**HETA 93-1134-2400**
**JANUARY 1994**
**STERLING VAN DYKE CREDIT UNION**
**STERLING HEIGHTS, MICHIGAN**

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## I. SUMMARY

On September 24, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) at the Sterling Van Dyke Credit Union in Sterling Heights, Michigan from employees of the credit union. These employees were concerned about recurring illnesses. Symptoms and illnesses reported by the employees included headaches, backaches, breathing difficulty, purple fingernail beds, disrupted menstrual cycles, asthma, and bronchitis. One requester also reported that at least four employees were using bronchial dilator inhalers. At least one of these employees was confirmed to have asthma by a pulmonologist; the others were thought to have, but not confirmed to have, asthma.

A survey was conducted at the credit union on October 20 through 22, 1993. On October 20, inspections were made of the heating, ventilating, and air conditioning (HVAC) system that served the building, and symptom questionnaires were distributed to all employees. On October 21, dry bulb temperature, relative humidity, and carbon dioxide ($CO_2$) measurements were made. Measurements were made at 9 locations in the building and one location outside of the building. Four sets of measurements were made inside the building and three sets outside the building. Measurements were made in the morning as employees were arriving, late morning, early afternoon, and late afternoon as employees were leaving. A closing meeting was held on October 22.

Questionnaire results of symptoms could only show possible, not definite, links to other survey findings. For example, 64% of the questionnaire respondents reported cough symptoms, and 57% reported tired or strained eyes and sore or dry throats on the day the questionnaire was completed. Given the design and operation of the ventilation systems, and the facts that smoking is allowed in the building and that over 50% of the employees smoke, exposure to environmental tobacco smoke (ETS) is a likely contributor to some of the symptoms. Questionnaire results about workplace conditions could be better explained by other findings made during the survey of the building. For example, 79% of respondents felt that the building had too little air movement on the day of the questionnaire. Corresponding to this result was the finding that the fans in the air handling units (AHUs) only operated when the thermostats demanded heating or cooling.

Dry bulb temperatures in the credit union building on October 21 ranged from 72 to 78 °F, but averaged 75 °F [standard deviation (s.d.) = 1.5] throughout the day. Relative humidity levels ranged from 44 to 51% and averaged 48% (s.d. = 2.0) throughout the day. Carbon dioxide concentrations, however, ranged from 475 to 550 parts per million (ppm) and averaged 542 ppm (s.d. = 93.5) in the early morning; but climbed to between 1125 and 1725 ppm and averaged 1600 ppm (s.d. = 200.0) by the end of the day. A peak of 1800 ppm was measured at one location in the early afternoon round of measurements.

During inspection of the HVAC systems, the AHUs were found to lack a means for providing outside air to ventilate the building. This finding, along with the thermostats being set to operate the AHUs' fans only on demand for heating or cooling, is believed to have caused poor air circulation throughout the building. The original design of the HVAC system was further believed to have caused thermal comfort problems reported by many employees. Inspection of the HVAC system also showed that the units had additional problems that could have caused bioaerosol generation inside the units that could be blown into the building.

Findings from the survey at the Sterling Van Dyke Credit Union are believed to show that deficiencies in the HVAC systems cause employee complaints. Contaminants such as ETS, bioaerosols, and sewer gases may also cause employee complaints and contribute to employees' symptoms. The operation and design of these systems are also believed to cause employee thermal discomfort.

**Keywords:** SIC CODE: 6062 (Credit Unions, Not Federally Chartered), indoor environmental quality, dry bulb temperature, relative humidity, carbon dioxide, environmental tobacco smoke (ETS), bioaerosols, thermal comfort, ventilation, air handling units (AHUs), maintenance.

## II. INTRODUCTION

On September 24, 1993, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) at the Sterling Van Dyke Credit Union in Sterling Heights, Michigan from employees of the credit union. These employees were concerned about recurring illnesses. Symptoms and illnesses reported by the employees included headaches, backaches, breathing difficulty, asthma, and bronchitis. Purple fingernail beds and disrupted menstrual cycles were also mentioned as symptoms; but these symptoms are not commonly associated with building illnesses. One requester also indicated that at least four employees were using bronchial dilator inhalers. At least one of these employees was confirmed to have asthma by a pulmonologist; the others were thought, but not confirmed, to have asthma.

## III. BACKGROUND AND DESCRIPTIVE INFORMATION

The Sterling Van Dyke Credit Union building is located in a fairly well-developed suburb of Detroit across the street from a Ford plant. The credit union is on the east side of and faces the street, which is a moderately busy four lane road. The credit union serves the Ford employees.

The 4,675 square foot (ft$^2$) (gross area) credit union is a single-story block and brick building on slab. The building was built in 1964. Most of the front of the building is floor-to-ceiling glass. Four, equally spaced, 2-foot wide floor-to-ceiling glass windows are in the north wall of the building, while four other smaller windows are in the west wall of the building. A layout of the building is shown in Figure 1.

Two counter-flow air handling units (AHUs), AHUs 1 and 2, service the building. The AHUs contain gas-fired heat exchangers and freon cooling coils. Air is supplied to the building through a subslab distribution system. Most of the supply air fixtures for the building are 3" x 24" floor registers: eleven are located under all of the windows; two in Office 4 in Figure 1; and one in Office 5. The other supply diffusers are 4" x 12" low side-wall registers in each of the two bathrooms, two 4" x 12" high sidewall registers in Office 2, two 2" x 12" high sidewall registers in Office 1, and two 6" circular ceiling diffusers on the south side of the teller area. AHU 1 supplies air to the registers along the south, east and part of the north walls and the two ceiling diffusers. AHU 2 supplies air to the registers along the west wall, in the interior offices, and the remaining registers along the north wall. Locations for the diffusers are shown in Figure 1.

Air returns to the AHUs through a ceiling plenum. Air enters the ceiling return plenum through four perforated metal grilles dispersed throughout the building, also shown in Figure 1. The return air in the ceiling plenum enters the return ducts through two parallel stub ducts that begin at the outer face of the mechanical room wall and run to each of the AHUs. No outside air is supplied to the AHUs, and no other mechanical system exists for supplying outside air to the building. Ventilation air can only enter the building through infiltration.

Changes to the supply air distribution system since the original installation were the installation of the two registers on the interior wall of Office 1 in Figure 1, in place of one register on the exterior wall, and the addition of the two ceiling diffusers in the Teller Area. Each of the ceiling diffusers is connected to one of the ducts supplying the high sidewall registers in Office 2 with flexible ducting. Dates of the changes were unknown. In May 1992, new furnace sections of the AHUs were replaced because of cracks in the heat exchangers; the cooling coil sections of both units were not replaced. A defective condenser was replaced for one of the AHUs in June 1993.

Each AHU is controlled by a programmable thermostat similar to those used for residences. The thermostat controlling AHU 1 is approximately in the middle of the teller area. The thermostat controlling AHU 2 is on an interior wall of the Conference Room. The exact thermostat locations are shown in Figure 1.

The building only has two exhaust fans, one for each bathroom. The exhaust fans are directly above their respective bathrooms. Air is exhausted from the bathrooms at ceiling level and directly ducted through the roof to the exhaust fans. The exhaust fans only operate when their respective bathroom's lights are in the "ON" position.

Smoking is permitted in all areas of the building, except in the offices where the occupants forbid it. Approximately half of the employees smoke.

## IV. EVALUATION METHODS

### Medical Evaluation

Questionnaires were distributed to 14 employees working in the credit union on October 20. The questionnaire asked if the employee had experienced, while at work on the day of the survey, any of the 13 symptoms (irritation, nasal congestion, headaches, etc.) commonly reported by occupants of "problem buildings." The questionnaire also asked about the frequency of occurrence of these 13 symptoms while at work in the building during the four weeks preceding the survey, and whether these symptoms tended to get worse, stay the same, or get better when they were away from work. The next section of the questionnaire asked about environmental comfort (too hot, too cold, unusual odors, etc.) experienced while the employees were working in the building during the four weeks preceding the questionnaire administration. The final section inquired about characteristics of the person's job.

No formal interviews were conducted with building occupants. Information in this report attributed to employees came from informal conversations.

### Environmental Evaluation

The environmental conditions were evaluated on October 21. Although this is not the same day that the questionnaire was administered, environmental conditions in the building on October 20 and 21 were judged to be similar.

During the environmental evaluation, information was collected using standardized checklists and inspection forms. These forms were grouped to address the whole building, the evaluation area, and the HVAC system. Descriptive information for the building (age, size, construction, location, etc.), the area to be evaluated (size, type of office space, cleaning policies, furnishings, pollutant sources, etc.), and the HVAC systems (type, specifications, maintenance schedules, etc.) were included. Inspections of the evaluated area and HVAC systems were conducted to determine current conditions. The purpose of the environmental investigation was to obtain information required to classify the building, determine the condition of building systems, and document the building’s current indoor environmental status.

In addition to collecting the standardized information described above, indicators of occupant comfort were measured. These indicators were carbon dioxide (an indicator of how well the building is being ventilated), and dry-bulb temperature and relative humidity. Chemical smoke was used to visualize airflow in the evaluated area and to determine potential pollutant pathways inside the building.

Real-time $CO_2$ concentrations were measured using a Gastech Model RI-411A, Portable $CO_2$ Indicator. This portable, battery-operated instrument uses a non-dispersive infrared absorption detector to measure $CO_2$ in the range of 0-4975 ppm, with a sensitivity of ±25 ppm. Instrument zeroing and calibration were performed prior to use with zero air and a known-concentration of $CO_2$ span gas (800 ppm).

Real-time temperature and humidity measurements were made using a Thermal Systems, Inc. (TSI), Model 8360, battery-operated meter. This meter is capable of providing direct readings for dry-bulb temperature and relative humidity.

## V. EVALUATION CRITERIA

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- Sources of odors or contaminants.
- Problems with the design or operation of the HVAC system.
- Pathways between contaminant sources and the location of complaints.
- The activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats and other respiratory irritations. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported high prevalence of symptoms among occupants of office buildings.[1-5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8-13] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related than any measured indoor contaminant or condition to the occurrence of symptoms.[14-16] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[16-19]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by Legionella bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[20-22] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[23,24] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[25]

Measurement of indoor environmental contaminants has rarely been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as $CO_2$, temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

### Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, and 15 cfm/person for reception areas, and provides estimated maximum occupancy figures for each area.[23]

Indoor $CO_2$ concentrations are normally higher than the generally constant ambient $CO_2$ concentration (range 300-350 ppm). When indoor $CO_2$ concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated $CO_2$ concentrations suggest that other indoor contaminants may also be increased.

## Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) consists of exhaled mainstream smoke from the smoker and sidestream smoke which is emitted from the smoldering tobacco. ETS consists of between 70 and 90% sidestream smoke. More than 4000 compounds have been identified in laboratory-based studies, including many known human toxins and carcinogens such as carbon monoxide, ammonia, formaldehyde, nicotine, tobacco-specific nitrosamines, benzo(a)pyrene, benzene, cadmium, nickel, and aromatic amines.[26,27] Many of these toxic constituents are more concentrated in sidestream than in mainstream smoke.[28] In studies conducted in residences and office buildings with tobacco smoking, ETS was a substantial source of many gas and particulate polycyclic aromatic compounds.[29]

ETS has been shown to be causally associated with lung cancer and cardiovascular disease in adults, and respiratory infections, asthma, middle ear effusion, and low birth weight in children.[30,31,32] It is also a cause of annoying odor and sensory irritation. The U.S. Environmental Protection Agency (EPA) has classified ETS as a known human (Group A) carcinogen.[33] NIOSH considers ETS to be a potential occupational carcinogen and believes that workers should not be involuntarily exposed to tobacco smoke.[34]

## Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature or the air and surrounding surfaces, humidity, air movement, personal activities, and clothing. Perception of thermal comfort is also influenced by the rate of temperature change. ANSI/ASHRAE Standard 55-1992 specifies conditions in which 90% or more of the occupants would be expected to find the environment thermally comfortable.[24] Figure 2 is a reproduction of the Thermal Comfort Chart from the standard. Dry bulb temperature may sometimes be used for the temperature on the chart. However, the other factors above must be considered in making this interpretation.

## VI. MEDICAL RESULTS

On October 20, questionnaires were distributed to the 14 Credit Union employees at work on that day. All 14 employees, all female, returned questionnaires. The median age of respondents lay in the range of twenty to twenty-nine years. Seven currently smoked cigarettes, 1 was a former smoker, and 6 had never smoked. Respondents had worked in the building for an average of 6 years and worked an average of 41 hours per week (range 40-47). They used a computer for an average of 6.4 hours/day.

The questionnaire results are shown in Table 1. The first column of Table 1 shows the percentage of the 14 respondents who reported the occurrence of symptoms while at work on the day of the survey. Eye irritation or strain, throat discomfort, headache, cough and tension or irritability are the most commonly reported symptoms.

The second column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey. With a few exceptions, these symptom prevalences are similar to those for symptoms experienced on the day of the survey.

The third column shows the percentage of employees who reported experiencing the respective symptom once a week or more often while at work during the four weeks preceding the survey and also reported that the symptom tended to get better when they were away from work. This latter criterion has, in some studies of indoor environmental quality, been used to define a "building related" symptom, but it is possible that a symptom which does not usually improve when away from the building could also be due to conditions at work.

The reported "building-related" frequent symptom prevalence shown in column 3, are somewhat lower than the corresponding symptom prevalence over the last 4 weeks shown in the second column, and are highest for eye irritation or strain, throat discomfort, nasal congestion, sneezing, cough, and tension or irritability. Overall, nine (64%) of the 14 respondents reported having one or more symptoms that had occurred at work one or more days a week during the preceding 4 weeks and tended to get better when away from work.

Table 2 shows results of employee reports regarding environmental conditions at their workstations on the day of the survey and during the four weeks preceding the survey. Column one shows the results for the day of the survey. It shows that 79% of the respondents perceived that the ventilation system was not providing sufficient air movement, 43% thought it was too hot, and 29% felt that it was too cold during at least part of their work day. Seventy-one percent sensed tobacco odors during the workday.

The second column shows the responses to the questions about environmental comfort conditions experienced in the facility during the 4 weeks preceding the survey. Adverse environmental conditions (too hot, too cold, odors, etc.) were considered "frequent" if they were reported to occur at work once a week or more often. The results are generally somewhat higher than those shown in the first column for work station environmental conditions experienced during the day of the survey. Eighty-six percent of respondents perceived insufficient air movement, none reported too much air movement, 50% frequently were too hot, 57% were frequently too cold, 50% perceived frequent chemical odors in the workplace, 36% frequently sensed other unpleasant odors, and 79% frequently sensed tobacco odors.

## VII. ENVIRONMENTAL RESULTS AND OBSERVATIONS

### Environmental Tobacco Smoke and Smoking Policies

Reports from the Surgeon General and the National Research Council have concluded that exposure to environmental tobacco smoke (ETS) may be associated with a wide range of health (e.g. lung cancer and asthma) and comfort (e.g. eye, nose, throat and respiratory irritation, and odor) problems.[26-31] NIOSH has determined that ETS may be related to an increased risk of lung cancer and possibly heart disease in occupationally exposed workers who do not smoke themselves.[32]

Over half of the employees at the Sterling Van Dyke Credit Union smoke. During the survey, the odor of tobacco smoke was evident, and a majority of the employees reported frequently smelling the odor. Moreover, many interior surfaces were stained a yellowish-brown color which is believed to be from the ETS.

Although survey results could not show a direct link, ETS is also believed to be a major factor in symptoms reported by employees on the questionnaires. Many irritant-related symptoms, such as those related to irritated eyes and respiratory problems, decreased when employees were away from work. Three employees personally complained to the investigator about respiratory problems that occurred while they were at work, but that disappeared upon leaving the building. Some of these individuals reported needing to take respiratory medications while at work, but being able to stop taking or reduce their intake of the medications after being away from the building for a prolonged period of time, for example over a weekend. All of these factors lead to the conclusion that ETS may contribute to respiratory complaints by the credit union employees.

Control of ETS through filtration is not an effective alternative. ETS is composed of both gaseous and particulate contaminants. Most filter systems can only remove the particulate contaminants, and some of the particulate can even pass through lower-efficiency filters. Gaseous contaminant filters can remove some of the gaseous contaminants of ETS; but the proper filter media needs to be selected. Currently, no standards exist for rating gaseous contaminant filters, similar to the standards used for particulate filters. In addition, determining when gaseous contaminant filters have reached the end of their life is currently not practical outside of the laboratory. The lack of standards for gaseous filters means that proper selection of the filter media and estimates of the filter life are questionable. The only true methods for removing ETS contaminants from buildings is making the building smoke-free or permitting smoking only in designated, controlled areas.

### Temperature and Relative Humidity Measurements

The dry-bulb temperature and relative humidity measurement results are summarized in Tables 3 and 4. The tables show that little change occurred in the temperature and relative humidity throughout the day and throughout the building. All of the readings were plotted on a copy of the thermal comfort chart in ASHRAE 55-1992 (Figure 2 in the standard). The plot showed that readings in the morning were marginally within the acceptable comfort zone for winter; but, throughout the day, most of the readings migrated out of winter comfort zone into the summer comfort zone due to a slight increase in temperature throughout the day. The data plot supports questionnaire results in Table 2 for the environment being too hot for at least part of the day of the survey, but doesn't explain the complaints about the environment being too cold. However, use of the thermal comfort chart to predict employee comfort is usually only marginally successful. Reasons for the lack of accurate prediction that are relevant to the credit union are as follows:

1. The comfort ranges in the thermal comfort chart are for 90% acceptance of the thermal environment. Therefore, the possibility exists that at least 10% of a building’s occupants will be thermally uncomfortable even if the thermal conditions are within the chart’s comfort ranges. Furthermore, even more than 10% of the occupants could be thermally uncomfortable at any one set of temperature and relative humidity conditions within the comfort zones because of the statistical methods used in the research to develop the zones.

2. Certain assumptions were made in comparing the temperature and

relative humidity measurements to the thermal comfort chart. The first of these assumptions was that the occupants were dressed in winter attire and fully acclimated for winter conditions. Neither of these assumptions may have been true for all occupants. Occupants who wore lighter clothing than that specified for winter conditions in the comfort chart or who were not adapted to winter conditions could report being too cold in the morning and comfortable in the afternoon for the thermal conditions in the credit union on the day measurements were made. A second assumption was that the occupants were similar to the study participants used in the research to derive the comfort chart. Current research is showing that the subjects in the original research used to develop the comfort chart may not be reflective of actual, current building occupants.[35] A third assumption was that other important parameters that could affect thermal comfort--such as thermal radiation, air movement, and activity levels--were within the limits of those defined in the thermal comfort standard. This assumption may not have been totally valid because the large glass areas in the credit union could cause significant thermal radiation effects on occupants near the windows.

These reasons explain possible disparities between thermal comfort measurements made at the building, but do not totally explain thermal discomfort questionnaire results in Table 2 for the 4 weeks (and possibly a longer time) prior to the survey. About 50% of the questionnaire respondents complained that the temperature in the 4 weeks prior to the survey was either too hot or too cold. Some aspects of the design and operation of the building's HVAC systems appear to agree with these responses, as follows:

1. The location of the supply air diffusers or registers relative to the thermostats could lead to hot and cold spots in the building. Occupants located in offices that had supply air diffusers or registers could become too hot or too cold as the HVAC systems work to satisfy the demand of the thermostats. Conversely, at the same time, occupants nearer to the thermostats could become too cold or too hot because of the time lag between when the thermostats demand heating or cooling and when they are satisfied. In addition, each of the thermostats is influenced by air from the HVAC system controlled by the other thermostat. The HVAC systems work properly only if their controlling thermostats are properly located relative to the supply air outlets and properly reflect the thermal conditions felt by the building's occupants. Ideally, thermal conditions in all parts of the building should be relatively equal, wide temperature variations should be minimized between all occupied areas, and each thermostat is affected only by the HVAC system it controls. Temperatures on the day measurements were made appeared to meet the first two conditions and therefore may not have been reflective of the conditions for the time prior to the survey.

2. No records existed for the balancing of the supply air

system to assure that the proper amount of air flows from each supply outlet. Moreover, changes have been made to the supply air systems without rebalancing of the system and all the dampers for most of the registers were set wide open. All of these factors indicate that the air flows from the various registers may not be adjusted according to original design (balanced according to industry terminology). This could lead to thermal discomfort because some areas would receive more supply air than needed, while others receive too little. Occupants in an area with too much supply air could subsequently be too cold in the cooling season and too hot in the heating season. Occupants in areas with inadequate supply air could be the opposite for each season.

3. An exhaust vent for the building’s ceiling space did not exist. Without a vent sun loads on the roof could heat up the roof and the air in the underlying ceiling space. This heat eventually radiates into the occupied space below the ceiling space, possibly causing occupants to become too hot. This heat load may not increase the air temperature in the occupied space, so the thermostat does not activate the cooling system. Should this be a problem, an exhaust vent for the ceiling space could remove the hot air in the ceiling space. The exhaust could be a gravity vent; but a fan-powered vent is better. Improved insulation of the roof area could also help relieve this problem.

4. Changeover of the credit union’s HVAC systems from heating to cooling or vice versa currently has to be performed manually. Reportedly, only managers were allowed to operate the thermostats, requiring employees to request a changeover when needed. The need for changeover was based on the perception that most employees wanted one. Therefore, some employees could become too hot or too cold before changeover. Conversely, some employees could become too cold or too hot if they did not want a changeover.

5. The thermostats for the AHUs’ fans were set on "Auto," meaning that the units’ fans operated only when the units’ heating or cooling systems were operating. During the survey, the AHUs operated very little. Lack of air movement could lead to perceptions by the occupants of stale or stuffy air, which can further lead to occupant's believing that the environment is too warm. In fact, lack of air movement was the most common complaint mentioned by employees on the questionnaires, as shown in Table 2.

   As shown in Table 2, more than half of the employees responded on the questionnaire that the air was too dry (humidity levels too low), both on the measurement day and during the 4 weeks prior to the survey. During the survey, the humidity was consistently between the 30 to 60% levels recommended in ASHRAE 55-1992. The responses about the air being too dry on the day of the measurements could be due to irritation that was really caused by the ETS being perceived as irritation caused by dry air. The office manager also reported that portable humidifiers were sometimes used during the winter because the building air is so dry. In the winter, when outdoor air humidity levels are very low, indoor humidity levels can become extremely low. The employees could have been responding that the air was too dry with this fact in mind.

## Carbon Dioxide Measurements

The $CO_2$ measurements made in the credit union are shown in Table 5. The table shows that the $CO_2$ concentrations early in the morning were slightly above the concentrations in the outside air, but rose to above 1700 ppm in most locations in the building by the end of the day. Most of the concentrations were above the 1000 ppm concentration recommended by ASHRAE 62-1989 less than 3 hours after the employees arrived for the day.

Two major factors appear to have contributed to the dramatic rise in the $CO_2$ concentrations: lack of outside air to dilute contaminants in the building and cigarette smoking. Under any circumstances, outside air needs to be introduced into the building to dilute the contaminants normally generated by office operations. In buildings with windows that cannot be opened, outside air is usually brought into the building through the AHUs. The credit union's AHUs were not equipped to bring in outside air, and no other means besides infiltration was evident. Infiltration is air leaking into the building through cracks and openings. It is generally an ineffective and inefficient way to ventilate buildings. One of the effects of infiltration can be seen in the results for Office 1 in Table 5. This office was closest to an outside door where air was leaking into the building and consistently had the lowest $CO_2$ concentrations in the building. The decreasing ventilation effectiveness of the infiltration can be seen by the increasing $CO_2$ concentrations in relation to the distance from the infiltration point. Without outside air for ventilation, $CO_2$ concentrations, as well as other contaminant concentrations, in the building would be expected to increase due to normal office operations.

Differences in the $CO_2$ concentrations between locations in the building appeared to be due to poor mixing of air in the building. Although some mixing occurs because of factors, such as convection and occupant movement throughout the building, air in buildings is mainly mixed by the HVAC systems. Air in the credit union had little opportunity to be mixed because the AHUs' fans operated only on demand for heating and cooling. With the fans operating constantly, the $CO_2$ concentrations between different locations should be more uniform. However, areas without supply air, such as Office 3, could still have different concentrations than areas with supply air, even though the AHUs’ fans were operated constantly. To promote mixing of building air, the AHUs' fans usually are operated constantly during occupied hours. Operating the fans constantly also helps to lower particulate concentrations in the building air by filtering the air more often.

On the day measurements were made, the credit union’s customers surely contributed to the $CO_2$ concentrations in the building. Two-hundred ninety-eight customers came to the credit union on that day. The distribution of customers by the hour throughout the day was relatively equal, except between 2:00 and 4:00 p.m. during which a greater number of customers were served. One manager indicated that these distribution characteristics were typical; but the customer load was moderate. Transactions for each customer normally lasted less than ten minutes; but this time did not account for the time spent standing in line, for which no information was collected. The contribution of the customers to the building’s $CO_2$ concentrations was not clearly indicated in the survey data. In fact, the teller area, the area where most of the customers would have been in the building, had lower $CO_2$ concentrations than most other areas in the building, possibly because the $CO_2$ in the area was diluted by outside air entering through the front entrance doors. In future determination of the outside air needs of the building, the contribution of the customers to the building’s $CO_2$ concentrations and other contaminants will need to be assessed.

ASHRAE believes that 20 cfm per person of outside air is adequate to dilute $CO_2$

concentrations to below 1000 ppm for a building population density of 7 occupants per 1000 ft$^2$. However, some flexibility is needed in the capacity of the outside air system to allow for changes in the amount of outside air needed in the building.

## Mechanical System Inspection

The following findings for the various components of the air handling system are presented in the direction of the air flow through the system:

1. Most of the return air grilles in the ceiling had dust covering the hole in the perforated metal grilles. This dust prevents the air from entering the return system through the grilles. Instead, the return air is forced to find alternate routes back to the AHUs, which can cause drafts and increased contaminant concentrations in locations along the altered path, contribute to air distribution problems, and decrease the supply airflow.

2. The entrances to the two return air ducts were above the hallway next to Office 1. This arrangement can cause more air to be pulled through returns closer to the duct entrance than those farther away. In turn, this causes drafts and uneven contaminant concentrations similar to those for the return grilles being plugged.

3. No fire detection/protection systems were found in the return ducts. Without this system, the AHUs would not be shut down during a fire and could help the fire spread. Moreover, smoke could be pulled in the direction of one of the two evacuation routes from the building, decreasing visibility of the evacuation route.

4. The filter systems for the AHUs had very low efficient (<20% efficiency according to the ASHRAE Dust Spot Test) open-cell foam filters. Although the filter frames were 1" thick, the actual media was 1/2" thick. ASHRAE recommends that a 35 to 60% efficient filter be used, and many new installations are installing 85% efficient filters.

   The filters had gaps around the edges that permitted by-pass around the filters. The original installation had no means of preventing this by-pass. The filters were arranged in the AHU so one filter lapped over the other, but did not have gaskets or other

   means to prevent by-passing of the filters through the gap formed at the overlap.

   Access to and changeout of the 15-1/2" x 19-1/2" filters in each unit was through a single 12" X 12” access hole. Filters had to be manipulated to get them out of or into the units. During removal, some of the filter cake is usually knocked into the unit. Furthermore, all of the filter frames were broken in the same location apparently to facilitate installation of the filters.

   Dust marks on the frames of the access holes in each unit showed that air could leak through gaps around the access panel and by-pass the filters. Because the panel was located directly above the burner area of the heat exchanger, burner operation may be affected by the draft caused by the leak.

The filters in the units needed changeout. The company currently maintaining the AHUs reported that the filters were last changed in June 1993. However, this company had no records of the filters being changed since the furnace sections were installed one year before. This changeout frequency is unacceptable because the filters could easily become too loaded and begin to shed debris from the filter. This debris accumulates in the HVAC systems and eventually becomes a maintenance problem. Under proper conditions, this debris can also serve as the source of and food for biological growth in the HVAC systems. Furthermore, as the filters become loaded, the air flow resistance increases, increasing by-passing around the filters or decreasing supply air flow.

5. No access was available to the upstream side of the cooling coils in either AHU. This side of the coil usually gets dirtier than the downstream side of the coil because it sees the air stream first. Without access, this face of the coil cannot be inspected or cleaned efficiently. Coils should be cleaned on a routine schedule to prevent their becoming loaded with debris. This debris is a potential source of or food for biological growth and restricts air flow through the coil. Restriction of the air flow through the coil can also increase the velocity of the air through the coil, which can further cause condensate water to be blown off the coil onto the plenum or supply ductwork insulation. Biological growth on the coil could be aerosolized and carried into the building, causing illness or symptoms in susceptible occupants.

   The access panel to the downstream side of the coils in both AHUs was not sealed and did not have gasketing, allowing air leakage from the cooling coil plenum. This air leakage decreases the effectiveness of the supply air system.

   Access to the downstream side of the coils in both AHUs was hampered by freon lines running horizontally across the face of the access opening. These lines hamper maintenance work on the coil and visualization of the supply air ductwork in the floor. The lines are also located where they could become damaged during maintenance work.

   The insulation on the access panel and lining the plenum, formerly yellow-colored, was black with dirt loading, moldy, and decomposing. The plenum area had a musty smell possibly from the mold on the insulation. The dirt loading of the liner is evidence of past filtration problems that allowed dust into the unit and supply ducting. The mold growth showed that the liner has been wet in the past. The dirt loading, wetness, and mold growth cause degradation of the liner. When the liner degrades, some of it may be blown downstream and out of the supply air fixtures. The liner contains fiberglass which can be a skin irritant. The dirt or mold in the liner can also be blown into the building, possibly causing symptoms or illness in occupants with allergies to the mold or dirt.

The drip eliminators downstream of the cooling coils were dirty. This dirt could become a contaminant or maintenance problem like the dirt on other interior surfaces of the AHUs and supply air ductwork.

Little debris was in the condensate pans of either AHU. Both AHUs' condensate pans had drains positioned at their mid-points. Although the drain pans were sloped, the location of the drains resulted in half of the pan being sloped downhill toward the drain and half being sloped uphill. Condensate water would therefore stand in the section of the condensate pan sloped downhill from the drain. The drain was also located about 1/2" above the bottom of the pan, further allowing water to stand in the pan. Standing water in the pan, when mixed with debris, could be a source of bioaerosols.

Neither of the condensate drain lines on the AHUs had traps; but little space existed between the floor and the drain lines for the installation of traps. Without traps, air can leak from the units decreasing the unit efficiency. The drain line on AHU 2 was sloped uphill from the condensate pan, hampering drainage of the pan and possibly causing water to stand in the pan.

6. The entrance to the supply air ductwork is in the floor directly beneath its respective AHU. The ductwork was difficult to view, even when using powerful lights and mirrors. Some parts of the ductwork could be viewed from the AHU and other parts from the registers after their removal; but most of the ductwork could not be seen.

   The ductwork was cleaned the month before the survey. The sections of the ductwork that could be viewed were clean; but, the firm reported that "a ton of dirt" had been removed from the ductwork. The manager also reported that the duct was sprayed with oxene, a anti-microbial solution.

   In all locations where the ductwork was inspected, watermarks were along the bottom part of the ducts, although the ducts were dry during the survey. The manager at the duct-cleaning firm reported that, when he was inspecting the ductwork before the cleaning, debris that he picked up from the bottom of the ductwork was damp. Water in the ducts could be a source of bioaerosols. Therefore, even though the ducts were dry during the survey, the possible existence of water in the ducts at other times of the year needs to be checked.

7. The location of the floor registers makes them prone to being partially or fully covered and blocked. Examples of floor registers being covered are: the open doors in Office 4 partially covered two registers; a rug and chairs partially blocked the registers in the lobby area; and an audiovisual cart and shelves partially covered the registers in the Conference Room. Blockage of the registers by

objects placed directly over the registers obviously prevents the proper amount of supply air from exiting the register; but objects placed above the registers, even 1 or 2 feet above the registers, can prevent some of the supply air from exiting the register or can alter the intended path of the supply air. An example of the latter case is that the floor registers along the outside walls were designed to direct air up the glass to counteract drafts caused by heat transfer through the glass. In the lobby area of the building, chairs were sitting above the registers, preventing the air from properly blowing up the glass surface.

Many of the dampers on the floor registers were fully open indicating that the air supply system was not balanced. The register dampers should have been opened various amounts depending on the register locations along the ductwork and the design air flows. Adjustment of the registers is made by measuring the air flows from the registers and adjusting them according to design. A qualified professional needs to test and balance the systems.

The louvers on the floor registers were angled to direct the air flow to one side of the register, in particular toward the wall or glass surface near to the register. Many of the registers were oriented in the wrong direction so that the air blew into the building instead of up the surface. Orienting the registers so they blow air in the wrong direction could lead to complaints about drafts or other thermal comfort complaints.

The low-wall supply register in the women's bathroom was fully closed, although some air flow was still coming from the register. Some employees complained about the duration of odors in the bathroom, which is understandable because no air was being supplied to the bathrooms to dilute the odors. The women’s bathroom was also reported to become too cold in the winter, so an auxiliary heating unit was installed to solve this problem. The register appears to have been closed due to the belief that this action would solve continuing thermal comfort problems in the room.

8. The exhaust fan for the women's bathroom was not working, while the fan for the men's bathroom was. Both fans had heavy debris accumulations on the impeller blades. The accumulated debris could decrease the amount of air moved by the fan, reducing the ability of the fan to remove odors from the bathroom. A decrease in exhaust air flow could further allow the bathroom to become positively pressurized, causing air that may contain odors to be blown into the building from the bathroom.

   Even though the fan in the women's bathroom was not working, air was pulled into the bathroom apparently because of air exiting through the exhaust duct by convection (the exhaust duct basically acts like a chimney). Air also was pulled into the men's bathroom when its exhaust fan was not working. When the AHU system serving the bathrooms was operating, air was blown from the men's but not the women's bathroom apparently due to the settings of the registers.  These findings indicate that odors could be blown from the men's bathroom when the AHU activates.

The bathroom exhaust ducts did not have dampers to stop air flow through the ducts when the fan was not working.  Although the open ducts help eliminate odors from the bathrooms through a chimney effect, they also waste energy in the winter by allowing heat to constantly escape from the building.  Spring loaded dampers are available to allow air to flow through the exhaust duct when the fan is working, but prevent flow when it isn't.

Both exhaust fans operated with the lights of their respective bathroom.  This arrangement helps save energy; but the fans may not be operating long enough to adequately eliminate odors from the bathrooms.  Timer switches can be installed that allow the fan to operate for a preset time after the lights are turned off.

9. Occupants complained about sewer odors inside the building near the bathrooms, particularly when the men's toilet had a run-on problem prior to the survey.  During the survey, a large accumulation of debris was found in the floor drains of both the men's and women's bathrooms.  In fact, pieces of metal that appeared to be from the original construction were in the men's bathroom drain.  Both traps were dry, even though water had been poured into the drains about two weeks before the survey.  The traps are believed to have dried out so quickly because the debris limits the amount of water the trap can hold. Sufficient water is needed in the traps to prevent sewer odors from entering the building from the sewer lines.  Small amounts of a smoke put into the drains was forced from the drain when the toilet in the drain’s respective bathroom was flushed.  However, a great deal of smoke was aspirated from the drains by a jet of air from under the door flowing over the drain opening.  In the men's bathroom, significant smoke was similarly aspirated from the drain by air from the supply register.

10. Smoke tests at the outside doors showed that the building was primarily under negative pressure (air flowed from outside to inside the building) whether the AHUs were operating or not.  On the day the doors were checked, a gusty wind was blowing, affecting the amount of air flowing into the building and sporadically pulling air from the building.  Having the building under negative pressure is not desirable because the infiltrating air can cause drafts that can make some occupants thermally uncomfortable.  Readjusting the thermostats to satisfy uncomfortable occupants usually causes other occupants to be thermally uncomfortable.  Another problem with the infiltration is that unfiltered air is brought into the building, potentially exposing susceptible occupants to outdoor irritants and allergens, and adding to the dust load in the building.

## VIII. SUMMARY

The survey at the Sterling Van Dyke Credit Union revealed that no provision existed for ventilating the building. Lack of outside air for ventilation could allow contaminants to accumulate in the occupied areas of the building. One of these contaminants, ETS, may be significantly contributing to some of the occupant’s respiratory and irritation symptoms. In addition, numerous problems were found with the building's mechanical systems. The primary negative effect of these problems appears to be thermal discomfort; but the potential for biological growth and bioaerosol generation appeared to exist. The thermal comfort problems are generally endemic to the design and type of HVAC system used in the building; some of the problems are due to long term neglect of the system.

## IX. CONCLUSIONS AND RECOMMENDATIONS

The following recommendations are steps that can be taken in the near-term to help answer employee complaints:

1. Worker exposure to ETS is most efficiently and completely controlled by simply eliminating tobacco use from the workplace. To facilitate elimination of tobacco use, employers should implement smoking cessation programs. Management and employees should work together to develop appropriate nonsmoking policies that include some or all of the following:

   ! Prohibit smoking at the workplace and provide sufficient disincentives for those who do not comply.

   ! Distribute information about health promotion and the harmful effects of smoking.

   ! Offer smoking-cessation classes to all workers.

   ! Establish incentives to encourage workers to stop smoking.

   The most direct and effective method of eliminating ETS from the workplace is to prohibit smoking in the workplace. Until this measure can be achieved, employers can designate a separate, enclosed area for smoking, with separate exhaust ventilation. Air from this area should be exhausted directly outside and not recirculated within the building or through the building’s HVAC systems. Ventilation of the smoking area should meet general ventilation standards, such as ASHRAE Standard 62-1989 which requires that 60 cfm per person of outside air be supplied to the area (this air can be clean air taken from other building area. The smoking area should also be under negative pressure relative to other building areas to ensure airflow into the area from the rest of the building. If the smoking area is also a room used for other functions, such as the Conference Room, smoking should not be permitted in the room when non-smokers are required to be in the room.

2. Outside air should be provided to ventilate the building. The outside air should be supplied at a rate of 20 cfm per person. The exact amount of outside air should be greater than that needed for only the employees because of the transient customers visiting the

credit union to conduct business. To determine the amount of outside air needed, the average population of the building under normal operating conditions should be determined.

The outside air should be supplied to the return air ducts of both of the current AHUs. A fan-powered outside air system is recommended, and the systems fan should have more capacity than estimated to be needed in case estimates are incorrect. A fan-powered system will assure that the proper amount of outside air is supplied to the building and eliminates the need to design the ductwork exactly to get the correct amount. Dampers should be placed in the outside air ducts to regulate the amount of air in each duct. The inlet of the outside air ducts should be located where it will minimize the introduction of outdoor contaminants into the building.

A mechanical firm should be consulted to determine what impact the outside air will have on the heating and cooling systems of the current AHUs. Ancillary equipment may also need to be installed to compensate for the effect of the outside air on the current systems.

3. The filtration system should be relocated to a more accessible location, and filters with a greater efficiency installed. The recommended new location is the plenums currently between the return air ducts and the AHUs. Access doors to the new filter plenum area should be installed instead of panels that are screwed over the opening in the plenum to facilitate access. The access doors should have adequate gasketing to prevent leaks and should be sized to permit optimal access to the filters for maintenance. The new filters should be the maximum efficiency, according to the ASHRAE Dust Spot Test, possible without substantially affecting the air flow of the current HVAC systems. The filter systems should also be designed to minimize bypass around the filters. The old filters should be removed, and the panels to the old filter locations should be sealed to prevent leaks around the panels.

4. An access door to the upstream side of the cooling coil should be installed in each AHU. Location of the doors appears to be possible in the opposite face of the plenum from the current access to the downstream side of the coils. This door should be as large as possible to allow easy maintenance of the cooling coils. On the downstream side of the coils, the freon lines that currently hamper easy maintenance of the coils should be relocated, if possible. The access panels to the upstream and downstream coil areas should be equipped with gaskets to prevent leaks around the panels.

5. The liner of the cooling coil plenum should be removed and the plenum decontaminated. The liner should be replaced with a new liner installed according to the recommendations of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

6. The coils, drip eliminators, and condensate pans should be power washed to remove current dirt accumulations. The contractor should be required to take steps to prevent cleaning solutions from getting into the ducts.

7. The drains for the condensate pans should be relocated to the lowest end of the condensate pan or new pans installed that would prevent standing water in the pans. Whichever option is chosen, the pan drains should be as close to the bottom of the pans as possible or in the bottom of the pans. Moreover, the lip of the drain should not extend into the condensate pan. Drain lines should slope downhill from the pans, and, if possible, traps should be put in the lines. The depth of the traps should be greater than the static pressure inside the plenum to prevent water in the trap from being blown out.

8. Restrictions to air flow for all supply air registers in the building should be removed. All registers should be turned to blow air against nearby wall surfaces. In the near future, a testing and balancing firm should be hired to adjust the air flows from the supplies according to design. The <u>person</u> performing the test and balance should be certified by the National Environmental Balancing Bureau (NEBB) or an equivalent certifying agency. After balancing, the dampers in the registers should be fixed in place to prevent easy readjustment of the damper.

9. All return air grilles, the grilles to the bathroom exhaust fans, and the exhaust fan impellers should be thoroughly cleaned.

10. The exhaust fan in the women's bathroom should be repaired. For both bathrooms, a timer switch system to operate the fans after the lights are turned off should be installed. Additionally for both bathrooms, dampers to prevent loss of air through the exhaust ducts when the fans are not operating should be installed.

11. All floor drains in the building should be cleaned out. Water should be added to the drains weekly to keep them from going dry. The drains should be routinely inspected.

12. The fans in the AHUs should be operated constantly during occupied hours to circulate the air in the building, and provide constant ventilation when the outside air system is added. Starting this practice now may reduce thermal discomfort problems in the building. With the addition of outside air, this practice will be necessary to provide ventilation air to all areas of the building.

13. The supply ducts should be checked on a monthly basis for water accumulations in the supply air ducts. If water is found in the ducts, the source of the water should be investigated and eliminated, and water in the duct should be removed. During the check, debris that has fallen through the registers in the ducts should be vacuumed up.

14. All of the mechanical systems in the building should be put on a preventive maintenance plan. A mechanical firm should be hired to oversee the plan. Specific records should be kept of all maintenance, and a copy of the records should be kept at the credit union.

15. Consideration should be given to a thorough cleaning of interior surfaces of the building, including ceiling tiles, after smoking has been eliminated or controlled. Such cleaning would brighten the interior and partially remove the tobacco odors. Because of the strong cleaning chemicals that are expected to be needed for this operation, the cleaning should be performed on the earliest day of a long weekend, and the building ventilated prior to re-occupancy.

    Thermal comfort complaints could persist after the above changes are made because of the design of the current supply system. Long-term plans should consider whether to replace the current subslab supply system with a ceiling supply system. A ceiling supply system could provide better air distribution and temperature control, and provide a supply system that is more easily changed. The current supply system could be used for return air if the building is converted to a ceiling supply system. If the subslab ducts are continued to be used for either a supply or return system, consideration should be given to installing new, more facilitative accesses to the ductwork through the floor in front of the AHUs.

    Long-term plans should also include investigating whether heat buildup in the ceiling plenum is a problem. If it is, gravity or powered ventilators should be installed in the roof to facilitate removal of the hot air from the ceiling plenum.

## X. REFERENCES

1. Kreiss KK, Hodgson MJ [1984]. Building associated epidemics. In: Walsh PJ, Dudney CS, Copenhaver ED, eds. Indoor air quality. Boca Raton, FL: CRC Press, pp 87-108.

2. Gammage RR, Kaye SV, eds. [1985]. Indoor air and human health: Proceedings of the Seventh Life Sciences Symposium. Chelsea, MI: Lewis Publishers, Inc.

3. Woods JE, Drewry GM, Morey PR [1987]. Office worker perceptions of indoor air quality effects on discomfort and performance. In: Seifert B, Esdorn H, Fischer M, et al, eds. Indoor air '87, Proceedings of the 4th International Conference on Indoor Air Quality and Climate. Berlin Institute for Water, Soil and Air Hygiene.

4. Skov P, Valbjorn O [1987]. Danish indoor climate study group. The "sick" building syndrome in the office environment: The Danish town hall study. Environ Int 13:399-349.

5. Burge S, Hedge A, Wilson S, Bass JH, Robertson A [1987]. Sick building syndrome: a study of 4373 office workers. Ann Occup Hyg 31:493-504.

6. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews. 4(4):575-592.

7. Norbäck D, Michel I, Widstrom J [1990]. Indoor air quality and personal factors related to the sick building syndrome. Scan J Work Environ Health. 16:121-128.

8. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews. 4(4):625-642.

9. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: A reanalysis of epidemiologic studies. Am J Public Health. 80(10):1193-1199.

10. Molhave L, Bach B, Pedersen OF [1986]. Human reactions during controlled exposures to low concentrations of organic gases and vapours known as normal indoor air pollutants. Environ. Int., 12, 167-175.

11. Fanger PO [1989]. The new comfort equation for indoor air quality. ASHRAE J 31(10):33-38.

12. Burge HA [1989]. Indoor air and infectious disease. Occupational Medicine: State of the Art Reviews. 4(4):713-722.

13. Robertson AS, McInnes M, Glass D, Dalton G, Burge PS [1989]. Building sickness, are symptoms related to the office lighting? Ann Occup Hyg 33(1):47-59.

14. Wallace LA, Nelson CJ, Dunteman G [1991]. Workplace characteristics associated with health and comfort concerns in three office buildings in Washington, D.C. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

15. Haghighat F, Donnini G, D'Addario R [1992]. Relationship between occupant discomfort as perceived and as measured objectively. Indoor Environ 1:112-118.

16. NIOSH [1991]. Hazard evaluation and technical assistance report: Library of Congress Madison Building, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 88-364-2104 - Vol. III.

17. Skov P, Valbjørn O, Pedersen BV [1989]. Influence of personal characteristics, job-related factors, and psychosocial factors on the sick building syndrome. Scand J Work Environ Health 15:286-295.

18. Boxer PA [1990]. Indoor air quality: A psychosocial perspective. J Occup Med 32(5):425-428.

19. Baker DB [1989]. Social and organizational factors in office building-associated illness. Occupational Medicine: State of the Art Reviews. 4(4):607-624.

20. CDC [1992]. NIOSH recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

21. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

22. ACGIH [1991]. 1991-1992 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

23. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

24. ASHRAE [1992]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1992.

25. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

26. Löfroth G [1989]. Environmental tobacco smoke: overview of chemical composition and genotoxic components.

27. Claxton L, Morin R, Hughes T, Lewtas J [1989]. A genotoxic assessment of environmental tobacco smoke using bacterial bioassays. Mutation Research 222(2):81-100.

28. Glantz SA, Parmley WW [1991]. Passive smoking and heart disease epidemiology, physiology, and biochemistry. Circulation 83:633-42.

29. Offermann FJ, Loiselle SA, Hodgson AT, Gundel LA, Daisey JM [1991]. A pilot study to measure indoor concentrations and emissions rates of polycyclic aromatic hydrocarbons. Indoor Air 4:497-512.

2. U.S. DHHS [1986]. The health consequences of involuntary smoking. A report of the surgeon general. U.S. Department of Health and Human Services, Public Health Service, Office of the Assistant Secretary for Health, Office of Smoking and Health. DHHS Publication No. (PHS) 87-8398.

    1. Taylor AE, Johnson DC, Kazemi H [1992]. Environmental tobacco smoke and cardiovascular disease: A position paper from the council on cardiopulmonary and critical care. American Heart Association, Dallas, TX.

    2. Martin TR, Braken MB [1986]. Association of low birth weight passive smoke and exposure in pregnancy. American Journal of Epidemiology 124:633-42.

    3. U.S. EPA [1993]. Respiratory health effects of passive smoking: Lung cancer and other disorders. U.S. Environmental Protection Agency Publication No. EPA/600/6-90/006F. Washington, D.C.

    4. NIOSH [1989]. Current Intelligence Bulletin 54: Environmental Tobacco Smoke in the Workplace; lung cancer and other health effects. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91-108.

    5. Schiller GE [1990]. A Comparison of measured and predicted comfort in office buildings. ASHRAE Transactions, Volume 96, Part 1.

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Copies of this report have been sent to:

1. The confidential requesters.
2. Supervisor, Sterling Van Dyke Credit Union.
3. Assistant Supervisor, Sterling Van Dyke Credit Union.

**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
### Symptoms Experienced At Work
### Sterling Van Dyke Credit Union
### Sterling Heights, Michigan
### HETA 93-1134

| Symptoms Of 14 Workers | Experienced On Days Of Survey While At Work | Frequently Experienced Last 4 Weeks While At Work | Have Frequent Symptoms That Improve When Away From Work |
|---|---|---|---|
| Dry, itching, or irritated eyes | 50 % | 50 % | 29 % |
| Tired or strained eyes | 57 % | 71 % | 50 % |
| Stuffy nose, or sinus congestion | 36 % | 43 % | 29 % |
| Sneezing | 29 % | 36 % | 29 % |
| Sore or dry throat | 57 % | 64 % | 43 % |
| Dry or itchy skin | 43 % | 57 % | 0 % |
| Unusual fatigue or drowsiness | 43 % | 50 % | 21 % |
| Headache | 50 % | 57 % | 21 % |
| Tension, irritability or nervousness | 50 % | 71 % | 36 % |
| Difficulty with memory or concentration | 14 % | 29 % | 7 % |
| Nausea or upset stomach | 7 % | 29 % | 14 % |
| Feeling depressed | 7 % | 7 % | 0 % |
| Pain or stiffness in back, shoulders, or neck | 29 % | 43 % | 29 % |
| Dizziness or lightheadedness | 0 % | 7 % | 7 % |
| Cough | 64 % | 64 % | 29 % |
| Chest tightness | 29 % | 43 % | 14 % |
| Wheezing | 14 % | 21 % | 7 % |
| Shortness of breath | 14 % | 29 % | 14 % |

### Table 2
### Description Of Workplace Conditions
### Sterling Van Dyke Credit Union
### Sterling Heights, Michigan
### HETA 93-1134

| Conditions | Experienced At Work During Days Of The Survey 14 workers | Frequently Experienced While at work During previous 4 weeks 14 workers |
|---|---|---|

| | | |
|---|---|---|
| Too much air movement | 0 % | 0 % |
| Too little air movement | 79 % | 86 % |
| Temperature too hot | 43 % | 50 % |
| Temperature too cold | 29 % | 57 % |
| Air too humid | 0 % | 0 % |
| Air too dry | 57 % | 57 % |
| Tobacco smoke odors | 71 % | 79 % |
| Chemical odors (e.g., paint, cleaning fluids, etc. | 36 % | 50 % |
| Other unpleasant odors (e.g., body odor, food odor, perfume) | 29 % | 36 % |