Indoor Air BULLETIN™ *Hal Levin, Editor*

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Temperature, Air Quality, and Occupant Reactions to Indoor Air

Many experts suggest that the first response to high or increasing SBS complaints should be to turn down the thermostat. Some recently reported research seems to strongly support that advice. In fact, some authorities say that many "problem buildings" simply are out of thermal control. They suggest that just operating a building according to its thermal control design may eliminate a substantial number of complaints.

It may follow that efforts to control air contaminants by source control and ventilation should be minimal until thermal control is achieved. However, if thermal control is not adequate, efforts to control contaminants may be even more critical to avoid adverse occupant comfort, health, and physiological effects.

How important is temperature indoors? What effect does it have on reported sick building syndrome (SBS) symptom rates? How does it affect subjective and objective reactions to a given concentration of volatile organic compounds (VOC)? Work done at Yale University in the late 1980s clearly established the importance of the thermal environment (temperature and relative humidity) for occupant reactions to IAQ (Berglund and Cain, 1989; please see the reference at the end of the next article).

Jouni Jaakkola and his colleagues at Helsinki University of Technology reported that temperatures above 22 °C correlated with increased SBS symptom prevalence. In an article in *Indoor Air,* (Vol. 2, pp. 111-121, 1991), they found that symptoms did not associate significantly with ventilation rates from 7 to 70 L/s/p (15 - 140 cfm/p), although there was a trend of decreasing symptoms at higher rates. However, there was a direct relationship between temperature and SBS symptom prevalence in their intervention study.

Recent Studies

Researchers in Denmark also suggest that indoor temperature is extremely important. In an article published in the latest issue of *Indoor Air* (Vol. 3, No. 3, September 1993), Lars Mølhave and his colleagues from Århus University report results of their tests that exposed subjects to different concentrations of various VOCs at different temperatures. Their research, described in detail beginning on page 2, strongly supports an emphasis on thermal control. What's more, it suggests the need for different VOC concentration guidelines or limits depending on temperature.

In the subsequent article, we describe the results of research completed recently at the Technical University of Denmark under the direction of Geo Clausen. The researchers studied the relative effects of different thermal conditions, "perceived air quality," and noise levels on human discomfort or dissatisfaction. Their results not only show the relative importance of each of the factors they studied, they suggest interactive effects as well.

Nearly everyone considers the causes of SBS to be "multifactorial." The challenge to scientists is to understand the contributions of each factor and the combinations of conditions causing higher symptom prevalence rates. The challenge to building designers and operators is to correctly interpret the abundant research on how indoor environmental factors can contribute to "problem buildings." The next step is to act effectively to minimize the risk of adverse health and comfort effects.

Inside This Issue:

Combined Effects of Air Temperature and VOC

VOCs should be evaluated differently when interacting factors are outside the comfort range, suggest researchers at Århus University in Denmark. They investigated interactions between air temperature effects and VOC effects on physiological and subjective responses. The researchers reported their findings in *Indoor Air*, Vol. 3, No. 3, just recently published.

Lars Mølhave and his colleagues studied subjects under controlled laboratory conditions at 0 $\mu g/m^3$ VOCs (clean air) and 10 mg/m^3 of a mixture of 22 VOCs and at room air temperatures of 18, 22, and 26 °C (64.4, 71.6, and 78.8 °F respectively). The VOC mixture was the same one previously studied by Mølhave's group and similar to one studied by researchers at the US EPA.

The results have important implications for researchers, designers, and building operators alike. We cannot rely on a single set of contaminant concentration guidelines when other important environmental factors vary over a significant range. While the results are based on a small sample, results from other laboratory studies, field studies, as well as much practical experience suggest that the findings are valid.

Study Methods

The researchers worked with two groups of five subjects. The subjects were exposed three times a week, on different days, in two separate weeks. Half were exposed in the morning and half in the afternoon. Each exposure lasted 60 minutes. The exposures were randomly arranged although the perceived odor of the VOCs prevented a truly double-blind experimental design. Researchers obtained baseline measurements of subjects' responses under clean air conditions in a separate stainless-steel climate chamber at 23-25 °C and 45% RH. Immediately after the 12.5 minute baseline measurements and acclimatization period, subjects entered the exposure chamber for 60 minutes and then returned to the clean chamber.

Researchers attempted to maintain subjects' skin temperatures above 32 °C to avoid any indirect thermal effects on the target organs. Subjects were instructed to change or modify their clothing as needed in order to maintain the minimum 32 °C skin temperature, although the researchers found this effort not entirely successful.

Researchers obtained subjective ratings of discomfort with a set of 28 questions on odor intensity, indoor climate, irritation, neurological symptoms, etc. Subjects answered the questions before and twice during the exposure. Researchers used the first response during exposure as indicative of a visitor's acute response and the second as an occupant's adapted response to the conditions.

The subjects' responses on a linear potentiometer showed quantifiable indications of perceived irritation of mucous membranes in the eyes, nose, and throat. Variations in responses from the early part of the exposure to the later part indicated adaptation.

Responses on a profile of mood scale (POMS) included tension, depression, anger, fatigue, and confusion.

The researchers used acoustic rhinometry to investigate the mucosa of the nasal cavity. To measure the nasal volume in each nostril, they used an elegant system that monitored local changes in acoustic impedance. The changes were due to an alternating cross-sectional area created by propagating audible sound waves with a spark.

Skin humidity was measured on the forehead and cheek. The detection threshold for the odor of n-Butanol was measured before and after each exposure period with a standard triangle olfactometer. Researchers used a slit-lamp microscope to measure tear film stability using break-up time (BUT) during the exposure period. Microscopic investigation of small samples of conjunctival secretions (mucus from eyes and tears) taken under the lower lid allowed researchers to conduct cytological examinations before and after exposure.

Statistical Analysis

Researchers analyzed interactions from different combinations of VOC exposure concentrations and temperature. They defined *additive interactions* as interactions that "...cause the presence of two stimuli to give a response equal to the sum of the responses of each stimuli alone." In other words, both exposure variables — temperature and VOC exposure — affected an effect measure but did not create a statistically significant VOC x temperature interaction. They defined *potentiating interactions* as interactions where the effects are different from the sum of the responses to each stimuli and when the combined effect of VOC x temperature is statistically significant regardless of the significance of either factor individually.

Results

The following discussion groups results into subjective ratings and objective measurements.

Subjective Ratings

Table 1 shows the results of comfort evaluations after one-minute and after sixty-minute exposures. Figures 1 and 2 show some of the subjective evaluations of comfort. Figure 1 shows the effect of air temperature and VOC exposure on perceived odor intensity. Figure 2 shows the effect of temperature and VOC exposure on perceived air quality. The vertical scale is given in millimeters from the linear analog scale for subjective evaluation of comfort. Subjects made a mark on a line extending 60 mm above and below the neutral point to indicate their response.

The visitor's situation (the first in-chamber questionnaire) is reflected in the 1-minute exposure. The adapted occupant's situation (the second in-chamber questionnaire) is reflected in the 60-minute exposure.

We note that adaptation appears fairly clear with respect to perceived odor intensity since subjects perceived the 10 μg/m^3 VOC exposures as much lower at 60 minutes than at 1 minute. This was also true for the 0 μg/m^3 VOC exposure which was, essentially, the background odor of the chamber. Remarkably, the perceived odor seems to have generally declined as the temperature increased, although the researchers indicated this decline was not significant for the statistical tests they performed. Statistically, the perceived odor intensity was affected by the concentration. On the other hand, the effects of both concentration and temperature were significant for perceived air quality as shown in Figure 2. In neither case were the interactions potentiating.

The differences in perceived odor intensity and perceived air quality from the first minute responses to the 60 minute responses both show dramatic effects, although the effects are not the same. It appears that the differences generally form more consistent patterns for odor intensity than for perceived air quality. This, we note, may have important implications for interpreting the "perceived air quality" measurements using the decipol system developed at the Technical University of Denmark by Ole Fanger and his colleagues. (See the following article and comment on the decipol unit.)

The multivariate analysis of variance of the effect of temperature and VOC on 1-minute and 60-minute responses to comfort questionnaires showed that air

Table 1 - Acute (after 1-minute exposure) and subacute (after 60-minute exposure) comfort evaluation (60mm linear analog rating scale) in a questionnaire completed during exposures to VOCs (0 and 10 μg/m3 and air temperatures (18, 22, and 26 ºC). The table shows mean values of baseline-corrected responses and the p-values in a multivariate analysis of variance (n=10). The unit is mm. The ten questions shown are those for which there was a relation to subacute exposure.

	VOC	Acute Comfort Evaluations						Subacute Comfort Evaluations					
	conc.	Temperature °C			P-values			Temperature °C			P-values		
Questions:	mg/m^3	18	22	26	C	T	C x T	18	22	26	C	T	C x T
Lighting	0	-3.0	-1.8	-.1	NS	NS	NS	-2.9	-5.0	-.4	NS	NS	NS
	10	-1.2	-.8	-1.3				-1.1	.4	.4			
Air temperature	0	-22.2	-17.5	4.7	NS	NS	NS	-17.2	-14.6	3.5	NS	0.0005	NS
	10	-25.2	-11.5	4.8				-20.5	-17.7	2.5			
Air movement	0	1.2	10.1	1.3	NS	0.047	NS	12.2	9.1	3.1	NS	0.04	NS
	10	12.2	5.0	-2.1				12.0	8.4	-5.1			
Air quality	0	-9.7	-6.7	6.7	0.001	0.02	NS	-5.2	-14.4	7.6	0.008	0.01	NS
	10	6.0	29.0	22.4				-5.0	17.6	13.0			
Odor intensity	0	6.2	6.7	4.2	0.0005	NS	0.097	4.7	3.6	1.2	0.066	NS	NS
	10	23.2	31.1	36.6				10.1	13.9	18.5			
Skin temperature	0	-4.8	-6.9	4.7	NS	0.014	NS	-5.3	-7.9	.7	NS	0.002	NS
	10	-3.8	-1.6	3.4				-12.4	-3.9	.7			
Sweating	0	-12.9	-10.4	.7	0.087	0.049	NS	-9.9	-17.2	-6.0	NS	0.003	NS
	10	-11.5	3.2	7.4				-17.7	-6.3	10.3			
Facial skin temperature	0	1.5	-2.3	3.5	NS	NS	0.044	-2.4	-3.5	2.5	NS	0.016	NS
	10	-6.3	-.1	.9				-6.9	-1.6	.1			
How do you feel generally now	0	1.6	.4	5.2	NS	NS	NS	1.7	.3	4.3	NS	0.053	NS
	10	.7	1.3	5.4				1.1	.2	11.9			
Need more ventilation	0	-11.5	-15.6	7.9	0.006	0.012	NS	-8.2	-14.1	4.1	0.087	0.011	NS
	10	5.0	9.3	19.0				.0	-3.0	14.2			

C = Concentration (mg/m^3); T = Temperature (°C); C x T = Interaction between C and T; NS = Non-significant (P > 0.10)

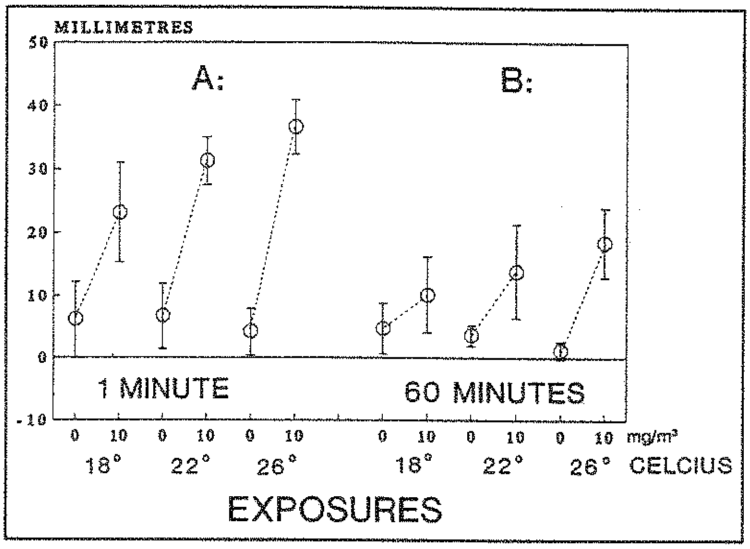

Figure 1 - The effect of air temperature and VOC exposure on perceived odor intensity (A: visitor's situation after 1 min., and B: occupant's after 60 min.). Ratings in mm are increasing intensity. Full scale = 60 mm.

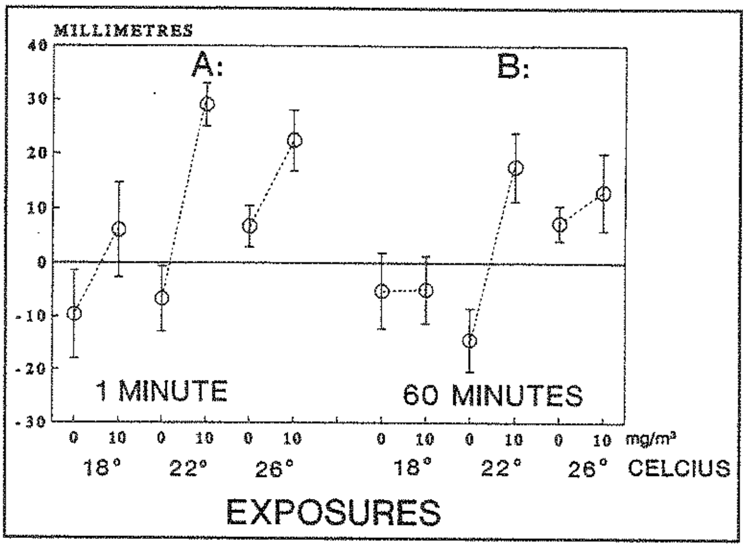

Figure 2 - The effect of air temperature and VOC exposure on perceived air quality (A: visitor's situation after 1 min., and B: occupant's after 60 min.). Ratings in mm are increasing discomfort. Full scale = 60 mm.

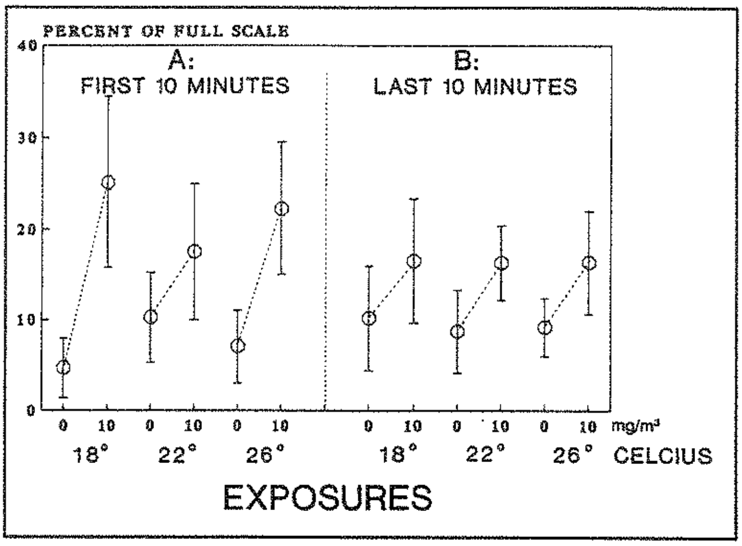

Figure 3 - Potentiometer registration of sensory effect of irritation in eye, nose, and throat for the first 10 and the last 10 minutes' exposure to combinations of air temperature and VOCs. Ratings are in percent of full scale. Full scale = 60 mm.

temperature significantly affected ratings of temperature, air movement, air quality, acute eye watering, skin temperature, sweating, acute dryness, and the need for more ventilation. It also affected the ratings for acute dryness and sub-acute facial skin temperature and general wellbeing. The VOC exposure affected evaluations of air quality, odor intensity, acute eye irritation, eye watering, nose irritation, and sweating, and the need for more ventilation.

Researchers found potentiating interactions between temperature and VOC exposures in questions on odor intensity, facial skin temperature, dry facial skin, and sub-acute interaction on general comfort in the comfort questionnaire. They found additive interactions for air quality and the need for more ventilation.

Figure 3 shows the results of the potentiometer ratings of irritation of eyes, nose, and throat in the first and last 10 minutes of the exposure period. There was a sensory effect of increasing discomfort throughout the 60 minutes, and statistical analysis showed that it was an especially pronounced effect at 18 and 26 °C. Potentiating interactions apparently occur only for the very acute ratings.

The potentiometer ratings for 10 $\mu g/m^3$ VOC exposures at all three temperatures showed decreasing intensity during the 60-minute exposure. The data suggest stronger irritation at high temperature and greatest adaptation at low temperature.

Objective Measurements

Rhinometry of the nasal passage showed VOC exposures decreased the minimum cross-sectional area significantly. Skin humidity measurements on the forehead showed an effect of both temperature and VOC exposure and a potentiating interaction. The effect on the cheek was significant only for temperature although VOC exposure effects on the cheek showed a trend similar to that for the forehead. Researchers found no significant relationship between the exposures and odor thresholds for n-Butanol.

Tear film stability measurements showed no significant differences in response to different VOC or temperature exposures. There was an interaction between tear film stability, VOC exposure, and temperature, but at biologically illogical dose relations. There were no significant cytological changes of tear fluid in relation to exposures; although median values increased after VOC exposure, the changes were not statistically significant.

Authors' Discussion

The authors offered comments on the observed effects and results of other experiments for the various measurements.

Study Design

The authors point out that the small number of subjects in the study limits the conclusions that can be drawn. Furthermore, the study subjects necessarily do not represent the general population. Finally, the interactions observed in the study between temperature and health pertain only to *direct effects* on perception and health. In the field (and in field studies), temperature may also *indirectly* affect results by increasing VOC emissions from materials.

VOC Effects

Sensory: The results of the study confirmed findings from previous studies at VOC concentrations of 25 $\mu g/m^3$. The results showed that VOC exposure significantly affects sensory evaluation of IAQ, odor intensity, and the need for ventilation. The potentiometer measurements showed significant effects of VOC exposure on sensory irritation in the eye, nose, and throat.

POMS: The researchers observed no significant effects on mood in the study.

Objective: The researchers say the observed effects of increasing VOC concentrations on objective measures of skin humidity had not been seen previously. The subjects did not report a difference in dryness of facial skin although such differences were reported in previous studies.

Mucus Membranes: The researchers claim to have demonstrated for the first time that VOCs influence mucous membranes of the nose as indicated by changes in nasal cavity cross-sectional area and volume. They suggest the nasal mucosa irritation response is swelling. Previous studies showed inflammation in the nasal mucosa in response to 25 $\mu g/m^3$ VOC exposure.

Odor Threshold: The researchers observed no reduction in olfaction using the n-Butanol test. Previous studies have reported mixed results, and no explanation is offered.

Tear Film Stability: The researchers' comments suggest they believe the lack of an effect found in this study may be due to the shortness of the exposure period. Previous studies reported a delayed response in the conjunctival inflammatory process.

Temperature Effects

Sensory: The authors say their study confirms temperature effects findings from other studies. They mention several studies that found relationships between temperature and SBS symptoms including general, eye, nose, and mucous membranes symptoms. Berglund and Cain reported that occupants perceived air as fresher and less stuffy with decreasing temperature and humidity. The Danes comment that their study showed significant sensory effects of temperature on evaluations of air quality and need for ventilation. Yet they found no significant effects of temperature on sensory irritation either in questionnaire responses or potentiometer ratings. We note that this raises questions regarding the mechanism of the temperature effects on SBS symptom prevalence.

POMS: The mean fatigue scale score correlated with the relatively small differences in temperature used in the experiment. Previous studies had not examined this potential effect but had seen other effects, e.g., on recognition memory at a wider range of temperatures.

Acoustic rhinometry: Concerning the objective effects of temperature, the researchers found that nasal airway dimensions increased in warm air and decreased in cold air. This finding was consistent with previous studies.

Interactive Effects Between VOC and Temperature

Sensory: Previous studies have reported interaction between VOC and temperature. The researchers stress that these findings mean that investigations of the effects of indoor environmental (climate) factors on the prevalence of SBS symptom reports should consider the possible indirect effects of these factors on exposure concentrations of VOCs and aerosols. Table 2 summarizes the interactions found by the researchers.

They say that the results indicate significant additive interactions between air temperatures and VOC exposures on air quality, watering eyes, sweating, and the need for more ventilation. They saw potentiating interactions on perceived odor intensity, facial skin temperature, feeling of dryness of facial skin, and sub-acute [adapted] general well-being. Due to the interactions, VOC sensory effects (except for odor intensity) were generally strongest at high and low temperatures.

They expressed surprise that the interactions on perceptions are acute while for general discomfort they are sub-acute. This, they say, suggests possible differences in adaptation mechanisms for perceptions and general discomfort, and, therefore, that perceptions and discomfort evaluations are based on different mechanisms.

Objective Measurements: Interaction on objective measurements occurred for tear film stability, forehead humidity, and nasal cross-sectional areas and volumes.

Rhinometric measurements: These measurements showed strong potentiating interactions. They speculate that limited reactions to VOC except at the high temperature "...may be that the decongested mucosa in the warm environment is more likely to respond to a congesting stimulus than the more congested mucosa in the cold environment."

Table 2 - Summary of the combination of effects or "interactions" between VOC and air temperature on health and comfort variables used in the experiment.

	Combination Effects or Interaction	
Variable	*Additive*[a]	*Potentiating*[b]
Subjective		
Air quality	y	—
Odor intensity	—	x
Watering eyes	x	—
Sweating	x	—
Facial skin		
- temperature	—	XX
- dryness	—	XX
General well-being	—	00
Need more ventilation	XX	—
Objective		
Tear film stability	—	00*
Skin humidity forehead	00	—
Rhinometry	—	00

[a] Additive interaction: both T and VOC significant, but not T x VOC; [b] Potentiating interaction: (T x VOC) significant; X = Acute; 0 = Subacute; xx, 00 = 95<P; x, 0 = 90<P<95; — = 90>P; * = meaningless associations; y = x + 0.

Summary and Conclusions

To conclude, the researchers wrote: "The interpretation of these interactions on occupants' objective and subjective reactions is that VOC exposure and air temperature may not be independent variables for evaluations of the quality of the indoor atmospheric environment. It follows that a reduction in air temperature may reduce VOC-related SBS symptoms and that guidelines for both VOC exposure and for the thermal environment should specify the values of VOC concentration or temperature on which they are based. Further, special thermal guidelines may have to be set for environments (such as occupational environments) in which increased VOC concentrations are accepted."

The *BULLETIN* Comments

We have reported this study in substantial detail because its findings and their implications are so simple yet so profound. There is a tendency to design, operate, and investigate indoor environments as though the important environmental variables were somehow disconnected and unrelated. There is abundant evidence for the relationship between air temperature, relative humidity, and air movement in determining thermal comfort. Previous studies have clearly shown relationships between the thermal environment and subjective responses to air quality.

This study extends the evidence for the importance of the inter-relationships by showing subjective and objective measures of effects including additive and potentiating interactions. It clearly reinforces the idea that running buildings cooler can help reduce occupant symptoms and discomfort if there are elevated VOC concentrations – whether they are irritants, odorants, or toxicants. We strongly recommend that designers, investigators, and building operators pay careful attention to potential direct and indirect effects of elevated temperature on environmental conditions and occupant responses.

References:

Lars Mølhave *et al.*, "Sensory and Physiological Effects on Humans of Combined Exposures to Air Temperatures and Volatile Organic Compounds." *Indoor Air* Vol. 3, No. 3, September 1993, pp. 155-169.

L.G. Berglund, and W.S. Cain, (1989). "Perceived air quality and the thermal environment." In *IAQ 89, The Human Equation: Health and Comfort.* Atlanta: American Society for Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and the Society for Occupational and Environmental Health, pp. 93-99.

Human Response Studies

Discomfort and the Combined Effects of Air Quality, Temperature, and Noise Levels

Geo Clausen, a leading researcher at Ole Fanger's laboratory, reported results of a provocative study conducted recently at the Technical University of Denmark in Lyngby and reported at Indoor Air '93 in Helsinki (1993). When Clausen and his colleagues exposed subjects to varying combinations of different noise levels, temperatures, and perceived air pollution, they were able to study the relative importance of the three environmental parameters. It is most interesting because it shows the relative effects of changes in operative temperature (21.3°C - 30.8°C), decipol (0.6 - 8.9), and noise (40 - 75 dBA) on human discomfort or dissatisfaction.

The researchers reported the following;

- A change of 1°C had the same effect on human comfort as a change in perceived air quality of 2.4 decipol or a change in noise level of 3.9 dBA.
- Up to 10 decipol, the effect of a 1 decipol change was the same as a 1.2 dBA change.
- When tested individually, raising the operative temperature from 21.3 °C to 28.4 °C or the decipol level from 0.6 to 8.9 had the same effect as raising the noise level from 40 dBA to 60 dBA.
- When exposed to the combination of 28.4°C and 8.9 decipol, the researchers report they found the combined effect the same as 71 dBA – an 11 dBA increase in sound level, which is approximately equivalent to a subjective doubling of loudness.

Authors of a 1985 review of research on the combined effects of heat and noise concluded that their effects on human performance were largely independent (Hancock and Pierce). The Technical University of Denmark looked at discomfort rather than performance, but the results would seem to challenge the review's conclusion. Clausen and his colleagues found a clear effect of each factor on the acceptability of the other by subjects in the climate chambers.

Clausen cautioned the ***BULLETIN*** regarding interpretation of the relationships they reported in the paper. He said the relative values "...are not models describing relationships between the different environmental parameters but rather first crude approximations of ...[the] relationships." Clausen's caution notwithstanding, the study clearly points toward the need for more comprehensive research involving multiple environmental factors. It also points to the importance of considering all environmental factors when creating acceptable indoor environments.

Methods

Eight male and eight female study subjects moved between two identical climate chambers (A and B) with various levels of temperature, odor, and recorded urban traffic noise. Subjects were exposed for one minute to each condition being assessed. Then they responded to questions evaluating discomfort, and they expressed preferences for varying condition sets.

In the first seven experiments, they compared different combinations of thermal load and sensory air pollution in chamber A with a range of noise levels in chamber B. In the second part they compared different sensory air pollution levels in chamber A with a range of thermal loads in chamber B. In one experiment both the air temperature and air pollution levels were increased in chamber A and compared to various sound levels in chamber B.

The noise was recorded urban traffic sounds, the thermal factors were controlled to produce the reported operative temperature, and the sensory air pollution was produced by different source strengths of a mixture of carpet, rubber, fresh paint, and cigarette butts.

Based on previous research, researchers selected the thermal and sensory pollution loads to correspond to previously determined levels of dissatisfaction (10, 20, 40, and 60%). These values are listed in Table 3.

The researchers have previously defined the decipol as the perceived air quality resulting from a source strength of 1 olf ventilated by 10 L/s outside air. An olf is the odor emitted by a "standard person" defined as one who bathes an average of once each 1.6 days. [See the sidebar for a discussion of some concerns regarding the use of the olf and decipol units.]

Results

Figures 4 and 5 show the noise levels in chamber B and the operative temperature and perceived air quality in chamber A equally preferred by the subjects.

The results shown in Figure 4 indicate that subjects experienced equal comfort (or dissatisfaction) with a 1 °C change in temperature or a 3.9 dBA change in noise level. Figure 5 indicates that changing the noise level 1 dBA had the same effects as a change in perceived air quality of 1 decipol at a neutral operative temperature.

Figure 6 shows the operative temperatures in chamber B and perceived air quality in chamber A equally preferred by the subjects.

Table 3 - Levels of dissatisfaction with different temperatures and perceived air quality values.

Level of dissatisfaction [%]	*Operative Temperature [°C]*	*Perceived air quality [decipol]*
10	21.3	0.6
20	23.3	1.4
40	26.0	4.1
60	28.4	8.9

Comments on Use of the Olf and Decipol Units

We have previously expressed concern about defining these units as measurements of perceived "air quality;" they should at least be termed measurements of perceived "air pollution." More importantly, others, such as odor expert Bill Cain, have recently raised questions about the relative importance of odor and of irritation in the assessment. While the researchers have demonstrated the repeatability of their approach with trained subjects, there remain substantial questions about the applicability of the units and the method to other situations. For example, how reliable are decipol measurements by untrained observers? What is the relationship between decipol values of visitors and occupants? What is the actual effect of adaptation on decipol ratings? What is the correlation between decipol rating and building occupant SBS symptoms? What is the mix of odor intensity, irritation, and odor preference that determines decipol values?

The results shown in Figure 6 indicate that with low background noise levels, a 1 °C temperature change had the same average effect on comfort as a 2.4 decipol change in perceived air quality.

Discussion

The experiments all involved a one-minute exposure to each condition being assessed, and the report says the effect of longer exposures are not known. Clausen told the ***BULLETIN*** that there appear to be linear relationships between each of the three factors and the degree of annoyance. The relation between percent dissatisfied and traffic noise level, however, is not linear, as shown in Figure 7.

The results showed that subjects found the operative temperature important relative to perceived air quality. This we conclude by comparing the relative magnitudes of the changes in the units. But, the derivation of each of the units is not based on scaling them against each other or a common reference, so we do not believe the numerical values themselves should be used for such comparisons.

Clausen commented to the ***BULLETIN*** that the interaction between air quality and temperature in chamber A may have influenced the subjects' overall perception of the chamber environment. Thus, he said, the combined effect of thermal factors and air quality may have varied as a result of changes in the operative temperature. This, we note, is consistent with the findings of Mølhave in the research described beginning on page 2 of this issue of the ***BULLETIN***.

The researchers compared three environmental factors based on linear regression analysis of the subjects' equal preference observations. There may be differences between equal levels of preference and equal levels of dissatisfaction that should be taken as cautions against over-extending application of the results of this small study. Clausen told us that the research was a preliminary experiment intended to explore methods and that it was not intended to establish the values to define relationships between the three environmental parameters.

Clausen further cautions that the results are based on one-minute exposures and that different results may be obtained with longer exposures, e.g., an hour or an eight-hour work day. He points out that adaptation may play an important role in our responses to sensory air pollution and thermal loads, and we note that the combined effects might also be modified. In a study done earlier at the same laboratory, Lars Gunnarsen (now at the Danish Building Research Institute) found that the type of pollutant source influenced the adaptation response (1990).

Also, Clausen warns that the perceived air quality levels were calculated from the percentage dissatisfied. Clausen says this method gives greater uncertainties than directly using the trained panel to determine decipol values.

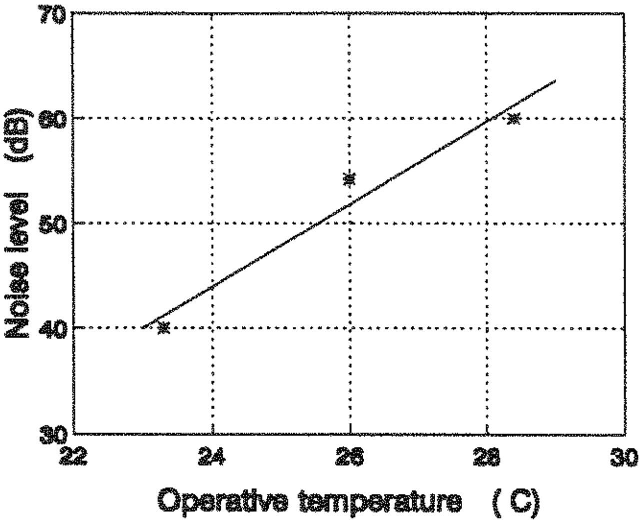

Figure 4 - Noise levels in chamber B and operative temperature in chamber A resulting in equal preference for the two chambers.

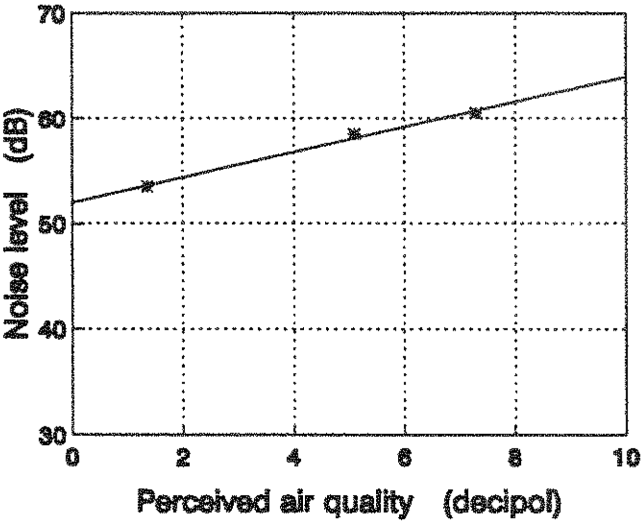

Figure 5 - Noise levels in chamber B and perceived air quality in chamber A resulting in equal preference for the two chambers.

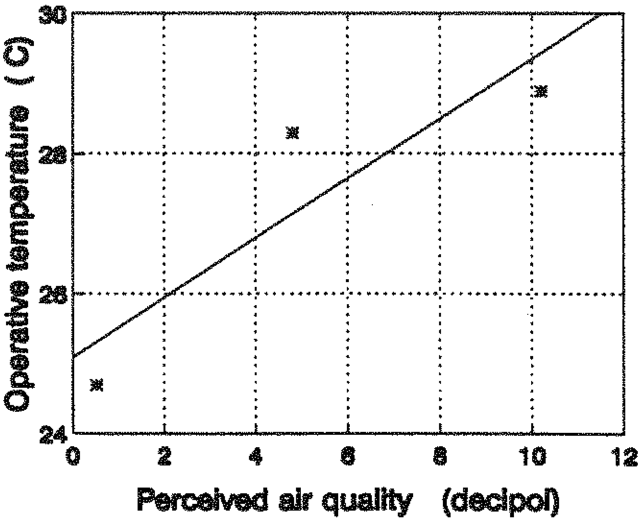

Figure 6 - Operative temperatures in chamber B and perceived air quality in chamber A resulting in equal preference for the two chambers.

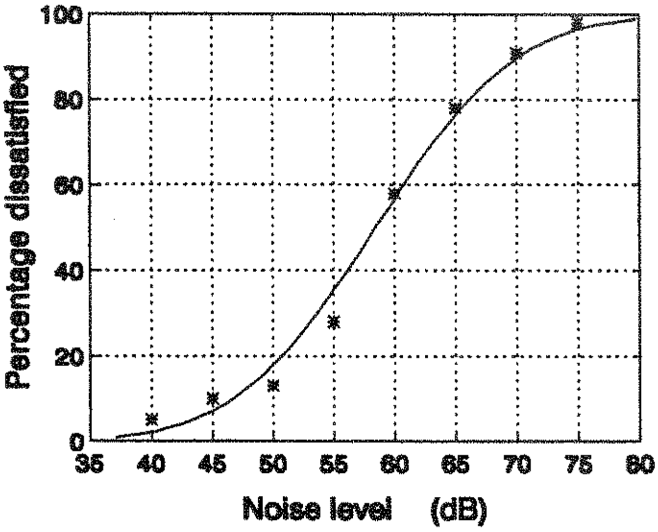

Figure 7 - Percent dissatisfied as a function of traffic noise level. The data points represent the mean of 112 assessments and the curve is the result of probit analysis.

Conclusion

Clausen and his colleagues have raised some very important questions by their work. They have clearly illustrated the complexity of the inter-relationships of noise, temperature, and perceived air quality, although their write-up tends to present it as simpler and more straightforward than it appears to us.

They have not established values for relative effects of discomfort caused by the three environmental variables they studied, but they have demonstrated an interesting methodology. Furthermore, their results confirm the interdependence of environmental variables and call our attention to it during design of studies or of buildings.

References:

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Thermal Comfort is Complex

Thermal comfort is a function of several environmental and personal factors, and the dry bulb air temperature alone does not adequately characterize the thermal environment. Environmental factors include air temperature, relative humidity, radiant temperatures, and air velocity. The personal factors include metabolic rate, skin wettedness, and clothing insulation value. We wonder how different some of these factors may be in environments with the same dry bulb air temperature. Most building HVAC systems' thermal controls are designed to respond to dry bulb measurements and some also consider relative humidity. However, exceedingly few actually integrate air movement or radiant surface temperatures into the control regime, although they clearly affect these variables and, in some cases, are studied for their ability to adequately control them. Sometimes the ability of the HVAC system is analyzed in mathematical models to determine its ability to maintain acceptable surface temperatures on the building envelope. And, any variable volume system will result in modulating air velocities although these are rarely considered in designing the environmental control system.

Human Response Studies

Subjective Aspects of Noise and Other Environmental Parameters

When I heard Ole Fanger describe Geo Clausen's noise study (see the previous article), it seemed that the use of recorded urban traffic sounds as the noise source would bias the results based on the sound quality. People have emotional reactions to different sounds, perhaps by associating the sound with some particular previous experience or familiar context. What might the results be if the researchers had used ocean waves, bird songs, Beethoven sonatas, or rock and roll music? Certainly the outcome would not be the same.

Noise is simply unwanted sound: a form of pollution. Our acceptance of it depends on what we are doing at the time as well as on the quality and intensity of the sound. Clearly people react differently to sound depending on the type. Calling the recorded urban traffic sounds "noise" indicates the researchers recognized that the sounds they chose to compare to various odor strengths and thermal conditions were, at least for most people, sound pollution.

Individuals find different light intensities and spectral distributions preferable to certain others. Again, preferences vary depending on the context; we may need brightness in order to perform a task; a soft, low-level light is always considered appropriate for "romantic" situations; in very hot weather, we prefer darker conditions. There are endless other examples.

Furthermore, the components of operative temperatures can be varied, and perhaps different individuals will vary in their responses accordingly. Since operative temperature is based on different mixes of dry bulb, wet bulb, and radiant temperatures, are different mixes of these factors simply equivalent if they yield the same operative temperature? Of course not. While they may serve to predict well within certain limits, their oversimplified use in design, standards, codes, building operation, investigations of complaints, and other applications is misguided and needs to be addressed. When we add the qualitative aspects of noise, light, and air quality, we have ourselves a very complex problem indeed — for designing or operating buildings.

Marcinowski on EPA Radon Policy

Frank Marcinowski is a Senior Health Physicist in the EPA's Radon Division. He wrote the following in response to our articles on radon policy in ***IAB*** Vol. 2, No. 11.

Dear Hal:

The article in Vol. 2, No. 11 entitled "Scientists, Policymakers Question EPA Radon Policy", which provided a review of Cole's book *(The Element of Risk; The Politics of Radon),* perpetuates the misconceptions about radon policy and science contained throughout the book. I would like to address some of these misconceptions which you highlighted in your review.

The main premise of the article/book is that EPA policy and science does not represent mainstream knowledge. That is absolutely incorrect. In fact, there is broad agreement among mainstream scientific organizations on the health effects of radon. The carcinogenicity of radon is based on extensive data from epidemiologic studies of underground miners. These studies have consistently shown a causal association between radon exposure and increased lung cancer risk. These findings have been well established by the scientific community, including the World Health Organization (IARC 1988), the National Academy of Sciences (NAS 1988), the International Commission on Radiological Protection (ICRP 1987), and the National Council on Radiation Protection and Measurements (NCRP 1984). In addition, the Centers for Disease Control and Prevention, the American Lung Association, the American Medical Association, the American Cancer Society, the National Medical Association, and many others have recognized radon as a serious public health problem. While there is some uncertainty associated with the health risks of radon, there is broad consensus that it causes thousands of lung cancer deaths per year

Cole argues that there is currently no evidence for a linear nothreshold relationship between radon exposure and lung cancer at low exposure levels. However, this is also true for exposure from any type of radiation. There is no rationale for treating the radon radiation risk differently from any other type of radiation risk. The only departure from the linear no threshold model for radon has been an observed decrease in risk per working level month (WLM) at very high mine exposure levels, i.e., above 2,000 WLM (NAS 1988). It is interesting to note that preliminary findings from some miner studies, as well as evidence from animal studies, indicate that chronic lowlevel exposures may carry higher-risk than highlevel exposures over shorter periods (Cross 1980, Hornung 1987, Sevc 1988). Again, mainstream scientific organizations at this time assume a linearno threshold dose response relationship.

The article also questions advocating testing for nonsmokers, and uses Cole's book to suggest that there is no evidence for radon risk for nonsmokers. On the contrary, increased lung cancer risk with radon exposure has been observed in nonsmoking populations. The National Institute for Occupational Safety and Health, the Centers for Disease Control and Prevention, the Harvard School of Public Health, and the University of California at Davis, recently conducted a study of nonsmoking miners exposed to varying levels of radon daughters (Roscoe 1989). The nonsmoking miners showed a statistically significant increase in lung cancer risk when compared with two control populations of nonsmoking nonminers. The authors concluded that exposure to radon daughters in the absence of cigarette smoke is a potent carcinogen that should be strictly controlled. Additionally, two studies conducted in Swedish and Czech mining populations have shown increased lung cancer risk among nonsmoking miners. Both studies found a ten times greater lung cancer risk in the nonsmoking miners when compared with nonsmoking males in the general population (although the findings of the Czech study were not statistically significant). Further, the Swedish miners had a mean exposure of 80 Working Level Months (WLMs) and the Czech miners had a mean exposure of 32 WLMs, comparable to cumulative lifetime residential exposures of 4 pCi/L.

Another example of an improper characterization of EPA's position occurs when Cole indicates EPA data implies 30% of US homes are above the action level of 4 pCi/L, while Nero estimates the frequency at about 6 or 7%. EPA has never stated or implied that 30% of homes would be above 4 pCi/L. In 1987, when EPA/State screening results were released there was some confusion in the press about this despite EPA's efforts to distinguish the difference between screening and annual average measurements. In every publication and communication since, EPA has made a special effort to explain the difference. In fact, EPA conducted a national survey (EPA October 1992) which has served to clarify earlier estimates of 6% of US homes having annual average radon levels greater than or equal to 4 pCi/L.

Another example of Cole's bias is his characterization of EPA's action level of 4 pCi/L as being inconsistent with a number of other European countries. Contrary to Cole's assertions, Germany, Ireland, Luxembourg, Sweden, Spain, Czechoslovakia, and Switzerland have recommended action levels in the 310 pCi/lL range. The recent trend in Europe has been to lower radon action levels.

There is also very little disagreement on the national costs of addressing radon. EPA has conducted extensive economic analyses on Radon Program strategies (EPA May 1992) and estimated a total cost of $45 billion (an estimated annual cost of $1.5 billion) for a fully implemented national program, within the range you quote of $20 to $100 billion. We recommend that all residents of homes below the third floor spend as little as $20 to find out if they might have a radon problem and an average of $1250 to mitigate if elevated levels are confirmed with followup testing. These analyses indicate that, if fully implemented at an action level of 4 pCi/L, the current program could avert over 2,000 lung cancer deaths per year at a cost of approximately $700,000 per cancer case avoided. (EPA is also pursuing strategies addressing radon in new construction which are even more costeffective.) These costs per case avoided fall within the range for other voluntary safety programs such as seatbelts and smoke detectors (OMB 1991). As with home fires and car accidents, not everyone is at high risk from radon. However, smoke detectors are required in all homes despite many being at very low risk because of occupancy habits and building codes. The use of seatbelts is not recommended just for those who travel above the speed limit or have a poor driving record.

Finally, the article questions the advisability of a national radon program when the largest source of lung cancer risk is smoking. While the risks of lung cancer from exposure to radon is much greater in smokers, radon exposure also increases lung cancer risk in former smokers and neversmokers. Smoking is also the greatest contributor to heart disease. As a society, we spend significant resources addressing secondary causes of heart disease including high blood pressure, improper diet, lack of exercise, and other risk factors. Likewise, it is appropriate and prudent to address lung cancer risk on multiple fronts.

Sincerely,

Frank Marcinowski, Senior Health Physicist, Radon Division, US EPA

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Editor's Reply

The questions Cole raises about EPA's radon policy do not challenge the consistent effects found in mine-worker studies. They pertain to issues around low-level effects. The uncertainty is great; however, Dr. Marcinowski refers to a consensus on the occurrence of thousands of lung cancer deaths without mentioning that they presumably occur primarily among smokers. Many of the organizations that he says have recognized radon as a serious public health problem have received funding support from EPA's radon program.

Inappropriate Comparisons

Relating risks from radon exposures to those from fires and seat belts is inappropriate. There are actuarial data for fire and automobile accident injuries and deaths; these data are not based on estimates or indirect experience but on actual deaths and injuries. In contrast, indoor air radon exposure risks are estimated from extrapolations of underground miner radon exposure levels and lung cancer-related deaths relying upon dose-response assumptions.

Questions raised by critics of EPA's policy regarding the miner data include possible radon measurement error and possible under-reporting of smoking by miners fearful of losing their jobs. Seatbelts protect us from other drivers even when we are driving safely, and their use is clearly effective in reducing both extent of injury and loss of life in accidents. There is no similar direct evidence to support the EPA radon testing and control program.

Wide Uncertainty

In fact, EPA's own Dr. Kevin Teichman in the Office of Research and Development discussed the uncertainty in his keynote lecture at Indoor Air '93 in Helsinki. He pointed out the absence of knowledge about the shape of the dose-response curve around the concentrations to which most Americans are exposed in their homes: about 1.2 pCi/L (45 Bq/m^3). He wrote that even "...small deviations from linearity [in the shape of the dose-response curve] ...could represent several thousand lung cancer cases per year."

While the ***BULLETIN*** raised the question of radon-related lung cancer risk for non-smokers, Teichman wrote that even for smokers the most significant step that can be taken to reduce their lung cancer risk "...is to stop smoking!" Dr. Marcinowski's point regarding the contribution of smoking to heart disease seems to argue forcefully for a larger anti-smoking campaign rather than the radon testing and control campaign he supports.

The issue Cole's book addresses is not whether radon is carcinogenic; the issue is what to do about it in a society with limited resources and many risks. We believe that our limited resources should be devoted to reducing the risks for those exposed to the highest levels of radon while on-going research resolves the issue of dose-response at typical indoor levels.

Scientific Issues

Dr. Marcinowski believes Cole's work perpetuates misconceptions, but each of his own major points can be considered misleading. He says that EPA policy and "science" represents mainstream knowledge. The statement is half right; however, the statement is misleading about the other half. With respect to the epidemiology, he is correct that principal scientific groups who have assessed the uranium miner data have concluded that radon daughters are a human carcinogen, and they have estimated a dose response factor for high exposures. This is a consensus (although, as usual, there are a few who would dispute even this). However, there is no agreement that this dose-response factor yields a reliable estimate of the risks at normal to moderately elevated indoor exposures.

Therefore, Dr. Marcinowski would be wrong to say "...there is a broad consensus that it [radon] *causes* [my emphasis] thousands of lung cancer deaths per year." There is only a consensus that it *may* cause some such number in the US. Casting this in terms of whether the dose-response relationship is linear, with no threshold, for environmental exposures, there is no consensus that this represents the reality, but only that it might.

Risk Issues

Finally, regarding risk, Dr. Marcinowski addresses the issue of non-smoker risk. The pertinent evidence is sparser for non-smokers, and — in any case — current risk models used by the scientific community yield far lower estimated radon risks for non-smokers, perhaps by a factor of ten, than for smokers. This calls into question a large-scale (multi-billion-dollar) program, the major benefit of which would be to smokers, whose risk is essentially self-imposed.

This leads to the practical aspects of a control program and the points made about that. First, Dr. Marcinowski's remarked that "there was some confusion in the press" about the percentage of homes exceeding 4 pCi/L "despite EPA's efforts." However, one has only to compare the EPA press releases and the resulting news stories to find that the public exaggeration of this percentage came directly from EPA materials (and related press conferences).

While the EPA has been more careful about this during the last two years, the false picture previously developed persists. It has also been more careful about characterizing the risks for smokers versus non-smokers, no longer associating 4 pCi/L as a risk equivalent to smoking half a pack of cigarettes per day even for non-smokers. Unfortunately this roughly ten-fold exaggeration has already become part of the EPA-generated lore of radon.

Dr. Marcinowski also believes Cole's work is biased in terms of representing the programs (and action levels) of other countries. Yet Cole's description appears to be relatively accurate historically. While some countries (and international organizations) are considering lowering their levels (or have done so), they are not acting with the objective of lowering the overall incidence of cancer that might be associated with radon exposures compared with the range experienced by their populations. This actually leads to relatively smaller programs in these countries, the purpose being substantially different. The corresponding program in this country would be that proposed by some scientists (such as LBL's Nero and EPA's Teichman) to focus near-term efforts primarily on houses with concentrations much higher than average. This would address the greatest potential health risks.

This would also lead to a much smaller size program (perhaps one — instead of one hundred — billion dollars) and substantially greater cost effectiveness than that described by Dr. Marcinowski. Further, the "effectiveness" would likely be much more certain than that in the EPA estimates, since the epidemiological data are less ambiguous for the higher exposures encountered in homes.

estimates, since the epidemiological data are less ambiguous for the higher exposures encountered in homes.

References:

Leonard Cole, *Element of Risk: The Politics of Radon*, Washington, DC AAAS Press, 1993. Available from Tasco. $29.95/copy + $4.00 shipping and handling. 301 645-5643, fax 301 843-0159.

Kevin Teichman, "Indoor Air Quality: Exploring Policy Options to Reduce Human Exposures," in Jantunen *et al.* (Eds) *Indoor Air '93: Proceedings of the 6th International Conference on Indoor Air Quality and Climate, Volume 3*, Helsinki. pp. 3-19.

Letters

White on CO_2 Testing

Jim White is a Senior Adviser - Building Science at the Canada Mortgage and Housing Corporation. He is a frequent correspondent and critical reader with a sophisticated understanding of fundamental physical laws.

Dear Hal:

Having read several of your recent articles on air change testing, especially those on using carbon dioxide as a tracer gas for measuring effective ventilation rate, I thought that some of my research into required testing time might be of use to your readers. For those who have been following the efforts of Andy Persily of NIST is this area, I suggest that these discussions are generally complementary, or at least not significantly at odds with his.

Using carbon dioxide (CO_2) as a tracer gas for the effective ventilation rate requires that several criteria be fulfilled but they seldom are: the source strength should be known and constant; the distribution of the sources should be known, especially the local ones; the concentration of CO_2 should be close to steadystate; the sampler should be appropriately sensitive and accurate; and, the mixing should be representative at the point of sampling.

I will deal only with the requirements for the "steadystate" requirement in this missive. I believe that a discussion of accuracy of measurement is required, however, and suggest that this become the focus of a future issue of the ***Indoor Air BULLETIN***.

Most usage of CO_2 testing fails because of the requirement to be at or near a steadystate condition. In many buildings, but especially in troubled areas within poorly ventilated ones, it takes a long time to approach steadystate. It is in explaining this situation that my research may be of most help.

Almost all indoor air situations are well modeled by using exponential equations, and many are adequately represented by only one time constant. Herein lies the rub! Because we chose to use air changes per hour (AC/h) to define ventilation, few of us seem to comprehend the basics of the processes we are measuring or modeling. Not many people can fully comprehend what 'per hour' really means, especially if it is not miles or kilometers per hour.

Hours we can understand, but not 'per hours', or 'air changes per hour'.

If we take the inverse of air changes per hour, however, e.g. hours per air change, we get the time constant (the appropriate 'characteristic time') of exponential systems. This important (nay 'critical') measure of system performance was available all along we just didn't 'see' it, because of the way we inverted the measurement and its presentation. If we sensible and used hours per air change in our performance plots, we would get straight lines, not the hard to understand hyperbolas that we get when we use air changes per hour but that is another story (related, mind you, but another one).

If the local effective air change rate is 4 AC/h, the effective time constant of the process is 1 / 4 = 0.25 hours. When the local effective air change rate is 1 AC/h, the effective time constant is the same, since 1 / 1 = 1 hour. In troubled areas, where the local effective ventilation rate is only 0.25 AC/h, the effective time constant is 4 hours. At low air exchange rates, processes move very slowly and take a long time to complete.

But they all relate simply to one universal exponential curve!

When source or removal conditions of simple exponential systems change from a steadystate condition, they move towards a new equilibrium at a rate that is well defined, at least in the time steps used by natural processes. The initial rate would create a full change in 1 time constant, but that rate soon drops off as the new equilibrium is approached (in exponential processes, the rate is proportional to the remaining difference between the present state and the final equilibrium). At the end of 1 time constant the process is only 1-1/e = 0.6321 or 63.21% of the way (where 'e' is the base of natural logarithms _ 2.718282). To reach 90% of the way to the new equilibrium, the process will take approximately 2.303 time constants [ln(1-0.9) = 2.3025851, where ln is the symbol for the natural logarithm]. To reach 99% of the way will take 2 x 2.303 = 4.605 time constants and it will take 3 x 2.303 = 6.908 time constants to be 99.9% of the way to the new equilibrium. These numbers come straight off the equation for an exponential. For any fraction 'x' towards the new equilibrium the equation is simply:

Time to 'x' completion = (the time constant)[ln(1-x)]

i.e., for 95% (0.95) it is ln(1-0.95) = ln 0.05 ≅ 2.9957 (~ 3 time constants)

If we were to require a process to be within 1% of final state, we have to wait about 4.6 time constants. When the air exchange rate is 4 AC/h and the time constant is only 0.25 hours, this means we can get a good reading 4.6 x 0.25 = 1.15 hours or about 70 minutes after the last change in source strength or effective air exchange rate. In a problem area, where the local mixing is poor and the distribution system has not moved a fair share of the outdoor air to that space, and/or the outdoor air dampers are shut right down "to conserve energy", a 0.25 air exchange rate could exist, and that corresponds to a 4 hour time constant. It will take 18.4 hours to get within 1% of the final state, but most spaces do not retain a constant source or exchange rate for any significant fraction of that time.

In an office, there would have been a significant bump after the 4th hour (lunch time) and an evacuation after the 9th. The conditions required for an accurate steadystate analysis cannot be met. Even if we were to settle for being within 10% of steadystate we would have to wait for 9.2 hours, without a change in occupancy or effective ventilation rate during that period (for a carbon dioxide tracergas test that requires constant occupancy).

The CO_2 tracer method works when the effective ventilation rate is high (over 4 AC/h) and constant and the occupancy has stabilized for about an hour before the test. Under troubled conditions the method does not and cannot work, at least not if the steadystate analysis method is used.

But all is NOT lost!

If: a) occupancy is relatively constant and known accurately enough; and b) if accurate sensors are used at the appropriate location in the correct way; we can get useful information by taking enough readings over a relatively short period of time, by using the dynamic form of the exponential equation. Because there is always some 'noise' in field readings, several dozen measurements may be needed to get stable answers, but an automatic data logging and analysis system could produce reliable results in a fraction (say a quarter) of a time constant. More field research is needed, as well as standardization of the techniques used for all phases of the process, much as has proposed by Andy Persily at NIST, for ASTM D22.05.

If consultants or researchers want to perform these tests, and want to know that their results mean something, they should get in touch with ASTM D22 and/or Andy, and find a way to contribute. Otherwise, they should beware of the data they are getting. It doesn't mean what they/we think it does, and there is always liability lurking when we don't know what we are doing and reporting.

Jim H. White, Senior Advisor - Building Science, Canada Mortgage and Housing Corporation

IAQ Events

Montreal 1995

An Announcement and Call for Papers has been issued for "Indoor Air Quality, Ventilation and Energy Conservation in Buildings," (2nd International Conference), May 10-12, 1995, to be held in Montreal, Canada. It is being organized by the Centre for Building Studies, Concordia University. A successful conference was held last year, and a publication of the papers was available after the conference.

The Call for Papers requests 400-500 word abstracts prior to June 1, 1994. Authors will be notified of acceptance by September 1, and manuscripts will be due December 1. Interested readers and potential authors should contact Fariborz Haghighat at the Centre for Building Studies, Concordia University, 1455 de Maisonneuve Blvd. W., Montreal, Quebec, H3G 1M8, Canada, 514 848-3200, fax 514 848-7965.

Calendar

Domestic Events

November 7-10, 1993. **IAQ '93: Operating and Maintaining Buildings for Health, Comfort and Productivity**, Philadelphia, Pennsylvania. Sponsored by ASHRAE. Contact ASHRAE Meetings Department, 1791 Tullie Circle NE, Atlanta, GA 30329, 404-636-8400.

November 16-17, 1993. **Bugs, Mold & Rot II**, presented by Building Environment & Thermal Envelope Council (BETEC), Alexandria, VA. Contact: BETEC, c/o National Institute of Building Sciences, 1201 L Street, #400, Washington, DC 20005. *The subject matter is of great interest* *to IAQ folks involved with design, construction, renovation, or investigation of humidity/mold-related building problems. Registration fee is $175 before November 5, $200 on-site, $50 less for BETEC members, $100 less for federal government officials.*

December 16-17, 1993. **The National Environmental Tobacco Smoke Conference: Public Battles, Private Choices**, The Hyatt Regency on Capitol Hill, Washington, DC, Sponsored by IAQ Publications, Inc. Contact: IAQ Publications, 4520 East-West Highway, Suite 610, Bethesda, MD 20814, 301 913-0115, fax 301 913-0119. *Federal officials; tobacco industry consultants, attorneys, and spokespersons; smoking control advocates; public health organizations; and many others involved with ETS policy and regulation will make presentations. Registration fee is $650 per person, $525 for government and non-profit organizations.*

January 22-26, 1994. **ASHRAE Winter Meeting and Exposition**, New Orleans, LA. See listing for November 7-10, 1993.

April 12-13, 1994. **ASTM Subcommittee D22.05 on Indoor Air**, Montreal, Canada. Contact George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103, 215 299-5571, fax 215 299-2630. *Standards for assessing Legionella outbreaks, for measuring emissions from carpets and from caulks and sealants, for determining the ETS contribution to RSP, and a variety of other standards are now under development.*

May 5-7, 1994. **Indoor Air Quality: Shaping the Industry**, 2nd Annual IAQ Conference & Exposition, Tampa, Convention Center, Tampa, Florida, sponsored by the National Coalition on Indoor Air Quality. Contact NCIAQ, 1518 K Street N.W., Washington, DC 20005, 202 628-5336, fax 202 638-4833.

May 21-27, 1994. **American Industrial Hygiene Conference and Exposition**, Anaheim, California. Sponsored by American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists. Contact: AIHCE, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031. 703 849-8888, fax 703 207-3561. *Sunday, May 22 there will be an all-day symposium on indoor air quality and standards.*

September 25-28, 1994. **Symposium: Emissions from Indoor Sources**, Washington, DC. Sponsored by ASTM Subcommittee D22.05 on Indoor Air. Contact: Symposium Chairman Bruce Tichenor, EPA/AEERL, Research Triangle Park, NC 27711, 919-541-2991, fax 919-541-2157, or ASTM Symposium Coordinator Dorothy Savini, 1916 Race Street, Philadelphia, PA 19103, 215 299 5400. *More details are available in Vol. 2, No. 11 of the BULLETIN.*

International Events

March 15 - 18, 1994. **Cold Climate HVAC '94 - International Conference on HVAC in Cold Climates**, City of Rovaniemi, Finland. Sponsored by FINVAC, Federation of Societies of Heating, Air Conditioning and Sanitary Engineers in Finland. Contact: FINVAC/Cold Climate HVAC '94, Mr. Ilpo Nousiainen, Sitratori 5, SF-00420 Helsinki, Finland, +358 0 563 3600, fax +358 0 566 5093. *The official conference language is English.*

April 17-19, 1994. **International Symposium on Volatile Organic Compounds in the Environment**, Montreal, Quebec, Canada. Sponsored by ASTM Committee E-47 on Biological Effects and Environmental Fate. Contact: symposium chair Dr. Wuncheng Wang, U.S. Geological Survey, WRD, P. O Box 1230, Iowa City, IA 52244, 319-337-4191, fax 319-354-0510.

May 10-12, 1994. **Indoor Air Quality, Ventilation and Energy Conservation in Buildings**, 2nd International Conference, Montreal, Canada, Organized by Centre for Building Studies, Concordia University. Contact Fariborz Haghighat, Centre for Building Studies, Concordia University, 1455 de Maisonneuve Blvd. W., Montreal, Quebec, H3G 1M8, Canada, 514 848-3200, fax 514 848-7965. *A Call for Papers has been issued; it requests 400-500 word abstracts prior to June 1, 1994.*

August 22-25, 1994. **Healthy Buildings '94**, Sponsored by CIB, ISIAQ, and HAS, and co-sponsored by the World Health Organization, ASHRAE, and other international organizations. Budapest, Hungary. President, Professor László Bánhidi, Healthy Buildings '94, Technical University of Budapest, H. 1521 Budapest, Pf. 91, Hungary, 361 1812 960, fax 361 1666 808. *The official language will be English. Discounted advance registration fee is $450, $150 for students.*

September 5-9, 1994, **Ventilation '94, The Fourth International Symposium on Ventilation for Contaminant Control**, Stockholm, Sweden, Sponsored by Swedish National Institute of Occupational Health. Contact Ventilation '94, National Institute of Occupational Health, S-171 84 Solna, Sweden, +46 8 730 9448, fax +46 8 275 307.

October 5-7, 1994. **Indoor Air Pollution, Sponsored by Indoor Air International**, Ulm University, Ulm Germany. Contact Dr. Lothar Weber, Institute of Occupational and Social Medicine, University of Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany, +49-731-502-3395, fax +49-731-502 3415. *The first announcement and Call for Papers has been issued. "Preliminary Abstracts" are due by January 31, 1994. The announcement says the official conference language is "English or other translated languages."*

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