GUIDANCE FOR INDOOR AIR QUALITY INVESTIGATIONS

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FOREWORD

This guidance was prepared by researchers in the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), National Institute for Occupational Safety and Health (NIOSH). It is based upon our experience in conducting approximately 450 field investigations of indoor air quality problems in many types of buildings. Because indoor air problems have become increasingly common, and because it is more efficient in certain instances for employers and/or employees to evaluate or be directly involved in the evaluation of indoor air problems, we have developed this information to guide employers and employees in this endeavor.

This guidance is presented in three sections:

1. OUR EXPERIENCE: which provides the reader with information regarding our experience with indoor air quality problems and describes some of the most common causes of these problems.

2. SELF-EVALUATION OF INDOOR AIR QUALITY PROBLEMS: a "self-help" approach to assist the reader in evaluating an indoor air quality problem.

3. INDOOR AIR QUALITY CONSULTATION SERVICES: where the reader can go, in addition to NIOSH, for outside assistance if self-evaluation cannot resolve the problem.

We would like your comments and suggestions about this guidance, specifically if it was helpful and more importantly, if it was not. If you would like to share your comments and suggestions, please write to: Hazard Evaluations and Technical Assistance Branch, NIOSH, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

Section I

OUR EXPERIENCE

Since 1971, investigators in the Hazard Evaluations and Technical Assistance Branch have responded to approximately 450 complaints of indoor air quality problems in a wide variety of office settings. The majority of these investigations have been conducted since 1979, paralleling the "energy efficiency" concerns of building operators and architects.

The majority of these indoor air quality investigations are part of the Health Hazard Evaluation Program. We conduct these evaluations upon request, from employee groups, unions, management, and local, state and Federal agencies. Generally, these requests are in response to existing worker health complaints and illness.

In this section, we have summarized our findings from indoor air quality investigations completed since the beginning of the Health Hazard Evaluation Program. Although these findings represent one of the single largest data and information bases that is currently available on the subject, the reader is advised that these findings should not be viewed as a statistically-valid cross section of the indoor air quality problem.

A. METHODS

We have found that investigating indoor air quality problems is not an easy job. These problems can be very complicated due to highly charged emotions, the complexity of the buildings themselves, and the fact that standard epidemiology and industrial hygiene evaluation techniques may be inconclusive.

Over time, we have tried to develop a consistent, solution-oriented approach to conducting these investigations. Our approach is probably best described as one of exclusion, by which we try to eliminate and narrow-down the range of possible problem causes.

Our investigation teams have typically included an industrial hygienist and a physician or non-physician epidemiologist, although other professionals (such as an engineer) have been included as well. Most of our investigations have included: a background assessment; an initial site visit; and follow-up site visits if necessary.

1. Background Assessment

The intent of the background assessment has been to obtain as much historical information as practical on the building itself, (when it was constructed, its fabric type, ventilation system, previous problems and previous investigations into air quality, recent renovations, etc.). In addition, to establish a chronology of the problems, we also have tried to obtain information about the kinds of symptoms employees have been experiencing and over what period of time. We have collected much of this information by using a questionnaire. Having access to these data prior to the initial site visit has allowed us to develop more effective strategies in dealing with these problems and has promoted more efficient use of investigator time during site visits.

2. Initial Site Visit

For the initial site visit, our typical protocol has been conducted in three separate steps: a walk-through evaluation, personal interviews, and environmental monitoring.

The walk-through evaluation is needed to obtain any additional background information not obtained during the Background Assessment (architectural plans, engineering reports, or previous environmental assessments, etc.) and to gain, first-hand, a visual appreciation for the building's design and floor plan. A critical inspection of the ventilation system is also important in order to thoroughly characterize the building with respect to potential sources of chemical and microbiological contaminants.

The personal interviews are needed to better characterize the building population and to determine the nature of the symptoms and complaints being reported. The personal interviews also have been critical in determining the magnitude of the problem, specifically if the problem is widespread throughout the building, or whether it is isolated in a particular section of the building or among a certain group of employees. In many of these instances, we again have used questionnaires, to collect this information.

On-site environmental monitoring is used to confirm or to rule-out a number of problem source possibilities identified from the background assessment, the walk-through evaluation, and the personal interview portions of the initial site assessment. During the initial site assessment, direct-reading monitoring methods have been most commonly used because they are excellent screening mechanisms that provide us with immediate results and thus, allows us to provide anxious employees immediate feedback. The most common instruments that we have used are: detector tubes for carbon dioxide, psychrometers for measuring temperature and humidity, and smoke tubes for determining air movement. We also, on occasion, have tested for specific chemical and microbiological contaminants, when appropriate. It has been our experience however, that standard industrial hygiene techniques for measuring chemicals may be inconclusive since most contaminants that we monitor are usually present at concentrations far below those known to cause health-related problems in industry. While this approach may be consistent with our solution-oriented philosophy, we recognize that the capability of substances to cause health effects in trace concentrations is not well understood.

Another limiting factor in understanding what environmental measurements mean, occurs with the Evaluation Criteria that are available to compare findings against, since these Criteria vary. In the classic industrial hygiene sense, the Occupational Safety and Health Administrations's (OSHA) permissible exposure limits (PELs), the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and NIOSH's recommended exposure limits (RELs) are most commonly used to assess exposures of workers in factories. Because these criteria are based on health effects that pertain to exposures in the manufacturing environment, they may not have the same relevance for workers in an office setting, whose primary concern may be for comfort or simply an absence of unusual sensory stimuli over their working period. The Environmental Protection Agency (EPA) has ambient air quality standards for a variety of pollutants designed to protect the public over an entire day (not just an 8-hour workday). However, these, too, may not have relevance to an indoor office environment, especially from the perspective of problem-solving.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) guidelines for acceptable indoor air quality have been developed specifically for the indoor environment. We have commonly used these as our guidelines in office building evaluations, especially for assessing the performance of ventilation systems. We also use the ASHRAE comfort guidelines as criteria for assessing the thermal performance of occupied space.

In addition to the ASHRAE guidelines, we use "rule-of-thumb" measures gleaned from the current scientific literature and from our own experience. An example of these "rules-of-thumb" is; the use of a carbon dioxide level of 1000 parts per million (ppm) indoors as a decision point for the determination of adequate amounts of outdoor air.

3. Follow-up Site Visit

If in the background assessment or during the initial site visit a problem has been identified that needs further definition, or if no problem can be isolated, an additional site assessment may be performed, but only in those cases where further work is most likely to result in meaningful recommendations. Subsequent site visits may result in more specific and extensive environmental monitoring for chemical and/or microbiological contaminants, and/or tracer gas monitoring to evaluate the ventilation system. In addition, follow-up site visits may be used to give building occupants a more detailed or widely distributed questionnaire or to conduct medical testing, if appropriate.

B. DISCUSSION

Through December 1986, we had conducted 446 indoor air quality health hazard evaluations. These do not include our investigations of asbestos-related building problems, but only those where the building occupants were actually experiencing ill-health effects which appeared to be related to air quality. The number of investigations has increased markedly since 1979. This probably has been due to two factors: (1) increased energy conservation measures and (2) increased worker awareness of office environments. We now average about two Health Hazard Evaluation requests per week for indoor air quality investigations.

While the majority (~80%) of our indoor air investigations have been conducted in government and private-sector office buildings, we also have evaluated problems in schools, colleges, and health care facilities.

Commonly, the symptoms and health complaints reported by workers have been diverse and not specific to any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, varying degrees of itching or burning eyes, irritations of the skin, including rashes, sinus problems, dry and irritated throats and other respiratory irritations. The workplace environment has been typically implicated by virtue of the fact that workers' symptoms normally disappear on weekends, when they are away from the office. At times, these symptoms have been severe enough to result in missed work, reassignment, and even termination. This has caused increased anxiety among the workers and, often times, has made the investigation of these problems even more difficult and frustrating.

Although some of these episodes may be multifactorial, we have been able to classify our evaluations by primary type of problem found: inadequate ventilation (52%); contamination from inside the building (17%); contamination from outside the building (11%); microbiological contamination (5%); contamination from the building fabric (3%); and unknown (12%).

1. Inadequate Ventilation

In 52% of our investigations, the building ventilation has been inadequate. When evaluating building ventilation, we normally use ASHRAE standards for comparison. ASHRAE standard 62-1981, "Ventilation for Acceptable Indoor Air Quality" and 55-1981, "Thermal Environmental Conditions for Human Occupancy" are both used. Some of the ventilation problems we commonly encounter are: not enough fresh outdoor air supplied to the office space; poor air distribution and mixing which causes stratification, draftiness, and pressure differences between office spaces; temperature and humidity extremes or fluctuations (sometimes caused by poor air distribution or faulty thermostats); and air filtration problems caused by improper or no maintenance to the building ventilation system. In many cases, these ventilation problems are created or enhanced by certain energy conservation measures applied in the operation of the building ventilation. These include reducing or eliminating fresh outdoor air; reducing infiltration and exfiltration; lowering thermostats or economizer cycles in winter, raising them in summer; eliminating humidification or dehumidification systems; and early afternoon shut-down and late morning start-up of the ventilation system.

2. Inside Contamination

Contamination generated by sources inside the office space is the major problem identified in 17% of our investigations. Copying machines are often found to be a significant source. Examples of this type of problem include; methyl alcohol from spirit duplicators; butyl methacrylate from signature machines; and ammonia and acetic acid from blueprint copiers. Still other inside contamination problems we have encountered include; exposures to pesticides; such as chlordane, which were improperly applied; dermatitis from boiler additives such as diethyl ethanolamine; improperly diluted cleaning agents such as rug shampoo; tobacco smoke of all types; combustion gases from sources common to cafeterias and laboratories; and cross-contamination from poorly ventilated sources that leak into other air handling zones.

Contaminants from inside or outside the office space, and from the building fabric are essentially chemical contaminants. Many times, odors are associated with some of these contaminants which may aid in source identification. In most cases, these chemical contaminants have been measured at levels above ambient (normal background) but far below any existing occupational evaluation criteria.

3. Outside Contamination

Contamination from sources outside the office space is the major problem identified in 11% of our investigations. Problems due to motor vehicle exhaust, boiler gases, and previously exhausted air are essentially caused by reentrainment of outside air. This is usually the result of improperly located exhaust and intake vents or periodic changes in wind conditions. Other outside contamination problems include contaminants from construction or renovation projects such as asphalt, solvents, and dusts. Also, gasoline fumes infiltrating the basement and/or sewage system can sometimes be a problem and these are usually caused by gasoline leaks from ruptured underground tanks at nearby service stations. One of the most common sources of outside contamination has been vehicle exhaust fumes from parking garages being drawn into the building ventilation system.

4. Microbiological Contamination

Five percent of our investigations have involved some type of microbiological contamination. Even though this is not a common cause of office problems, it can result in a potentially severe health condition known as hypersensitivity pneumonitis. This respiratory problem can be caused by bacteria, fungi, protozoa, and microbial products that may originate from ventilation system components. A similar condition known as humidifier fever, most commonly reported in Europe, is also the result of microbiological contamination in ventilation systems. In our investigations, microbiological contamination has commonly resulted from water damage to carpets or furnishings, or standing water in ventilation system components.

Although a variety of disorders (hypersensitivity pneumonitis, humidifier fever, allergic rhinitis, conjunctivitis) can result from microbiological exposure, we generally have not documented the existence of these disorders on the basis of medical or epidemiological data. However, even if visible microbial growth can not be directly related to the health complaints reported, it is a problem that needs to be addressed and corrected.

5. Building Fabric Contamination

Contamination from building materials and products is the major problem in 3% of our investigations. Formaldehyde can off-gas from urea-formaldehyde foam insulation, particle board, plywood, and some glues and adhesives commonly used during construction. Other building fabric contamination problems encountered include: dermatitis resulting from fibrous glass erosion in lined ventilating ducts; various organic solvents from glues and adhesives; and acetic acid used as a curing agent in silicone caulking.

C. CONCLUSION

The major problems[1] identified in our indoor air quality investigations can be placed into three general categories listed with decreasing frequency: inadequate ventilation, chemical contamination, and microbiological contamination. Inadequate ventilation is the single largest problem we see in buildings. Although varied, these ventilation problems commonly can allow a build-up of any contaminants present in the occupied space to the point that adverse health effects are experienced or allow the environment to become annoyingly uncomfortable to the office workers. As our experience has increased over time, we have developed a solution-oriented approach to conducting these evaluations which places a high priority on building ventilation.

1. Although not specifically mentioned, it is also important to recognize tobacco smoke as a potentially major contributor to indoor air quality problems. Tobacco smoke contains several hundred toxic substances, the more important are: carbon monoxide, nitrogen dioxide, hydrogen cyanide, formaldehyde, hydrocarbons, ammonia, benzene, hydrogen sulfide, benzo(a)pyrene, tars, and nicotine. Tobacco smoke can irritate the respiratory system and, in allergic or asthmatic persons, often results in eye and nasal irritation, coughing, wheezing, sneezing, headache, and other related sinus problems. People who wear contact lenses often complain of burning, itching, and tearing eyes when exposed to cigarette smoke. The ASHRAE ventilation guidelines for smoking areas recognize the need to provide additional ventilation (fresh outside air) to maintain air quality.

Section II

SELF-EVALUATION OF INDOOR AIR QUALITY PROBLEMS

After reading the first section, you should have a good idea of what constitutes an indoor air quality problem and what we have found to be some of the common causes. The information in this section will provide guidelines on how to proceed to evaluate your specific question of indoor air quality. Many of these steps you can undertake by yourself or with the assistance of your building maintenance personnel. For some you may need to seek outside assistance from an industrial hygiene or ventilation consultant.

A. INITIAL ASSESSMENT

1. Documentation of Complaints

You will first need to obtain an estimate of the magnitude and distribution of the problem. This may be accomplished by questionnaire (example attached - Appendix I) or interview, or may be evident by how the problem was initially identified. A review of the interview/questionnaire data should help to better define what the complaints are, whether there is any localization of the problem in the building, and any particular circumstances of weather, time of day, day of week, building occupancy, or activity which improve or worsen the problem.

Some questions that you will want to include in the questionnaire or interview outline are:

a. What health complaints have been experienced?

b. When is the first time they were noticed?

c. Is there any specific incident or event that is linked with the initial onset of the complaints? (building renovations, new carpeting, new equipment, etc.)

d. How often do they occur? (several times per day/week, etc.)

e. How long do they last? (minutes/hours, all day)

f. Are there particular times of the day they occur? (morning vs. afternoon, etc.)

g. Do they occur in particular areas of the building vs. others?

h. Are there any specific activities, tasks or unusual circumstances that accompany the problem?

i. When do the health complaints go away? '(soon after leaving the building, at home, on weekends)

As you review the data from the questionnaires, or your interviews, you will begin to get an idea of who has experienced health complaints and who has not. In addition, you should also begin to get a clearer picture of what symptoms and complaints are being reported. At this point, you may find it helpful to place individuals into categories to determine; those who definitely have health complaints, those who do not, and those who fall somewhere in between the first two categories. This exercise will at least provide you with numbers, to help determine the extent of the problem. You may also find it helpful to plot this information on a simply drawn sketch of the floor-plan, that identifies individuals in each category according to where their work stations are located. This will provide a graphic display of how complaints are distributed in the building and may help determine if the problem is wide-spread, or localized in a particular area.

You should also keep in mind as you review your data, that it's not unusual to have building occupants with health or comfort complaints from time-to-time; in fact it's normal! For example, the ASHRAE guidelines for thermal comfort strive to satisfy 80% of the building occupants. It would therefore not be unreasonable in a survey to find 20% of the occupants thermally "uncomfortable". Using the same reasoning, not every health complaint will necessarily be air quality related. In summary, your questionnaire data should be interpreted with care.

2. <u>Building Characterization</u>

Another important set of data to be obtained is associated with the building itself. What is known about the building composition and the ventilation system may provide important clues leading to problem solution. To assist you in gathering information about the building and the ventilation system, you should begin by filling in the answers to the questions listed below. (You may find it helpful and necessary to get assistance from persons who are responsible for building and ventilation system maintenance, or from an industrial hygienest or engineer. In addition, access to blue prints, diagrams, and specifications for the ventilation system etc., will also be valuable in answering the questions and assessing potential problem areas.)

a. What is the building's age?______________________________

What is the basic construction?__________________________

Number of floors?__________ No. square feet/floor__________

Type of windows?____________________ Do they open?__________

b. Who is responsible for the functioning of the building systems? (i.e., ventilation)______________________

c. Who is responsible for cleaning the interior of the building?______
____

How often is cleaning done?______________________

d. Have there been any major renovations or operating changes?________

What were they?______________________

When did they occur?______________________

e. Does the building have sprayed or foamed insulation?______________

When was it applied?______________________

f. What type of heating system is used?______________________

g. What type of cooling system is used?______________________

h. What type of humidification system is used?______________________

i. How is the total ventilation system operated?______________________
____

j. What floors and rooms are served by each system?__________________
____

k. What type of filtration system is used?______________________

How often is it changed/maintenanced?______________________

l. How much fresh air is being introduced into the ventilation system?
____

Does this amount meet system specifications?______________________

m. Where are the fresh air inlets and are they functioning properly?
____

n. Are there any possible sources of contamination located in the general vicinity of the air inlets?______________________

o. How likely are contaminants to be drawn into the air inlets due to prevailing winds and inversions?______________________

p. How does exhaust air leave the building?______________________

q. Is the building being used for the same purpose(s) for which it was designed?______________________________________

r. What type of activities are building occupants engaged in?________

____

s. What processes or activities are present in the building that may serve as contaminant sources?______________________________________

How are they vented?____

3. <u>Walk-Through Survey</u>

A walk-through survey of the building is essential to ensure that information collected by interview and/or questionnaire is accurate. A walk-through survey of the building is also helpful to assess the overall condition of the building and to determine that systems are functioning properly.

The following are some specific problem areas which may be identified and some possible solutions.

a. Specific equipment is giving off solvent fumes, ozone (older dry copiers or sparking electric motors) or heat which is not being adequately dissipated. If this type of problem needs better definition, assistance should be obtained from an industrial hygienist or manufacturing representative.

b. Improper cleaning procedures may be leaving irritating residues in the carpets. Underdilution of industrial strength cleaners can do this. Repeated steam or clean water cleaning can improve or eliminate the problem.

c. Equipment or cleaning products may be giving off solvent fumes (such as typewriter or duplicator cleaners). Also other use of solvent based materials in greater than minimal quantities may be a source of contaminants. Work practices may be able to be modified sufficiently to prevent a problem, or increased dilution ventilation, or local exhaust ventilation may be necessary.

d. Filters and wet areas (humidifiers, dehumidifiers, cooling coils) in the ventilating system may not be cleaned frequently enough. Wet areas may not be draining properly. The most unfortunate outcome can be excessive fungal spores being distributed through the system with some individuals becoming hypersensitive to them and developing hay fever like symptoms or hypersensitivity pneumonitis. Because assessment of spore counts is neither simple nor cheap, cleaning up the system is the preferred first step.

e. The air intake for the ventilating system may be located where it brings in contaminated air. Perhaps it only happens during rush hour traffic, or under specific weather conditions. If it appears to happen only under specific circumstances of short duration, one solution may be to shut off the air intake during the specific time. If it is a more general problem and the major contaminant is carbon monoxide (CO) from auto exhaust or a chimney, a general assessment using low range CO detector tubes can be made. If other substances appear important an industrial hygienist should be consulted. Correction of a building's air intake problem will probably require some structural modification and/or changing traffic patterns.

f. There may be adequate exhaust ventilation with inadequate make-up air. This reduces the efficiency of the exhaust ventilation and may lead to reverse flow in some vents. Under more extreme conditions this may show up as an inrush of outside air whenever a door or window is opened. This condition can also lead to the back-drafting of flue gases from vented natural gas appliances such as hot water heaters and boilers. Such situations will require that more make-up air be supplied. Outside environmental conditions will dictate how much treatment the additional outside air will need. It may be necessary to get professional engineering help to correct this problem.

g. The ventilating system may be out of balance or the temperature control may be inadequate. The feed-back from the building occupants should be quite helpful in pin-pointing these problems. Poor temperature control may be due to inadequate recovery time after the ventilating system has been shut down over night or over the weekend. Another possibility is that windows allow given rooms to pick up a greater solar heat load than the ventilation system can handle. Professional help may be necessary to correct this problem. The desirable temperature is dependent on customary dress, level of physical activity, amount of air movement, and individual variation. There is no one "ideal" temperature, however, ASHRAE guidelines state the operative temperature for thermal acceptability of sedentary or slightly active persons at 50% relative humidity is 73 to 79°F.

h. During winter in the colder climates, indoor air can become excessively dry when heated to comfortable temperatures. This can lead to drying and irritation of mucus membranes of the eyes, nose and throat. It may be necessary to humidify the air in excess of the water vapor added by the occupants' respiration. If the air is to be humidified (ASHRAE guidelines recommend 20-60%), remember the necessity of adequately cleaning the humidifier. Also, recirculating or independent steam humidification is preferable to filter plate type humidifiers.

i. A few individuals may be excessively sensitive, perhaps on an allergic basis, to some substance in the environment (cigarette smoke included). Increased ventilation may handle this, but it may be necessary to either modify the environment more drastically, or to move the worker(s).

j. The pressures of work, interpersonal stresses, management-labor stresses, home-demand vs. work-demand stresses, etc. may result in the workforce being aggravated by minor problems in the work environment which otherwise might simply be ignored.

At this stage of the evaluation, it is quite possible that specific problems such as non-functioning ventilation equipment, poor temperature control, etc. will become evident as a major factor in the problem. If this is the case, the problem or problems should be corrected before the evaluation continues. Correction of problems may or may not require assistance from outside contractors.

In other instances the cause or causes of an indoor air quality problem may not be so easily determined. In such instances we advise initially using a simple approach to evaluating the effectiveness of the ventilation system, including temperature and humidify factors.

B. INTERMEDIATE ASSESSMENT

1. Guidelines

a. Carbon Dioxide Levels

Carbon dioxide (CO_2) is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh outdoor air are being introduced into a building or work area. The outdoor, ambient concentration of CO_2 is usually 250-350 ppm. Usually the CO_2 level is higher inside than outside, even in buildings with few complaints about indoor air quality. However, if indoor CO_2 concentrations are more than 1000 ppm (3 to 4 times the outside level), there is probably a problem of inadequate ventilation and complaints such as headaches, fatigue and eye and throat irritation are frequently found to be prevalent. The CO_2 concentration itself is not responsible for the complaints. However, a high concentration of CO_2 may indicate that other contaminants in the building may also be increased and could be responsible for occupant complaints. If CO_2 concentrations are maintained below 600 ppm, with comfortable temperature and humidity levels, complaints about air quality should be minimal. If CO_2 levels are greater than 1000 ppm, widespread complaints may occur and thus 1000 ppm should be used as an upper limit guideline. This does not mean that if this level is exceeded the building is hazardous or that it should be evacuated, but rather this level should be a guideline that helps maximize comfort for all occupants. Levels between 600 ppm and 1000 ppm are less clearly interpreted.

b. Temperature

ASHRAE has published guidelines describing thermal environmental conditions, (ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy). These guidelines are intended to achieve thermal conditions in a given environment, that at least 80% of the persons who occupy that environment will find acceptable or "comfortable." The following is an example of the guideline that ASHRAE recommends for a building environment that is occupied by sedentary or slightly active persons, during the summer season, and when the relative humidity is at 50%: The operating temperture to achieve thermal acceptibility (comfort zone) should be 73° to 79°F. If the operating temperature is outside this range, (at either end-point), then more than 20% of healthy people occupying the area are likely to experience some degree of discomfort.

c. Humidity

The majority of references addressing temperature and humidity levels as they pertain to human health frequently appear in the context of assessing conditions in hot environments. Development of a "comfort" chart by ASHRAE presents a comfort zone considered to be both comfortable and healthful. This zone lies between 73 and 77°F (23 and 25°C) and 20 to 60 percent relative humidity. ASHRAE's recommended design conditions are an effective temperature and dry bulb temperature of 76°F (24.5°C), a relative humidity of 40 percent, and an air circulation rate of less than 45 feet per minute. Effective temperature is an index of relative comfort determined by successive comparisons of individuals to different combinations of temperature, humidity, and air movement. Relative humidity levels below 20 percent are associated with increased discomfort and drying of the mucous membranes.

d. Provision of Adequate Amounts of Outside Air

ASHRAE Standard 62-1981 (Ventilation for Acceptable Indoor Air Quality) recommends guidelines for a wide variety of commercial, institutional, and industrial facilities, including office buildings. For general offices where smoking is not permitted, indoor air quality is considered adequate if outside air is provided at the rate of 5 cubic feet per minute (CFM) per occupant. Higher ventilation rates are recommended for areas where smoking is permitted because tobacco smoke is one of the most difficult air contaminants to control. Thus, where smoking is allowed, a minimum of 20 CFM of outdoor air per occupant should be provided (ASHRAE 62-1981, Table 3, Section 3.1).

2. <u>Sampling Techniques for Carbon Dioxide, Temperature, Humidity and Air Flow</u>

CO_2 concentrations can easily be determined by using direct reading detector tubes which indicate concentration as a function of length of color change on a sampling tube. Tubes and their associated sampling pumps can be obtained from most local industrial safety equipment supply houses. (See example - Figure 1.)

Plan your sampling locations. Include some areas where there are problems and some where there are not. If there is no difference between areas, pick some from each area of the building.

Start sampling first thing in the morning. You should be among the first people in the building that day. Get baseline samples at all your major sample spots including an outside sample. During the day get representative samples in all your major sampling locations, the frequency determined by the variety and duration of activities. You will probably want to get samples just before the lunch break, particularly if there is a significant decrease in building occupancy at lunch. You will want samples again at the end of the work day just before everyone starts leaving (a lot of in-out traffic would allow more air exchange than during the major part of the day). Depending on the number of sampling sites and activities involved, you may want additional samples at other locations. Record all CO_2 measurements in ppm, by specific location and time of day.

To round out the monitoring, temperature and humidity should be checked at various times and places throughout the day, and if necessary, air flow at vents and return air grills should be evaluated as well. Although wet bulb, dry bulb thermometers can be used, that degree of accuracy is unnecessary. A desk thermometer and relative humidity meter should be adequate. Measurements for air flow are intended to assure that vents are functioning (perhaps intermittently) and to possibly see if the airflow is directed in a suitable direction. Air movement from vents is easily checked with smoke tubes, which are also available from any safety supply house. (See example - Figure II.) Exact measurements are less important at this stage of the evaluation.

3. Interpretation of Results

Your decision to take further action will be determined by what you have found during your day of sampling. The following, represent some of the possible general trends and recommendations for followup, that have been identified through CO_2 monitoring.

a. Initial CO_2 readings inside the building are close to outside readings (250-350 ppm). During the day there are a few rises and falls, but by quitting time readings are still close to initial readings. This suggests that fresh air intake is sufficient. Perhaps the first approach to improving the livability of the building will be to look at temperature and humidity, and check for imbalances in the ventilating system.

b. Initial CO_2 readings inside the building are close to outside readings. During the day levels rise and are definitely elevated by the close of work. This suggests that over 24 hours the air intake is sufficient, but may not be sufficient during the hours the building is occupied.

c. Initial CO_2 readings inside the building are appreciably higher than outside readings. This may simply be due to the shutdown of the ventilating system when the building is unoccupied, or it may be due to underventilation which will require provision of significantly more fresh air. In this case it will be necessary to arrange to have the system left on for several hours after the occupants leave.

d. Temperature, humidity and air flow readings compare unfavorably with specified guidelines. Steps should be taken to adjust systems to comply with the guidelines.

4. Contaminant Sources

Additional evaluation of point sources of contaminants also may be necessary. If point sources such as copy machines, blue print machines, solvents, etc. are suspected to be causing the problem, the assistance of an industrial hygienist, or a manufacturing representative, may be necessary.

5. General Recommendations for the Correction and Prevention of Indoor Air Quality Problems

a. Ensure an Adequate Fresh Outdoor Air Supply

This has been shown to be the single most effective method of correcting and preventing problems and minimizing complaints related to poor indoor air quality. Even if a specific contaminant is identified (such as formaldehyde) dilution may be the most practical way of reducing exposures.

(1) If mechanical ventilation is on, check that the outdoor air supply louvers are open. They may have been closed deliberately to save energy, or automatically by a faulty control system.

(2) Fresh, outdoor air should be adequately distributed to all office areas during the entire time they are occupied, at a minimum rate of 5 cubic feet per minute (cfm) of fresh air per person. In areas where smoking is permitted this rate should be increased to 20 cfm per person. These levels are specified in the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality." If the exact number of occupants is not known, an estimate of 7 persons per 1000 ft^2 may be used to calculate ventilation requirements. Fresh air ventilation rates should be measured on a regular basis to ensure they remain at optimal levels.

(3) During occupancy periods it should be assured that outdoor air dampers (vents) do not close, nor do fans of air handling units turn off at certain times of the day or within certain temperature ranges. These problems may mean that modifications must be done on the ventilation system so that it can handle very cold or very warm air.

(4) All air vents (diffusers) should be checked to ensure they are open and unobstructed, providing for adequate air mixing in each supplied area. Also the diffusers should be adjusted so that occupants are not sitting in a direct stream of air. Often the air stream temperature will be less than body temperature and be uncomfortably cool.

(5) If the office layout has been changed (e.g., by erecting partitions, room dividers, or new walls), care must be taken that adequate air flow is still being provided.

(6) An insufficient supply of make-up (fresh) air can cause the building to be at a negative pressure with respect to the outdoor atmosphere, creating a situation where untreated air and/or contaminants can infiltrate from outside. This can be determined by observing the direction of air movement at windows and doors. In order to prevent this problem, particular attention must be paid to proper balancing of the air supply and exhaust systems.

(7) A program of preventive maintenance must be in place for all ventilation equipment, including checking; damper positions and functioning belts, baffles, ductwork, and system balance. Actual air flow supplied to occupied areas must be measured and any necessary maintenance or repairs done to comply with the original design specification and the ASHRAE Guidelines.

(8) If possible, gauges should be installed to provide information on air volumes delivered by supply and return fans, and maintenance people should be trained to read them and respond appropriately.

(9) Filters on air handling units must be replaced at regular intervals. Permanent static pressure gauges are helpful in deciding when to change filters. Filters should have a moderate efficiency rating, as measured by the ASHRAE atmospheric dust spot test, and should be of an extended surface type. Pre-filters (e.g., roll type) should be used before air passage through higher efficiency filters.

b. Eliminate or Control all Known and Potential Sources of Chemical Contaminants

(1) Use local exhaust where appropriate to capture and remove contaminants generated by specific processes. In some instances, the manufacturer of office machines will advise whether exhaust ventilation is recommended.

(2) General room air from areas where contaminants are generated (e.g., a printing area where solvents are used) should be exhausted directly outdoors rather than recirculated into the rest of the building's air supply.

(3) Check to be sure outside air intakes or other building vents or openings are not located in close proximity to potential sources of contamination (e.g., places where motor vehicle emissions collect, downwind of exhausts, cooling towers, etc.). If necessary, raise stacks or relocate intakes or exhausts.

(4) Isolate areas of renovation, painting, carpet laying, etc., from occupied, non-construction areas through use of physical barriers and separation of involved ventilation systems. If possible, perform this type of work on evenings and weekends. Supplying a maximum amount of ventilation to the areas initially on a 24 hour basis can assist in rapid dispersion of contaminant levels.

(5) Pesticides should be applied only while the building is unoccupied, and the building should be thoroughly ventilated before reoccupation.

(6) Eliminating or reducing contamination of the air supply with cigarette smoke is a recognized method of improving the indoor environment. Cigarette smoke contains many substances (e.g., carbon monoxide, formaldehyde, particulates) that pollute the air and may build up in poorly ventilated areas. Bans on smoking or restriction of smoking to designated areas (preferably that have their air supply exhausted rather than recirculated) are methods of dealing with this pollution source.

c. Eliminate or Control all Known and Potential Sources of Microbial Contaminants

(1) Promptly detect and permanently repair all areas where water collection or leakage has occurred.

(2) Maintain relative humidity at less than 60% in all occupied spaces and low-air-velocity plenums. During the summer, cooling coils should be run at a low enough temperature to properly dehumidify conditioned air.

(3) Check for, correct, and prevent further accumulation of stagnant water under cooling deck coils of air handling units, through proper inclination and continuous drainage of drain pans.

(4) Use only steam, not water, as the moisture source for humidifiers in the ventilation systems. Steam should not be contaminated with volatile amines (sometimes used as rust inhibitors).

(5) Once contamination has occurred (through dust or dirt accumulation or moisture-related problems) downstream of heat exchange components (as in ductwork or plenum), additional filtration downstream may be necessary before air is introduced into occupied areas.

(6) Water-damaged porous furnishings, including carpets, upholstery and ceiling tiles, should be discarded rather than disinfected, to effectively eliminate microbial contamination.

(7) Air handling units should be constructed so that equipment maintenance personnel have easy and direct access to both

heat exchange components and drain pans for checking drainage and cleaning. Access panels or doors should be installed where needed.

(9) Non-porous surfaces where moisture collection has promoted microbial growth (e.g., drain pans, cooling coils) should be cleaned and disinfected with detergents, chlorine-generating slimicides (bleach), and/or proprietary biocides. Care should be taken to insure that these cleaners are removed before air handling units are reactivated.

C. CONCLUSIONS AND FOLLOW-UP ASSESSMENTS

If sufficient information has been obtained to identify the problem or problems, corrective action can be taken. Depending on the complexity of the problem, it may or may not be necessary to call in expert help, such as that of an engineering/ventilation consultant or an industrial hygienist. Keep in mind that early recognition of a problem, with a timely and systematic evaluation, are key factors to a quick and effective resolution.

In summary:

1. Make a log of employee complaints.

2. Assess the ventilation system for the building, including temperature and humidity factors.

3. Identify and evaluate sources of contaminants.

4. Correct identified deficiencies and control or eliminate identified sources of contaminants.

5. Monitor complaints after remedial action has been taken.

Section III

INDOOR AIR QUALITY CONSULTATION SERVICES

If further evaluation is needed to resolve the problem or if technical expertise is needed to complete any of the self-evaluation steps outlined above, on-site assistance is available from the following sources.

1. Local or State Health Departments or Consulting Programs (Availability and expertise vary with locality and state)

2. Private Consultants (availability and expertise vary)

    a. A list of industrial hygiene consultants who are members of the American Industrial Hygiene Association (AIHA) is available from the AIHA:

        American Industrial Hygiene Association
        475 Wolf Ledges Parkway
        Akron, Ohio 44311-1087

    b. A list of engineering firms certified by the National Environmental Balancing Bureau (NEBB) is available from the NEBB:

        National Environmental Balancing Bureau
        8224 Old Courthouse Road
        Vienna, Virginia 22180

3. NIOSH - Health Hazard Evaluation Program:

        National Institute for Occupational Safety and Health
        Hazard Evaluations and Technical Assistance Branch
        4676 Columbia Parkway
        Cincinnati, Ohio 45226

Additional background information concerning indoor air quality can be obtained from the following sources.

1. Environmental Protection Agency
   820 Quincy Street, N.W.
   Washington, D.C. 20011

2. Consumer Product Safety Commission
   Washington, D.C. 20207

3. Office of Scientific and Technical Information
   Department of Energy
   P.O. Box 62
   Oak Ridge, Tennessee 37830

6. Federal Employee Occupational Health Program (contact your regional Public Health Service Office)

INDOOR AIR QUALITY QUESTIONNAIRE

1. Complaints Yes_____ No_____
   (If yes, please check)

   _____ temperature too cold
   _____ temperature too hot
   _____ lack of air circulation (stuffy feeling)
   _____ noticeable odors
   _____ dust in air
   _____ disturbing noises
   _____ other (specify)_______________________________

2. When do these problems occur?

   _____ morning
   _____ afternoon
   _____ all day
   _____ no noticeable trend
   _____ daily
   _____ specific day(s) of the week
   which day(s)?_______________
   ____

3. Health Problems or Symptoms

   Describe in three words or less each symptom or adverse health effect you experience more than two times per week.

   Example: runny nose

   Symptom #1 _______________________________

   Symptom #2 _______________________________

   Symptom #3 _______________________________

   Symptom #4 _______________________________

   Symptom #5 _______________________________

   Symptom #6 _______________________________

   Do the above symptoms clear up within 1 hour after leaving work?
   Yes ____ No ____

   If no, which symptom or symptoms persist (noted at home or at work) throughout the week? Please indicate by drawing a circle around the symptom number below.

   Symptom: #1 #2 #3 #4 #5 #6

   Do you have any health problems or allergies which might account for any of the above symptoms? Yes ____ No ____

   If yes, please describe._______________________________

   ____

   ____

(over)

4. Do any of the following apply to you?

_____ wear contact lenses
_____ operate video display terminals at least 10% of the work day
_____ operate photocopier machines at least 10% of the work day
_____ use or operate other special office machines or equipment (specify)

____

_____ currently taking medication
reason for taking medication (specify) _____________________

____

5. Do you smoke? Yes_____ No_____
6. Do others in your immediate work area smoke? Yes_____ No_____

7. Your office or suite number is _____________________

8. What is your job title or position?_____________________

9. Briefly describe your primary job tasks. _____________________

____

____

10. Can you offer any other comments or observations concerning your office environment? (optional)

____

____

____

____

____

____

____

____

11. Your name? (optional) _____________________

12. Your office phone number? (optional)_____________________

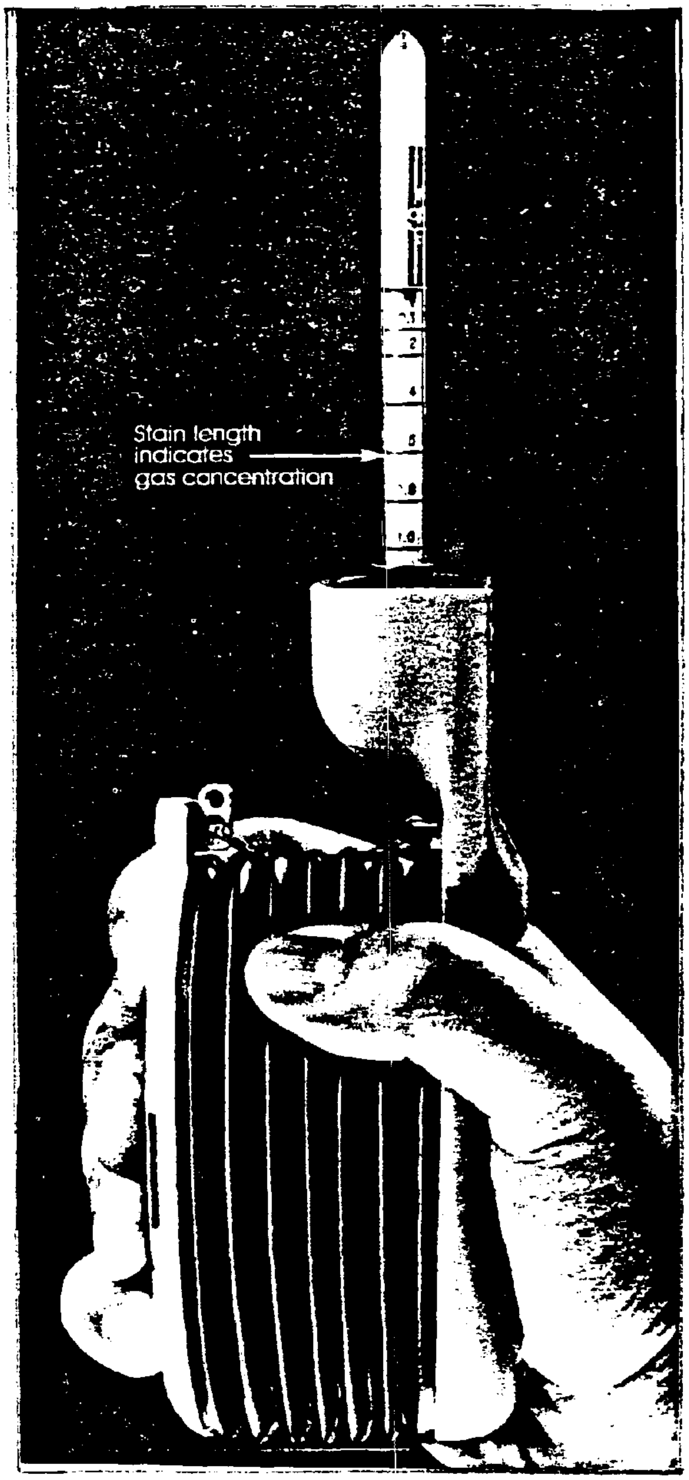

Figure I

Direct Reading Detector Tube and Pump

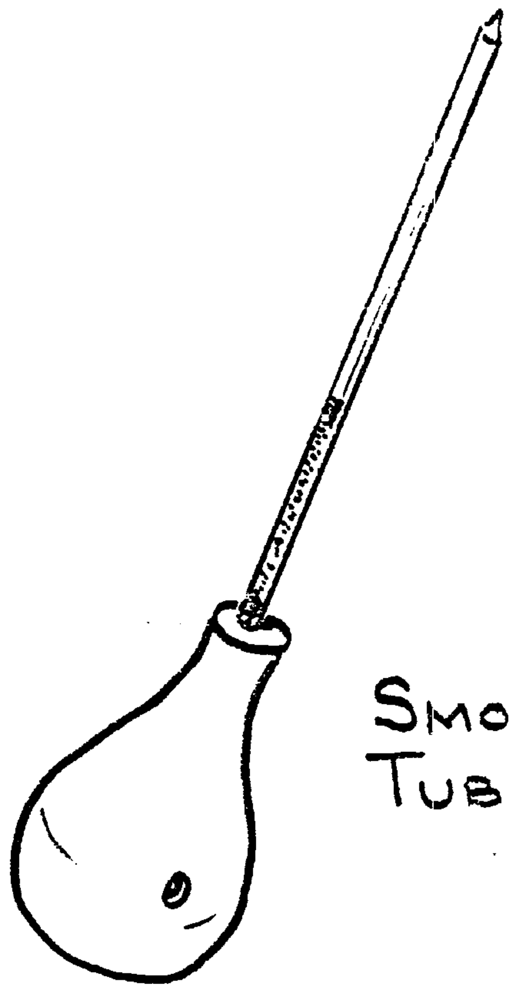

Figure II