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E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA

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I. SUMMARY

On September 25, 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the Superintendent of Schools for the Souderton Area School District, Souderton, Pennsylvania, to evaluate complaints of headache, nasal congestion, sore throat, and eye irritation among students and teachers at the E.M. Crouthamel Elementary School.

On October 16, 1986, environmental and medical evaluations were conducted at the school. Six general area air samples for formaldehyde were collected in lower wing classrooms where the complaints were focused and in control areas. Formaldehyde concentrations with the ventilation system off ranged from 0.02 to 0.07 parts per million (ppm) in the areas monitored. A decrease in formaldehyde concentration was measured in the complaint areas with the ventilation turned on. The plywood underlayment in recently carpeted rooms was implicated by bulk sample analyses as the source for the formaldehyde.

Fifty-seven percent of interviewed employees had complaints that they attributed to the school environment. The complaints were not associated with exposure to specific rooms. Most teachers did not notice a recent increase in student health complaints. We were unable to adequately evaluate the prevalence of student health complaints using school nurse logs or a parents' committee survey. The NIOSH investigators recommended that the school ventilation system be inspected and that it be operated at all times that the school is occupied.

A follow-up environmental evaluation conducted on January 28, 1987 found trace quantities of formaldehyde throughout the school. Twenty-eight area air samples were collected in 14 areas. One result, 0.04 ppm, was above the limit of quantitation (LOQ) for the analytical method. All of the other sample results ranged from 0.02 to 0.03 ppm, between the analytical limit of detection and the LOQ. This range of values for formaldehyde is low and typical for indoor air. Carbon dioxide (CO_2) concentrations measured during this follow-up evaluation ranged between 600 and 1700 ppm during the school day. The higher concentrations were measured in the upper wing of the school. Many of the measurements exceeded 1000 ppm which is commonly used as a guideline or indicator of inadequate ventilation. Temperatures and relative humidities were found to be outside (lower than) recommended comfort ranges and thus may be associated with some of the health complaints.

On the basis of the environmental and medical evaluation results, it was concluded that a health hazard did not exist. Low levels of formaldehyde diffusing from plywood carpeting underlayment and inadequate ventilation may have contributed to an increase in complaints of discomfort. Increased ventilation improved air quality. Recommendations were made, including improving the ventilation system in the school.

KEYWORDS: SIC 8211 (Elementary and Secondary Schools), formaldehyde, carbon dioxide, indoor air, ventilation

II. INTRODUCTION

On September 25, 1986, officials for the Souderton Area School District, Souderton, Pennsylvania, requested that NIOSH investigate health complaints at the E.M. Crouthamel Elementary School. There was concern among school officials, teachers, and parents that exposure to formaldehyde posed a health risk to students and teachers at the school.

On October 6, 1986, an initial medical and environmental investigation was conducted at the school. An Interim Report of this evaluation was submitted to the school district later that month.

On January 28, 1987, a follow-up environmental evaluation was conducted to determine whether the school heating and ventilation system could control occupant exposures to formaldehyde by providing adequate amounts of fresh air and also maintain a comfortable environment for school occupants. The results from this evaluation were transmitted to the school district in a letter on February 20, 1987.

III. BACKGROUND

The E. M. Crouthamel Elementary School was built in 1962. It is a single story brick structure similar to many schools from that era. An addition to the school was constructed in 1969. Figure 1 is a floor plan of the school.

A systematic program for carpeting the classrooms in the older section (lower wing) of the school was started in 1979. A plywood underlayment was used beneath the carpet. The new section (upper wing) of the school was carpeted during construction in 1969. No underlayment was used in the upper wing.

The appearance of health complaints among the students and teachers reportedly began after carpeting was installed in classrooms in the lower wing of the school. The reported symptoms included headache, nasal congestion, sore throat, and eye irritation.

At the time NIOSH became involved, the focus of the investigation was on three rooms located in the lower wing, rooms 22, 31, and 32. Classes in these rooms had been discontinued. Environmental air monitoring conducted in September 1986 by a contractor hired by the school district indicated that there were concentrations of formaldehyde present above usual background levels. These rooms had had carpeting installed, room 22 in 1984, and rooms 31 and 32 in 1985, all with plywood underlayment.

The school heating and ventilation (HV) system consists of centrally controlled, individual room units (Nesbitt, Model 500-UR). The units are located on the outside wall of the room to allow for fresh air intake. This is a hot water heating system with no air cooling feature. Fresh air dampers are open whenever the system is operating. The dampers cycle between the maximum and minimum stops under control of the room thermostat. A certain amount of room air is recirculated through the ventilator units. The school has a passive air exhaust system through hallway ceiling vents in the lower wing and from a common

above-ceiling plenum in the upper wing. Air passes from the classrooms through grilles in the wall or ceiling between the rooms and the exhausted areas.

IV. EVALUATION DESIGN AND METHODS

A. Initial Environmental Evaluation

During the initial visit on October 6, 1986, we collected six air samples for formaldehyde. Five of the air samples were collected in three rooms in the lower wing of the school which had been carpeted within the last three years. Two of these, rooms 22 and 32, were classrooms associated with the health complaints. The third was the audio/visual (A/V) storeroom which had the newest carpeting. One air sample was collected in an occupied classroom, room 51, in the upper wing, which was not associated with the current health complaints.

The rooms were sampled under two different conditions. The first set of three air samples was collected with the rooms closed and not actively ventilated, which was typical for the season. This set included the samples from classrooms 22, 32, and the A/V storeroom. The second set of samples, from classrooms 22, 32, and 51 were collected with the school ventilation system in operation. The system was turned on at the beginning of the second air sampling period.
All air samples for formaldehyde were collected using calibrated battery-operated sampling pumps, at a flowrate of 1.0 liters per minute (lpm), through midget impingers containing 20 milliliters (ml) of a 1% sodium bisulfite solution. Sampled air volumes were 90 liters. Analysis was by visible absorption spectrophotometry according to NIOSH Method 3500.[1] The analytical limit of detection (LOD) for this method was 0.5 micrograms per sample (ug/sample), and the limit of quantitation (LOQ) was 2.0 ug/sample (0.02 parts per million air concentration).

Two air samples were collected for organic hydrocarbons, one in classroom 22 and one in 32, to determine whether any other organic vapor that could cause the reported health effects was present. These samples were collected by drawing air through a glass tube containing 150 milligrams of activated charcoal, at a flowrate of 1.0 lpm, using calibrated battery-operated sampling pumps. The samples were desorbed with 1 ml carbon disulfide and analyzed by gas chromatography (GC) with a flame ionization detector. Additionally, one of the samples was concentrated and analyzed by GC using a mass spectrometer as a detector for major compound identification.

Four bulk material samples were submitted for latent formaldehyde analysis. These included two samples of carpeting from room 22 and one from room 32, and one sample of plywood underlayment material from room 22. The carpet and plywood underlayment from room 22 had been in place for two years (installed August 1984) and the carpet from room 32 had been in place for one year (installed August 1985).

Each carpet sample was divided into three sub-samples for analysis. A piece of the whole carpet was analyzed, as well as separate portions of the fibers and the rubberized binder material which held the fibers together. These samples were analyzed using a modification of the Burlington Industries method for latent formaldehyde. Approximately one gram of each sample was suspended over 50 ml of distilled water in a sealed container over a 20-hour period at 50°C. A 10-ml aliquot of the water was then reacted with

chromotropic and sulfuric acids, and the resulting absorbance was read on a spectrophotometer set at 570 nanometers. Quantitative results were determined by comparison of the absorbance exhibited by the samples with that of standard solutions.
Carbon dioxide concentrations were measured in selected areas using a Gastech Portable CO_2 Indicator, Model RI-411. The measurement range of the instrument is 0-9950 parts per million (ppm). The instrument was calibrated prior to use, using CO_2 calibration span gas (800 ppm).

B. Medical Evaluation

Fourteen school employees (13 teachers and the principal) and four parents were interviewed during the medical evaluation. Medical histories and complaints thought to be related to the school environment were recorded. The parents' committee provided a listing of pupils' complaints elicited from telephone calls to parents. School nurse attendance logs for the past year were obtained from E. M. Crouthamel and from another elementary school (without reported problems).

C. Follow-up Environmental Evaluation

On January 28, 1987 air samples for formaldehyde were collected at 14 locations throughout the school (11 classrooms, reading room, library, and principal's office). The concentration of formaldehyde in the outdoor air was also measured. An air sample was collected at each location in the morning and in the afternoon. Classes were being conducted in all classrooms except room 22. Measurements of the carbon dioxide (CO_2) concentration, temperature, and relative humidity were obtained at each air sampling location during each sampling period.

The formaldehyde sampling and analytical methods were the same as in the initial evaluation (NIOSH Method 3500), except the analytical LOD was 2.0 ug/sample and the LOQ was 4.0 ug/sample. Carbon dioxide concentrations were measured using Drager tubes. The measurement range of these tubes is 0.01-0.30% (100-3000 parts per million). Temperature and relative humidity levels were obtained using a Belfort Instrument Company, Model 556 battery-operated psychrometer.

V. EVALUATION CRITERIA FOR BUILDING-RELATED ILLNESS EPISODES

A. Environmental Evaluation

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

While the majority (N80%) 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 suggestive of 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 because workers' symptoms normally disappear when they are away from the office. At times, these symptoms have been severe enough to result in missed work and reassignment.

Although some of these episodes were multifactorial, the investigations we have conducted can be classified 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 the 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: inadequate fresh outdoor air supplied to the office space; poor air distribution and mixing, causing 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 the 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 the 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 the investigations have involved some type of microbiological contamination. Even though this is not a common cause of indoor air 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 the NIOSH 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.

5. Building Fabric Contamination

Contamination from building materials and products is the major problem in 3% of the investigations. Formaldehyde vapor can diffuse 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 erosion of fibrous glass in lined ventilating ducts; various organic solvents from glues and adhesives; and acetic acid used as a curing agent in silicone caulking.

In summary, the major problems identified in the NIOSH 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 occupants become uncomfortable or experience adverse health effects.

B. Formaldehyde

Formaldehyde and other aldehydes may be released from foam plastics, carbonless paper, particle board, plywood, and textile fabrics. Symptoms of exposure to low concentrations of formaldehyde include irritation of the eyes, throat and nose, headaches, nausea, congestion, asthma, and skin rashes. It is difficult to ascribe specific health effects to specific concentrations of formaldehyde to which people are exposed, because they vary in their subjective responses and complaints. Irritation symptoms may occur in people exposed to formaldehyde at concentrations as low as 0.1 ppm, but more frequently in exposures of 1.0 ppm and greater. Some sensitive children or elderly, those with preexisting allergies or respiratory diseases, and persons who have become sensitized from prior exposure may have symptoms from exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. However, cases of formaldehyde-induced asthma and bronchial hyperreactivity developed specifically to formaldehyde are rare.[2]

There is little scientific data pertaining to the effects of formaldehyde exposure specifically on children. A recent Canadian study compared 29 children living in homes insulated with urea- formaldehyde foam with a comparison group of randomly selected children. The study failed to find significant differences in respiratory symptoms or pulmonary function between the two groups.[3]

Formaldehyde vapor has been found to cause a rare form of nasal cancer in Fischer 344 rats exposed to a 15 ppm concentration for 6 hours per day, 5 days per week, for 24 months. Whether these results can be extrapolated to human exposure is the subject of considerable speculation in the scientific literature. Conclusions cannot be drawn with sufficient confidence from published mortality studies of occupationally exposed adults as to whether or not formaldehyde is a carcinogen. Studies of long term human occupational exposure to formaldehyde have not detected an increase in nasal cancer. Nevertheless, the animal results have prompted NIOSH to recommend that formaldehyde be handled as a potential occupational carcinogen. An estimate of the cancer risk to workers exposed to formaldehyde levels at or below the current 3-ppm Occupational Safety and Health Administration (OSHA) standard has not yet been determined. In the interim, NIOSH recommends that workplace exposures be reduced to the lowest feasible limit.[4]

The fact that formaldehyde is found in so many home products, appliances, furnishings, and construction materials has prompted several agencies to set standards or guidelines for residential formaldehyde exposure. The American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has recommended, based on personal comfort, that exposure to formaldehyde be limited to 0.1 ppm. This guideline has also been adopted by the National Aeronautics and Space Administration (NASA), and the

Federal governments of Canada, West Germany, and the United Kingdom.[5] An indoor air formaldehyde concentration of less than 0.05 ppm (0.06 mg/m^3) is of limited or no concern according to the World Health Organization (WHO).[6]

Table I summarizes data from many studies of formaldehyde levels in homes in different parts of the United States, Canada, and the United Kingdom. Mobile homes, due to the large amount of pressed wood products used in their construction, have the highest formaldehyde concentrations. A mean of 0.4 ppm has been found in most of the studies conducted in mobile homes. Most other types of homes have average formaldehyde levels less than 0.1 ppm. Interestingly, mean formaldehyde levels in homes with foam insulation are only slightly higher than levels in homes without foam insulation, although a higher percentage of foamed houses do have formaldehyde levels exceeding 0.1 ppm. In one study older (>15 years) conventional homes, with a mean formaldehyde level of 0.03 ppm, had lower formaldehyde levels than newer homes (0.08 ppm in homes less than 5 years old).

C. Carbon Dioxide

Carbon dioxide CO_2 is a normal constituent of exhaled breath. Its concentration in indoor air can be used as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into a building. The outdoor, ambient concentration of CO_2 is usually 250-350 ppm. It is important to realize that the CO_2 concentrations are normally higher indoors than outdoors, even in buildings with few reported complaints. However, if the indoor CO_2 concentration is more than l000 ppm, or 3 to 4 times the outdoor level, ventilation may be inadequate, and there may be complaints such as headache, fatigue, and eye and throat irritation. The CO_2 concentration itself is not responsible for the complaints, but the elevated concentration of CO_2 indicates that other contaminants in the building may also be increased.

At this point in time, there seems to be general agreement among health agencies studying indoor air quality that if CO_2 levels are maintained below 600 ppm, with comfortable temperatures and humidities, complaints referable to air quality should be minimal. When CO_2 levels are above l000 ppm, complaints may occur, and many health agencies recommend that this level should be used as an upper limit guideline. This does not mean that if this level is exceeded the building is hazardous or should be evacuated. Rather the level should be used as a guideline that helps maximize comfort for all occupants. The consequences of CO_2 concentrations between 600 and l000 ppm are not as well understood. Previous evaluations conducted by NIOSH have shown that CO_2 is a sensitive measurement; the quality of the room air is very quickly affected by occupancy.

D. Provision of Adequate Amounts of Outside Air

Neither NIOSH nor OSHA has developed ventilation criteria for schools or general offices. Criteria often used by design engineers are the guidelines published by ASHRAE.

In 1981, ASHRAE published its Ventilation Standard, ASHRAE 62-1981, "Ventilation for Acceptable Indoor Air Quality". For classrooms in "educational facilities", the maximum occupant density for the recommended standard is 50 persons per 1000 ft^2 of floor area. This ASHRAE standard states that indoor air quality shall be considered acceptable if the supply of outdoor air is sufficient to reduce carbon dioxide to less than 2500 ppm and to control contaminants, such as various gases, vapors, microorganisms, smoke, and other particulate matter, so that concentrations known to impair health or cause discomfort to occupants are not exceeded. The rate recommended for classrooms in "educational facilities" is 5 cfm of outdoor air per person. The rate is higher if smoking is permitted.[7]

Currently under public review is a draft version of ANSI/ASHRAE 62-1981R (July 1986), a proposed revision of the ASHRAE Standard 62-1981. In this revision, the ventilation requirements for classrooms for educational use is increased to 15 cfm per occupant. The basis for this rate is to limit CO_2 concentrations to 1000 ppm (0.1%)[8].

E. Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of the heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by environmental factors such as temperature, humidity, and air movement as well as personal factors such as activity and clothing.

ANSI/ASHRAE Standard 55-81 "Thermal Environmental Conditions for Human Occupancy", published in l981, specifies conditions in which 80% or more of the occupants will find the environment thermally comfortable. Figure 2, which was taken from this document, presents the acceptable ranges of temperature and humidity according to ASHRAE.[9] It should be noted that as many as 20% of the occupants because of individual preferences, may not feel thermally comfortable even if general room temperatures and humidities are within the ASHRAE comfort range. Figure 3 presents the currently accepted criteria for comfort of normally clothed, sedentary individuals, from the Industrial Ventilation Manual, 18th edition, published by the American Conference of Governmental Industrial Hygienists. In general, if the relative humidity is below 30%, the mucous membranes tend to dry and occupant discomfort is increased.

VI. RESULTS AND DISCUSSION

A. Initial Environmental Evaluation

1. Formaldehyde

The October 6 air sampling results for formaldehyde are presented in Table 2. Prior to activating the ventilation system, air levels were 0.03 parts per million (ppm) in the A/V storeroom, 0.04 in classroom 32, and 0.07 ppm in classroom 22. Following the ventilation system activation, levels were 0.05 ppm in classroom 22, 0.03 ppm in classroom 32, and 0.02 ppm in classroom 51. All samples were collected for a 90-minute period.

Samples collected in classrooms 22 and 32 showed a significant decrease in formaldehyde concentrations while ventilating for 90 minutes.

2. Bulk Material Samples

The whole carpet sample from classroom 22 contained 100 ppm formaldehyde on a weight basis. The whole carpet sample from classroom 32 contained 25 ppm. Results from the separate portions of the carpet fiber and binder material were variable among the samples with no consistent pattern. Two pieces of the same plywood underlayment sample were analyzed and the formaldehyde content of these averaged 600 ppm.

3. Hydrocarbons

Air samples for hydrocarbons showed very small amounts of toluene and some aliphatic hydrocarbons in the C_{10}-C_{11} region. Toluene concentrations were less than 1 ug per sample (0.003 ppm).

4. Carbon Dioxide

The CO_2 concentrations measured on October 6, 1986 were 550 ppm in the unoccupied rooms and 700 ppm in an occupied room (room 51). This measurement was made within a few minutes following the afternoon recess. The students had just reentered the classroom and the door had been open a few moments earlier, allowing for some amount of dilution to take place. The CO_2 concentration outside was 350 ppm.

Bulk sample analysis clearly showed that the source of the formaldehyde in room 22 was the carpet underlayment. One explanation for the higher concentrations of formaldehyde in room 22, where the carpet had been installed two years earlier, versus rooms 31 and 32, where the carpet was installed just one year before, is variability in the formaldehyde concentrations in the plywood underlayment.

Air sampling indicated that without ventilation it would be possible for formaldehyde concentrations to increase over time to the point where exposure could cause irritation. After using ventilation for 90 minutes the concentrations decreased to background levels commonly found in office and residential buildings. With the use of maximum ventilation, the relatively high concentrations of CO_2 found inside the school should also decrease.

B. Medical Evaluation

Eight of fourteen employees (57%) interviewed during the initial evaluation reported symptoms which they attributed to the school environment. Several teachers had more than one symptom. Five (36%) of the employees reported headache and nasal congestion, ear problems and eye problems were each replaced by two (14%) employees. Two employees (14%) felt that stress from recent contract negotiations contributed to complaints. Seven of fourteen employees noticed an odor in the school. Five employees (36%) noticed an increase in student complaints of headache or stomach ache during the past year. Employee complaints were from a wide range of grade levels and different classrooms.

The parents' committee at E.M. Crouthamel surveyed parents of approximately fifty students by telephone. The survey log listed thirty-three students with health problems, most of which were headaches and allergic symptoms.

We are unable to draw conclusions from this study about the prevalence of building related symptoms in students. The log of visits to the school nurse may be of limited value in estimating symptom prevalence. The high suggestibility of children to complaints by other pupils or their parents and teachers make it impossible to know whether visits to the nurse were due primarily to the health effects of an air contaminant in the school. Our interviews revealed that most of the teachers (64%) have not observed a recent increase in student complaints. The parents committee survey contains many reports of headaches and allergic symptoms. However this list cannot be used to measure the number of students' building-related complaints. Such a measurement would require an unbiased poll of a representative selection of the population.

C. Follow-up Environmental Evaluation

After the initial evaluation, we recommended that the ventilation system at the E.M. Crouthamel Elementary school be used whenever the school is occupied in order to introduce as much fresh air as possible into the building. We also recommended that the ventilation system be inspected by a experienced ventilation engineer to determine that it was operating within design parameters. Between the initial and the follow-up evaluations school officials implemented these recommendations and also decided to remove the carpet and underlayment from room 22. Classes were moved back into rooms 31 and 32.

1. Formaldehyde

Formaldehyde air sampling results for the January 28, 1987 evaluation are presented in Table 3. Only one sample concentration was above the LOQ of 4 ug/sample; the morning sample from room 62 in the upper wing of the school had a formaldehyde concentration of 0.04 parts per million (ppm). All other samples results, including the afternoon sample in room 62, were either between the LOD and the LOQ or were below the LOD (none detected). Values between the LOD and LOQ are considered to be trace values and are only semi-quantitative. The range of trace values found was from 0.02 to 0.03 ppm. A trace value of 0.02 ppm was found in the morning sample collected outside. There was none detected outside in the afternoon. It is not uncommon to find formaldehyde in ambient outside air in urban areas.

The concentrations of formaldehyde found inside the school are are at the lower end of the range of values normally found in mobile homes and conventional residences (Table 1). In office environments, similar concentrations of formaldehyde have been measured by NIOSH investigators and have not generally been associated with health effects.

2. Carbon Dioxide

The CO_2 concentrations measured during the morning and afternoon of January 28, 1987 are reported in Table 4. Indoor concentrations of CO_2, measured throughout the schoolday, ranged between 600 and 1700 ppm. The outdoor CO_2 concentration was 200 ppm. The concentrations of CO_2 in the lower wing of the school were generally lower than those in the upper wing. Lower wing CO_2 concentrations ranged from 500 t0 1000 ppm. Upper wing CO_2 concentrations ranged from 1000 to 1700 ppm.

The lower wing of the school is apparently better ventilated than the upper wing. On the day of this evaluation, we requested that no windows be opened so that all fresh air introduced was from the ventilation system. A few of the teachers left classroom doors open to the hallway. All CO_2 measurements in the upper wing (classrooms 42, 52, and 62) showed concentrations greater than the 1000 ppm upper limit guideline. The CO_2 concentrations in the lower wing rooms averaged near 750 ppm, which is in a gray area with respect to air quality and comfort complaints. Room occupancy and size in the two wings of the school is similar, and these factors may be ruled out as reasons for the variability in the CO_2 concentrations.

3. Temperature and Relative Humidity

Temperatures and relative humidities measured in all areas of the school during the follow-up survey are presented in Table 4. Temperatures ranged from 67 to 74° F. The relative humidity levels on this day ranged from 12 to 40%. These levels, except for the measurement of 40%, are outside the comfort ranges indicated by ASHRAE in Figure 2, although they are typical of levels usually found indoors during the winter heating season in buildings not humidified. Indoor relative humidity will change with outside air conditions, unless the building HV system has the capability of adding or removing moisture. Outdoor relative humidity can vary moderately from day to day, and greatly from season to season.

The temperature and relative humidity were slightly cooler and dryer than what may be considered comfortable on the day of the survey. Irritation of the eyes, nose, and upper respiratory tract, due to dryness of the mucous membranes, can occur at these low relative humidity values. It is likely that the relative humidity measured during this survey was near the minimum in the range of values which would be expected during the winter heating season. There is little that can be done to change the dry conditions in the school during the heating season except to humidify the air.

Before and during the initial NIOSH evaluation, concentrations of formaldehyde near 0.10 ppm and greater were measured in classrooms in the lower wing of the E.M. Crouthamel Elementary School. These were likely the result of diffusion of formaldehyde from the plywood underlayment and a lack of ventilation in the rooms. At the time the measurements were made the school ventilation system was not being used since the weather was warm and there is no air cooling provided in the system. The initial NIOSH evaluation showed that ventilation could be effective in reducing the concentrations to usual background levels.
During the follow-up NIOSH evaluation, low levels of formaldehyde were found throughout the school building. We feel that every reasonable effort should be made to reduce these indoor concentrations. A single source for the formaldehyde is not likely, such as the plywood underlayment in the lower wing, since there is no mechanism for such even distribution throughout the school from a localized source. Many building materials may contain formaldehyde. Ambient (outdoor) air concentrations may even be a contributor. It is most apparent from the CO_2 concentrations found that more fresh air is needed in the school.

Although some sensitive individuals may experience irritative effects at the formaldehyde concentrations found, the temperature and relative humidity conditions measured during the follow-up evaluation may have been more responsible for occupant discomfort in the school at that time.

VII. CONCLUSIONS

Formaldehyde diffusing from plywood carpeting underlayment and inadequate ventilation may have contributed to cause an increase in complaints of discomfort among occupants of the school. The teachers' symptoms were intermittent and not associated with exposure to specific rooms in the school. The symptoms are typically associated with upper respiratory infection and common allergies. They may also be associated with low relative humidity. There is no satisfactory way of distinguishing symptoms due to a chemical contaminant in the building from those due to other causes. Increased ventilation will improve air quality.

VIII. RECOMMENDATIONS

1. A procedure to ensure the involvement of parents, teachers and local and state health authorities when a potential health problem is identified should be developed.

2. In order to remedy the general ventilation problems at the E.M. Crouthamel Elementary School, we recommend obtaining the service of a ventilation contractor with experience with the type of system at the school and with the capability of making adjustments to the system to provide adequate fresh air. Optimally, the system should be made to provide fresh air in amounts according to the number of room occupants, as indicated by the most current ASHRAE guidelines. Following these modifications, the CO_2 concentrations should be monitored to determine effectiveness.

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1. Superintendent of Schools, Souderton Area School District
2. Principal, E.M. Crouthamel Elementary School
3. Representative of the Teachers, E.M. Crouthamel Elementary School
4. Representative of the Parents, E.M. Crouthamel Elementary School
5. NIOSH, Cincinnati Region
6. OSHA, Region III

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1
REPORTED LEVELS OF FORMALDEHYDE IN THE INDOOR AIR
CLASSES OF PRIVATE RESIDENCES
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
HETA 86-535

Type of Residence	No. of Residences	Formaldehyde (ppm) Range	Mean
U.S. homes without area-formaldehyde foam insulation (UFFI)	41	0.01-0.1	0.03
U.S. homes with UFFI (complaint and noncomplaint)	636	0.01-3.4	0.12
U.S. mobile homes	431	0.01-3.5	0.38
Canadian houses without UFFI	383	(3% ß0.1ppm)	0.036
Candian houses with UFFI	1850	(10% ß0.1ppm)	0.054
U.S. houses without UFFI and without particle board	17	-	0.025
U.S. houses with UFFI but without particle board subfloors	600	-	0.050
U.S. mobile homes	several hundred		0.12
U.K. buildings without UFFI	50	§0.02-ß0.3 (3% ß0.1ppm)	0.047
U.K. buildings with UFFI	128	0.01-ß1 (7% ß0.1ppm)	0.093
U.S. houses without UFFI	42	0.03-0.17	0.06
U.S. houses without UFFI	32	-	0.07
U.S. houses with UFFI	-	-	0.06
Mobile homes (Minnesota complaint)	100	0.3.0	0.4
Mobile homes (Wisconsin complaint)	-	0.02-4.2	0.9
Mobile homes (Wisconsin complaint)	65	§0.10-3.68	0.47
Mobile homes (Washington complaint)	-	0-1.77	0.1-0.44

(continued)

TABLE 1
(continued)
REPORTED LEVELS OF FORMALDEHYDE IN THE INDOOR AIR
CLASSES OF PRIVATE RESIDENCES
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
HETA 86-535

Type of Residence	No. of Residences	Formaldehyde (ppm) Range	Mean
U.S. mobile homes			
Never occupied	260	-	0.86
Older, occupied			0.25
East Tennessee homes	40	§0.02-0.4	0.06
Age 0-5 years	18	-	0.08
Age 5-15 years	11	-	0.04
Age ß15 years	11	-	0.03
Conventional California, Colorado, and S. Dakota homes	64	0.02-0.11	0.05
Specialized U.S. housing	52	0.03-0.3	0.1

*Gammage R.B., Hawthorne A.R. "Current Status of Measurement Techniques and concentrations of Formaldehyde in Residences." Turoski V. Formaldehyde: analytical chemistry and toxicology. Page 125. "Developed from a symposium sponsored by the Division of Environmental Chemistry at the 187th Meeting of the American Chemical Society, St. Louis, Missouri, April 8-13, 1984."

TABLE 2

AIR SAMPLING RESULTS FOR FORMALDEHYDE
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
OCTOBER 6, 1986

HETA 86-535

Location	Sample Time	Sample Volume (liters)	Concentration, ppm
Before ventilation			
Classroom #22	1328-1458	90	0.07
Classroom #32	1323-1455	92	0.04
A/V Room	1331-1459	88	0.03
During ventilation			
Classroom #22	1507-1627	80	0.05
Classroom #32	1508-1626	78	0.03
Classroom #51	1516-1636	80	0.02

TABLE 3
AIR SAMPLING RESULTS FOR FORMALDEHYDE
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
JANUARY 28, 1987
HETA 86-535

Location	Sample Time	Sample Volume (liters)	Formaldehyde Concentration (parts per milllion)
Room 11	0917-1104	107	(0.02)*
	1219-1359	100	(0.02)
Room 12	0925-1105	100	(0.02)
	1220-1400	100	ND**
Room 22	0900-1042	102	ND
	1221-1401	100	ND
Room 31	0937-1112	95	(0.02)
	1222-1402	100	(0.02)
Room 32	0940-1113	93	ND
	1229-1409	100	ND
Room 42	0944-1137	113	(0.02)
	1232-1412	100	(0.02)
Room 52	0948-1138	110	(0.02)
	1234-1414	100	(0.02)
Room 62	0951-1139	108	0.04
	1235-1415	100	(0.02)

* - Values in parentheses are between the analytical limit of detection (LOD, 2ug/sample) and the analytical limit of quantitation (LOQ, 4ug/sample).

** - ND means none detected, the value was below the analytical LOD.

(continued)

TABLE 3
(continued)
AIR SAMPLING RESULTS FOR FORMALDEHYDE
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
JANUARY 28, 1987

HETA 86-535

Location	Sample Time	Sample Volume (liters)	Formaldehyde Concentration (parts per million)
Reading Room	1000-1140	100	(0.03)*
	1239-1419	100	(0.03)
Nurse°s Office	1002-1142	100	(0.02)
	1240-1422	102	(0.02)
Principal°s Office	1005-1148	103	(0.02)
	1244-1423	99	(0.02)
Library	1006-1149	103	(0.02)
	1247-1426	99	(0.02)
Art Room	1008-1150	102	(0.02)
	1249-1439	110	(0.02)
Room 20	1010-1150	100	(0.02)
	1241-1431	110	(0.02)
Outside	1015-1155	100	(0.02)
	1255-1435	100	ND**

* - Values in parentheses are between the analytical limit of detection (LOD, 2ug/sample) and the analytical limit of quantitation (LOD, 4ug/sample).

** - ND means none detected, the value was below the analytical LOD.

TABLE 4
CARBON DIOXIDE, TEMPERATURE, AND RELATIVE HUMIDITY MEASUREMENTS
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
JANUARY 28, 1987
HETA 86-535

Location	Time	Number in Class	CO_2 Concentration (ppm)	Dry Bulb/Wet Bulb Temperature (°F)	Relative Humidity (%)
Room 11	0920	27	800	72/50	15
	1545		600	69/50	21
Room 12	0930	24	700	69/49	18
	1400		500	68/50	23
Room 22	0900	0	600	67/47	15
	1230		600	67/47	15
Room 31	0940	20	800	72/52	21
	1410		1000	71/50	17
Room 32	1035	16	800	70/56	40
	1520		1000	68/50	23
Room 42	1040	27	1000	72/51	18
	1350		1700	75/50	10
Room 52	1050	16	1250	70/50	19
	1510		1000	71/51	20
Room 62	1100	18	1250	71/51	20
	1515		1500	71/52	23
Reading Room	1020	--	900	72/51	18
Nurse°s Office	1025	--	1000	74/51	14
	1540		900	70/50	19
Principal°s Office	1030	--	700	77/53	14

(continued)

TABLE 4
(continued)
CARBON DIOXIDE, TEMPERATURE, AND RELATIVE HUMIDITY MEASUREMENTS
E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA
JANUARY 28, 1987

HETA 86-535

Location	Time	Number in Class	CO_2 Concentration (ppm)	Dry Bulb/Wet Bulb Temperature (°F)	Relative Humidity (%)
Library	1115	--	600	74/51	14
Art Room	1120	20	800	73/50	13
	1520		1000	73/53	22
Room 20	1130	9	800	70/48	12
	1530		600	71/51	20
Outside	1300	--	200	36/--	--

FIGURE 1

E.M. CROUTHAMEL ELEMENTARY SCHOOL
SOUDERTON, PENNSYLVANIA

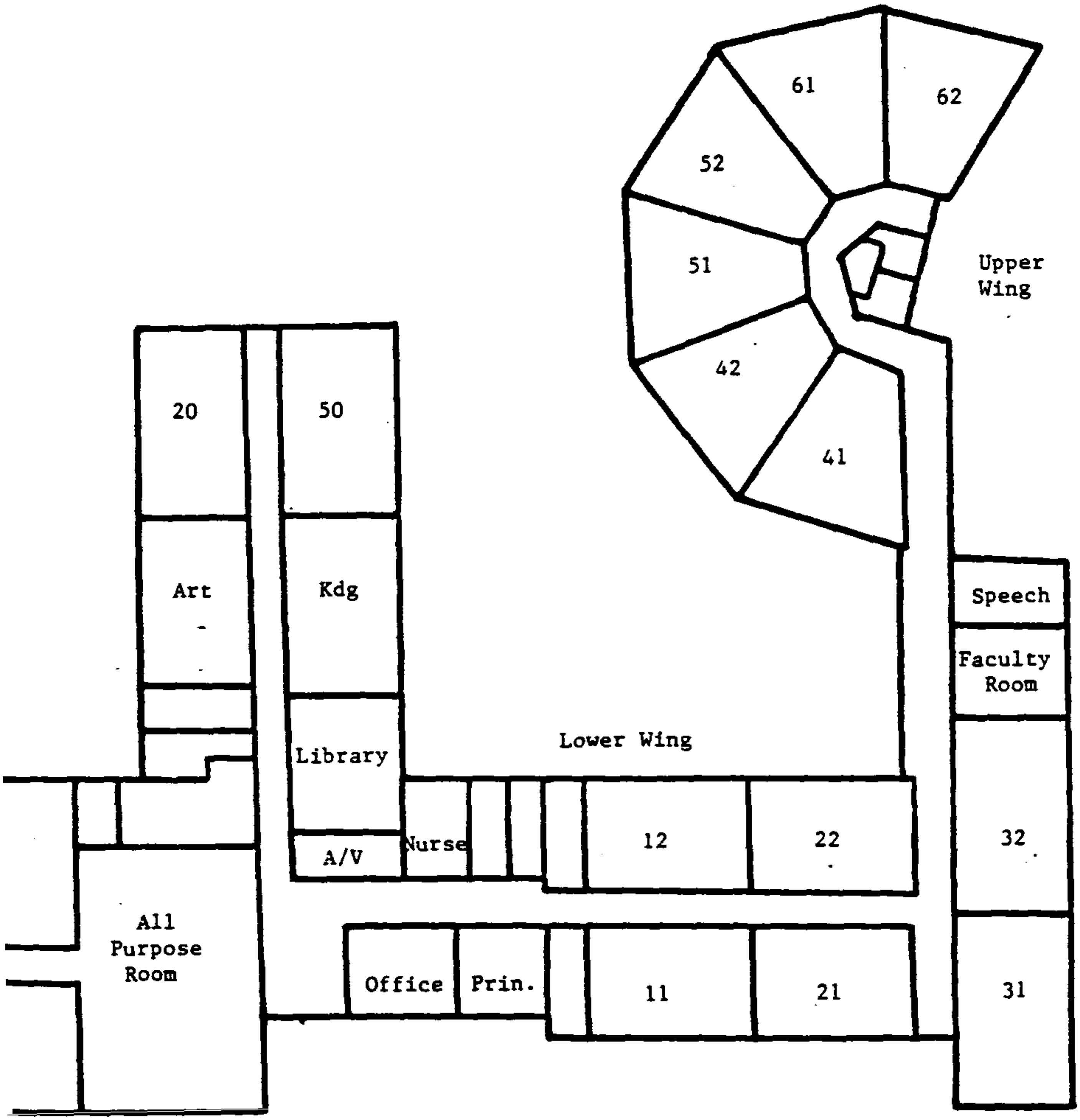


FIGURE 2

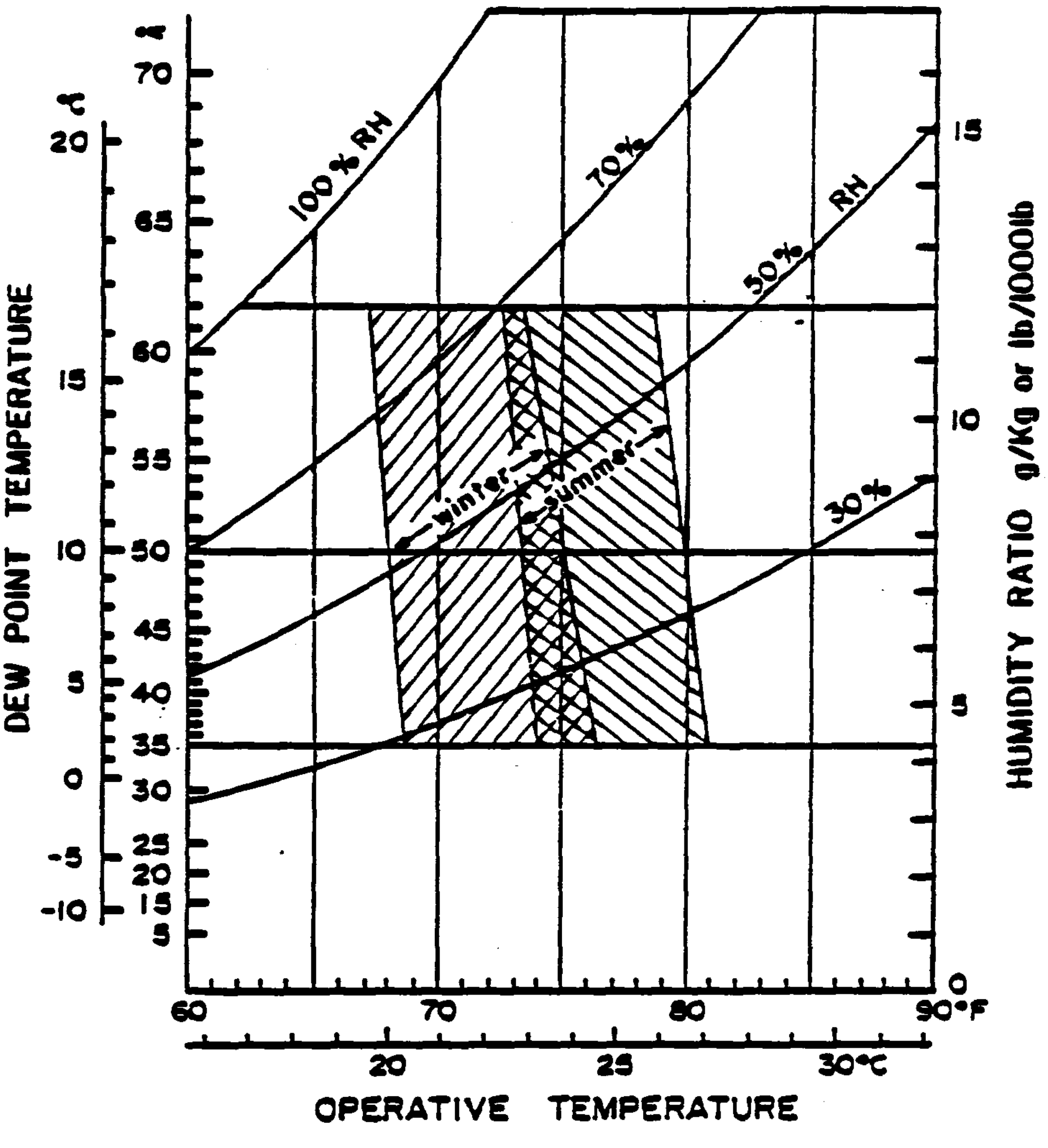
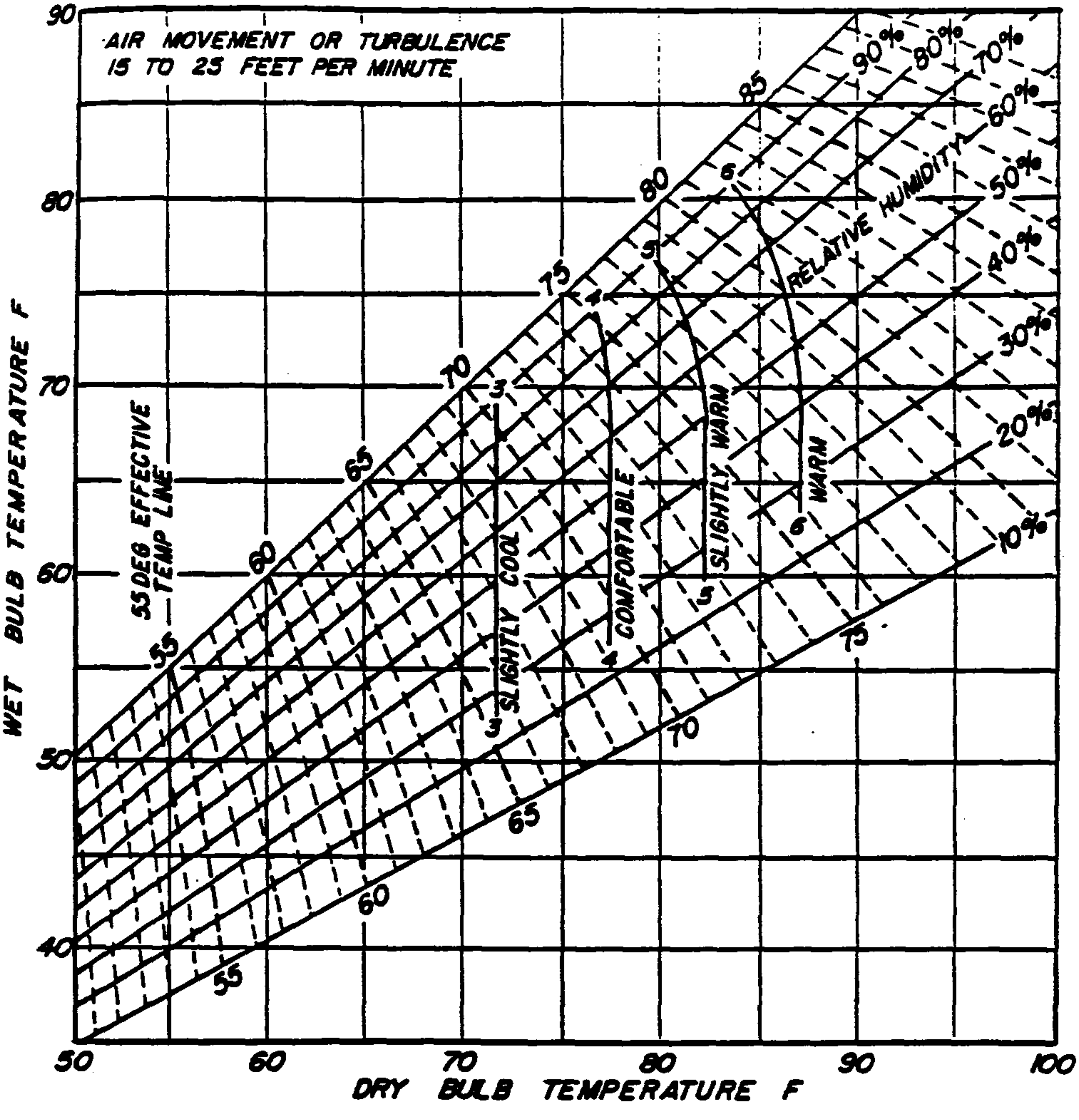


Figure 2 Acceptable ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, at light, mainly sedentary, activity (≤ 1.2 met).

FIGURE 3



Notes

1. Effective Temperature (dashed) lines indicate sensation of warmth immediately after entering conditioned space.
2. Solid lines 3, 4, 5, and 6 indicate sensations experienced after three hour occupancy.
3. Both sets of curves apply to people at rest and normally clothed.

Comfort Chart for Still Air