29, 1992. **ASTM Subcommittee D22.05 on Indoor Air; Spring Meeting.** Contact: George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103-1187, (215) 299-5571 Fax (215) 299-2630.

April 30 - May 2, 1992. **The First Annual IAQ Conference and Exposition,** "Indoor Air Quality: Service & Technology," Tampa Convention Center, Tampa, Florida. Sponsored by the National Coalition on Indoor Air Quality. Contact: National Coalition on Indoor Air Quality, 1518 K Street, NW, Washington, DC 20005

May 4-8, 1992. **"Improving Indoor Air Quality in Non-Industrial Buildings,"** Sponsored by EOHSI/CET, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School and Rutgers, The State University of New Jersey. Contact: Centers for Education and Training (CET), 45 Knightsbridge Rd., Piscataway, NJ 08854-3923. (908) 463-5064. Course fee is $750 for five days.

June 18-22, 1992. **American Institute of Architects Committee on the Environment** (AIA COTE), Meeting in conjunction with the AIA Convention. Boston, Massachusetts. Contact: Kristine Dombrowski or Patrick Lally, AIA, 1735 New York Avenue NW, Washington, DC 20006, Tel. (202) 626-7400, Fax (202) 626-7518.

June 27-July 1. **ASHRAE Annual Meeting,** Baltimore, Maryland. Contact: ASHRAE Meetings Dept., 1791 Tullie Circle N.E., Atlanta, GA 30329, (404) 636-8400.

July 12-17, 1992. **"Asbestos Measurement, Risk Assessment, Laboratory Accreditation."** Johnson State College, Johnson, Vermont. Sponsored by ASTM Committee D-22 on Sampling and Analysis of Atmospheres. Contact: George Luciw, ASTM, 1916 Race Street, Philadelphia, PA 19103, (215) 299-5471.

July 14-15, 1992. **"Indoor Air Quality for Facility Managers."** Sponsored by International Facility Managers Association (IFMA), Boston, Massachusetts. Contact: Susan Biggs, IFMA, 1 East Greenway Plaza, 11th Floor, Houston, TX 77046-0194, (800) 359-4362, Fax (713) 623-6124. *Instructor is BULLETIN Editor Hal Levin. More details in the next issue of the BULLETIN.*

August 30 - September 5, 1992. **"Achieving Technical Potential: Programs and Technologies that Work!"** ACEEE 1992 Summer Study on Energy Efficiency in Buildings, Asilomar Conference Center, Pacific Grove, California. Sponsored by The American Council for an Energy-Efficient Economy. Contact: ACEEE 1992 Summer Study Office, 2140 Shattuck Avenue, Suite 202, Berkeley, CA 94704. *The ten topics include "human dimensions" of which indoor air quality, health and comfort are a part.*

September 22-25, 1992. **International Symposium on Radon and Radon Reduction Technology**, Minneapolis, Minnesota. Contact: For registration information, Diana, Conference of Radiation Control Program Directors, Inc., (502) 227-4543, Fax (502) 227-7862. For Call for papers or to submit abstracts: Timothy M. Dyess, Radon Mitigation Branch, MD 54, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

October 5 - 8, 1992. **ASTM Subcommittee D22.05 on Indoor Air; Fall Meeting.** Contact: George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103-1187, (215) 299-5571 Fax (215) 299-2630.

October 18-20, 1992. **IAQ 92 - Environments for People,** Golden Gate Holiday Inn, San Francisco, California. Sponsored by ASHRAE, ACGIH, and AIHA. Contact; Jim Norman, Manager of Technical Services, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329, (404) 636-8400.

International

March 23-27 1992. **"Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality"** - State of the Art in SBS, Commission of the European Communities, Joint Research Centre, Ispra, Italy. Contact: EUROCOURSES Secretariat, Joint Research Centre, I-21020, Ispra (Varese) Italy. Tel. +39-332-789308, Fax +39-332-789839. *Organized with the scientific coordination of the EC Joint Research Centre Environment Institute and the Danish National Institute of Occupational Health, in collaboration with the EC Concerted Action "Indoor Air Quality and its Impact on Man." "[For those] with an interest in identifying causes of complaints about indoor air quality of the SBS type and their remedy."*

April 28-30, 1992. **"Quality of the Indoor Environment,"** Sponsored by The International Association for Indoor Air Quality, Athens, Greece. Contact: Conference Secretariat, Quality of the Indoor Environment, Unit 6, 2 Old Brompton Road, London SW7 3DQ, UK.

June 9-11, 1992. **Aerobiology 1992:** Symposium of the Pan-American Aerobiology Association, Scarborough College, University of Toronto, Toronto, Canada. Contact: Christine Rogers, Conference Organizer, Life Science, Scarborough College, University of Toronto, 1265 Military Trail, Scarborough, Ontario, Canada M1C 1A4. (416) 287-7421; Fax (416) 287-7642. *A wide variety of topics will be covered. The main focus is the distribution, production, dispersal, and deposition of airborne biological particles, and the implication of these processes to ecology, allergy, and plant pathology among other areas. Oral and poster sessions are proposed on the following topics. General Aerobiology, Ecology and Evolution, Indoor Air Quality, and Allergy.*

July 22-24, 1992. **1992 International Symposium on Ventilation Effectiveness,** Tokyo, Japan, sponsored by the Institute of Industrial Science, The University of Tokyo. (co-sponsored by ASHRAE). Contact ASHRAE in the US.

September 2-4, 1992. **Roomvent '92, The Third International Conference on Air Distribution in Rooms.** Aalborg, Denmark. sponsored by Danish Association of HVAC Engineers. Contact: Danish Association of HVAC Engineers, Ørholmvej 40B, DK-2800 Lyngby, Denmark.

October 12-16, 1992. **Second International Course on Sick Building Syndrome,** sponsored by the Nordic Institute of Occupational Health (NIVA). Hotel Oranje Boulevard, Noordwijk aan Zee, The Netherlands. Contact: Gunilla Ahlberg, NIVA, Topeliuksenkatu 41 a A, SF-00250 Helsinki, Finland. Tel +358 0 474 498. Fax +358 0 414 634. *A five day course intended for occupational safety and health experts and industrial hygienists working in the field of indoor air quality. Enrollment limited to 50. Enrollment limited to 50.*

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