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April 5, 2012

James Scully
Superintendant of Schools
City of Haverhill
4 Summer Street
Haverhill, MA 01830

Dear Mr. Scully,

Enclosed is a copy of the report by the Indoor Air Quality Program on their visit to the C.D. Hunking Middle School to conduct an indoor air assessment. The report shows that there were problems identified. Please refer to the recommendations section for advice on how to correct these problems.

If you have any questions regarding the report or if we can be of further assistance in this matter, please feel free to call us at (617) 624-5757.

Sincerely,

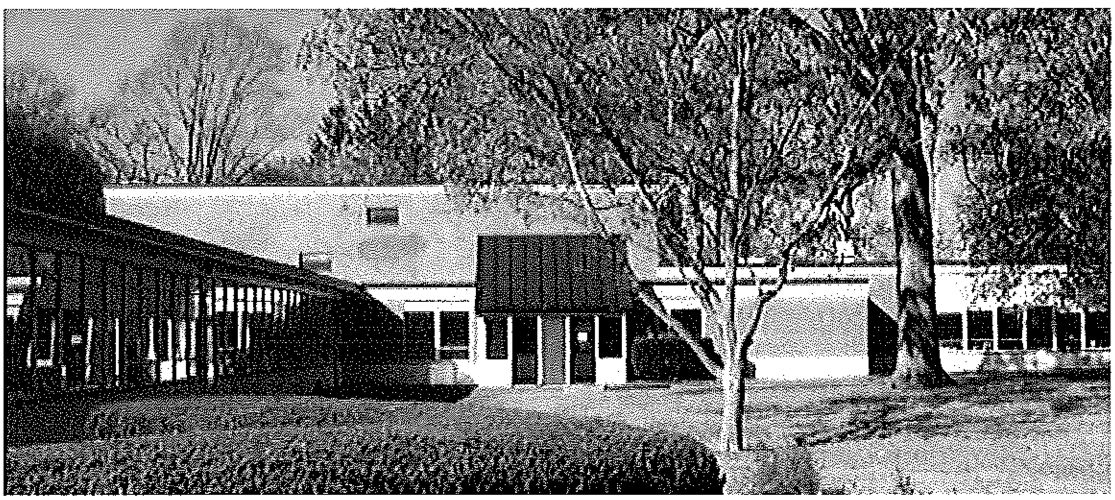
Suzanne K. Condon, Associate Commissioner
Director, Bureau of Environmental Health

cc: Michael A. Feeney, Director, Indoor Air Quality, BEH
Jan Sullivan, Director, Community Assessment Program, BEH
David Cook, Principal, Hunking Middle School
Tom Geary, School Facilities Manager, City of Haverhill
Senator Steven A. Baddour
Representative Harriett Stanley

Enclosure(s)

INDOOR AIR QUALITY ASSESSMENT

C.D. Hunking Middle School
98 Winchester Street
Haverhill, MA



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
April 2012

Background/Introduction

At the request of James F. Scully, Superintendent, Haverhill Public Schools (HPS), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality (IAQ) concerns at the C.D. Hunking Middle School (HMS), 98 Winchester Street, Haverhill, Massachusetts. The request was prompted by concerns associated with skin rashes experienced by staff members. On December 6 and 16, 2011 visits to conduct IAQ assessments were made to the HMS by Michael Feeney, Director of BEH's IAQ Program. Mr. Feeney was accompanied by Sharon Lee, an Environmental Analyst/Inspector in BEH's IAQ Program on December 6, 2011. BEH/IAQ staff were accompanied by Christine Gorwood and Brenda Netreba, Environmental Analysts/Risk Communication Specialists in BEH's Community Assessment Program (CAP) on both days of assessment.

The HMS is a one-level brick and concrete building constructed in 1959. The school consists of four wings: sixth and seventh grade (occupied wing), seventh and eighth grade (unoccupied wing), cafeteria/auditorium and gymnasium/art wings (Figure 1). A catwalk connects the two classroom wings to the cafeteria/auditorium. The gymnasium/art (former woodshop) wing is at the end of the unoccupied (seventh and eighth grade) wing (Figure 1).

As reported by school officials, the crawlspaces in the school have experienced steam and roof drain leaks. In response to chronic moisture issues and cracking/displacement observed in the floor, masonry walls and structural beams, HPS contracted with an engineering firm (AECOM) to examine the structural integrity of the entire HMS complex. AECOM recommended that the seventh and eighth grade wing be vacated due to "structural deficiencies," but also stated that the currently occupied wing was "not affected by the structural deficiencies which plague the [unoccupied] wing" (AECOM, 2011). AECOM further concluded that "the lifespan of the mechanical systems has been reached and failure has occurred in many locations" (AECOM, 2011).

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 7565-X. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. BEH staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The HMS typically housed approximately 440 students in grades 6 through 8 and approximately 45 staff members. At the time of assessment, approximately 295 students and 35 staff remained at the HMS. Tests were taken during normal operations in the occupied areas of the school. Results appear in Table 1. Air sampling was not conducted in the unoccupied wing.

Discussion

Ventilation

It can be seen from Table 1 on December 6, 2011, carbon dioxide levels were above 800 parts per million (ppm) in 12 of 31 areas surveyed, indicating inadequate ventilation in a number of the areas surveyed. Of note are areas where carbon dioxide levels exceeded 2,000 ppm (Table

1). Elevated levels of carbon dioxide were largely the result of deactivated mechanical ventilation equipment; neither supply nor exhaust were operating. On the December 6, 2011 visit, the weather was unseasonably warm (62 °F). The heating season began mid-October, at which time the HMS facility staff reportedly set the heating, ventilating and air-conditioning (HVAC) system to its winter setting. In the winter setting, the HVAC system is reportedly deactivated when the thermostat does not call for the provision of heated air. As a result, no fresh air was being provided at the time of the assessment. Once HPS staff were alerted of the HVAC equipment's status, the ventilation system was reactivated in the warm weather mode (heating off) to allow for the provision of fresh air. With regards to exhaust ventilation, as mentioned, this system was in disrepair at the time of assessment.

During the December 16, 2011 visit, the weather was still rather mild for this time of year (outdoor temperature of 52 °F). Carbon dioxide levels were elevated in 15 of 21 areas, indicating poor air exchange in the majority of areas at the time of the assessment. It is also important to note that during both visits several classrooms had open windows/exterior doors and/or were empty/sparsely populated. Each of these factors can result in reduced carbon dioxide levels. Carbon dioxide levels would be expected to increase with full occupancy and windows closed.

Fresh air in classrooms is supplied by unit ventilator (univent) systems (Picture 1). A univent draws air from outdoors through a fresh air intake located on the exterior wall (Picture 2) of the building and returns air through an intake located at the base of the unit (Figure 2). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents were found obstructed by papers, books, furniture and other stored materials (Picture 3; Table 1). A heavy buildup of dust and debris was also observed on the air diffusers of several univents. In order for univents to provide fresh air as designed, air diffusers, intakes and returns must remain free of obstructions. Importantly, these units must remain "on" and be allowed to operate while rooms are occupied.

Please note, univents in the school were installed when the building was constructed, over 50 years ago. The age of the equipment makes service and repairs of these units difficult. According to the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), the service life[1] for a unit heater using hot water or steam is 20 years, assuming routine maintenance of the equipment (ASHRAE, 1991). Despite attempts to maintain the univents, the operational lifespan of the equipment has been exceeded. Maintaining the balance of fresh air to exhaust air will become more difficult as the equipment ages and as replacement parts become increasingly difficult to obtain.

Exhaust ventilation in classrooms is provided by wall-mounted vents (Picture 4) that are connected to ductwork and exhaust fans located inside the crawlspace. At the time of assessment, BEH staff could not detect any draw of air by the mechanical exhaust systems. As reported by AECOM (2011), "structural deficiencies [in the crawlspace] have caused collapse of many of the heating, ventilation and drainage systems." Corrosion and physical deterioration have rendered the exhaust system inoperable. Without adequate supply and exhaust ventilation, excess heat and normally occurring environmental pollutants can build up, leading to indoor air/comfort complaints.

Please note, a ducted vent observed in an office (room 158) was sealed with duct tape and cardstock (Picture 5). The purpose of this vent was unknown. Measures should be taken to determine whether this vent can be made operable to create air movement in this office. This office currently lacks any sources for ventilation, relying on air movement from doors opening

[1] The service life is the median time during which a particular system or component of ... [an HVAC]... system remains in its original service application and then is replaced. Replacement may occur for any reason, including, but not limited to, failure, general obsolescence, reduced reliability, excessive maintenance cost, and changed system requirements due to such influences as building characteristics or energy prices (ASHRAE, 1991).

into adjacent offices. If a means of ventilation can be restored through this vent, a source of fresh air could be established. If the vent is no longer functional, it should be sealed in a manner that does not allow odors, dust/debris and moisture that may be within the vent to penetrate the occupant area.

Please note, some classrooms, especially those located in former shop spaces, have switch-activated exhaust fans (Picture 6). Consideration should be given to operating these fans during classroom occupancy, or periodically if noise is of concern, as a means to remove any normally-occurring pollutants from these areas.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust systems, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). In the current condition, the HVAC systems cannot be balanced.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the designated occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose, and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

Temperature measurements in the HMS ranged from 73 °F to 80 °F on December 6, 2011 and 68 °F to 75 °F on December 16, 2011. Indoor temperatures were above the MDPH recommended comfort range in some areas on the December 6, 2011 visit and slightly below that range on the December 16, 2011 visit (Tables 1 and 2). The MDPH recommends that indoor air temperatures be maintained in a range of 70 °F to 78 °F in order to provide for the comfort of building occupants. As mentioned, no fresh air was being provided on the December 6, 2011 visit, resulting in elevated temperatures. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Furthermore, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents/exhaust vents deactivated/obstructed).

The relative humidity measured in the building ranged from 37 to 59 percent on December 6, 2011 and from 24 to 38 percent on December 16, 2011. the majority of areas had relative humidity levels within the MDPH recommended comfort range (Tables 1 and 2). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As mentioned, there are a number of structural concerns at the HMS. Much of the structural damage is limited to what is now the unoccupied wing. Such damage is likely attributed to water penetration in the crawlspace causing deterioration and shifting of the foundation, resulting in impacts to the structural stability (horizontal and vertical shifting) of load-bearing roof beams (Pictures 7 and 8), as well as deterioration of mechanical and electrical components in the crawlspace below the unoccupied wing. These concerns are further discussed in the *Structural Damage* section that follows. Other factors contributing to water damage and potential microbial growth in the occupied portion of the building are discussed in the *General Concerns* section.

Structural Damage

As reported by HPS personnel, the crawlspaces below the building are subject to repeated moisture exposure due to steam leaks from the heating system as well as rainwater from cracked roof drain pipes. BEH staff examined the building and noted an additional source of water penetration. Based on observations of the exterior of the building, it is likely that water is also penetrating through the foundation. Compressed soil, forming up to 4-inch depressions, was observed on both sides of the unoccupied wing. These depressions can allow pooling water to come into extended contact with the foundation (Picture 9). Based on these observations as well as documented reports, the crawlspace beneath the unoccupied wing has been chronically exposed to moisture, which in turn has caused significant structural and mechanical damage.

Passive vents are typically installed to allow water vapor and other materials in a crawlspace to be removed or diluted. Such vents were observed beneath classroom exterior doors on the western side of the occupied wing (Picture 10). These vents were installed in a manner to create cross-ventilation in the crawlspace. Of note is the orientation of the exterior doors and their stairs/landings, which likely takes advantage of New England's prevailing westerly wind direction. The stairs at position 1 face northwest, while the stairs at positions 2 and 3 face southwest (Figure 3; Picture 11). Depending on the orientation of the wind, the cement stairs/landings either form an air scoop to direct air into the passive vents (windward side) or provide a sheltered location for air to escape from the crawlspace (leeward side). For example, a southwest wind can force air to enter the space formed by the stairs and landing in Positions 2 and 3, creating pressurization that forces air in the crawlspace to escape via the passive vent in Position 1. This airflow created through passive ventilation allows water vapor to escape the crawlspace.

Another feature that aids in drying the occupied wing's crawlspace is the boiler room, which is adjacent to this area (Figure 1). The boiler room is depressurized, since an operating boiler draws air to combust fuel. This condition would likely draw air and water vapor from the crawlspace. This additional removal of air and water vapor from the crawlspace likely has limited the moisture-induced structural damage that was observed in the unoccupied wing crawlspace.

While crawlspace vents were observed beneath the unoccupied wing, the configuration and condition of these vents are unlikely to result in sufficient air movement/moisture removal from the crawlspace. Two crawlspace vents were identified: one sealed vent near the gym entrance (Picture 12) and another near the front entrance (Figure 3; Picture 13). No corresponding vent was noted on the rear of the building, limiting any potential for cross-ventilation. A cement casing with ductwork connected to an operating rooftop exhaust motor was observed near the restrooms (Picture 14). The configuration of the ductwork (two right angle bends) would result in reduced draw of air, thereby providing minimal exhaust/removal of water vapor from the unoccupied wing crawlspace.

Due to lack of ventilation, any water accumulated in the crawlspace beneath the unoccupied wing does not have a ready path to exit. Without moisture removal, mechanical equipment (e.g., exhaust ventilation) and electrical utilities in the crawlspace become corroded. Continued water impingement from within the crawlspace and water penetration through the exterior has likely weakened the crawlspace walls/building foundation. The decreased ability of the crawlspace walls/foundation as support structures have also resulted in concerns regarding the roof frame, which is designed to carry additional dead load (e.g., weight of snow) by transferring the weight downwards through classroom walls and support beams.

The roof of the HMS appears to be convex, with water draining to the low point in the center of the roof of each wing (Picture 15). This structure is typical in schools where the roofs are either peaked or flat. The type and configuration of the beams used to support the roof in each wing likely explain the shape of the roof. The roof beams consist of eight layers of industrial strength engineered wood adhered together to form glue laminated beams (e.g., plywood; Picture 16). In other buildings assessed by BEH staff, this type of roof beam typically runs from exterior wall to exterior wall through a school's classroom and hallway; any seams/joints that may exist in the beams rest on load bearing walls or support beams.

According to the report by AECOM (2011) and observations made by BEH staff, the roof support system at the HMS consists of three components: two classroom beams and a hallway beam (Figure 4). Bolts join the beams to create a system consisting of classroom beam - hallway beam - classroom beam (Picture 17); this beam system traverses the building. Seams where beams were joined were observed to be roughly one-quarter the distance from the interior wall within the classroom. This configuration creates a discontinuous system from the exterior wall to the interior wall within the classroom.

The beam traversing the hallway is oriented in a manner that does not provide support for roof load. As installed, the lips of the hallway beams rest on the classroom beams, forcing the classroom beams and exterior walls to provide support for the roof (Figure 4). To allow the hallway beam to provide support and transfer load through the interior walls, the entire beam system would be installed in an inverted orientation (Figure 5). In this inverted orientation, the lips of the classroom beams would rest on those of the hallway beam, resulting on the weight of the roof being transferred to interior walls.

In its current configuration, the roof load at the HMS is supported by a bolt system and exterior walls/classroom beams, receiving no support from the interior walls/hallway beam. As a result, the classroom beams shift under the roof load (e.g., snow). This movement is evidenced by vertical (Picture 18) and horizontal (Picture 19) displacement of beams in the unoccupied wing. As mentioned, the crawlspace under the unoccupied wing is subject to chronic moisture exposure. Water impingement has weakened the foundation walls, reducing the ability of these walls to take on the transferred roof load. Over time, the roof of this wing will cave inwards due to lack of support from interior walls (from beam orientation) and reduced support from exterior walls (from the weakened foundation walls).

The beam system in the occupied wing is also oriented in the same manner as that observed in the unoccupied wing. At the time of assessment, there was no shifting/displacement observed in the beams of the occupied wing. This is likely due to the orientation/presence of appropriate crawlspace vents as well as drying attributed to the proximity of the boiler room. It is likely that the crawlspace foundation walls and support structures for the currently occupied wing have neither been exposed to chronic water damage nor experienced horizontal and vertical beam movement as observed in the unoccupied wing.

Building-wide Concerns

The interiors of some univents were examined. Spaces and holes in the wall, floor, around pipes, and within the air-handling cabinet were observed (Pictures 20 and 21). These breaches can serve as pathways for air, odors and particulates to be drawn from the crawlspace into classrooms. Breaches in cabinet walls allow draw of air, post-filtration.

Similar breaches were observed around water utility pipes for sinks (Picture 22). Breaches around these water pipes can allow for air from the crawlspace to enter classrooms. Air penetration is magnified when the exhaust ventilation is operating, since exhaust vents are adjacent to the sinks in some classrooms.

Musty odors were detected in the AV storage room, where a crawlspace access door was observed. The door to the crawlspace access was not flush to the floor (Picture 23), which can allow materials/odors from the crawlspace to migrate into occupant areas. Measures should be taken to render the access door airtight to prevent penetration of odors into the AV storage room.

A number of areas were observed to have water-damaged ceiling tiles, indicating roof leaks. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired. Some water-damaged ceiling tiles were constructed of 9" by 9" interlocking mineral tiles that may contain asbestos mastic (Picture 5). It was reported to BEH staff that this water damage occurred many years ago and the leaks have been repaired. A determination should be made concerning whether these tiles contain asbestos. If they do, the tiles should be left in place until they can be removed by a licensed asbestos remediation contractor.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed/discarded.

BEH staff also observed cracks in the foundation, which can undermine the integrity of the building envelope and provide a means of water entry by capillary action into the building (Lstiburek & Brennan, 2001). The freezing and thawing action of water during the winter months can create cracks and fissures in the foundation. In addition, they can serve as pathways for insects, rodents and other pests into the building.

Plants were observed in a number of classrooms (Picture 3). Plants, soil and drip pans can serve as sources of mold growth and should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. In addition, flowering plants can be a source of pollen. Therefore, plants should be located away from the air stream of univents to prevent aerosolization of mold, pollen and particulate matter.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon Monoxide

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On both days of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Tables 1 and 2). Carbon monoxide levels measured in the school were also ND (Tables 1 and 2).

Particulate Matter (PM2.5)

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the December 6, 2011 were measured at 12 $\mu g/m^3$ (Table 1). On December 16, 2011 outdoor PM2.5 concentrations were measured at 1 $\mu g/m^3$ (Table 2). PM2.5 levels measured inside the school ranged from 5 to 15 $\mu g/m^3$ on December 6 (Table 1), 2011 and 1 to 6 $\mu g/m^3$ on December 16, 2011 (Table 2). Both indoor and outdoor PM 2.5 levels were below the NAAQS PM2.5 level of 35 $\mu g/m^3$ on both days of the assessment.

Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Volatile Organic Compounds

Indoor air concentrations can be greatly impacted by the use of products containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to identify materials that can potentially increase indoor VOC concentrations, BEH staff examined classrooms for products containing these respiratory irritants.

Dry erase boards and related materials were observed in a number of classrooms. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Household cleaning products, air fresheners and deodorizing materials were found in several areas (Picture 24, Table 1). Cleaning products and air deodorizers contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. Many air fresheners contain 1,4-dichlorobenzene, a VOC which may cause reductions in lung function (NIH, 2006). Furthermore, deodorizing agents do not remove materials causing odors, but rather mask odors that may be present in the area. Additionally, a Material Safety Data Sheet (MSDS) should be available at a central location for all school chemicals in the event of an emergency such as an adverse chemical interaction between residues left from cleaners used by the facilities staff and those left by cleaners brought in by others.

Other Conditions

In several classrooms, items were observed on floors, windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation.

A number of fans/blades (Picture 25), exhaust vents (Picture 6) and air-conditioners (Picture 26) had accumulated dust/debris. Fans should be cleaned periodically in order to prevent them from serving as a source of aerosolized particulates. Exhaust vents should also be cleaned to prevent re-aerosolization of dust due to back drafting. Air-conditioners and their filters should be cleaned periodically to prevent distribution of materials.

Open food items were seen in classrooms, including being used as art materials (Picture 27). Food is an attractant to pests and rodents. Proper food storage is an integral component in maintaining IAQ. Food should be properly stored and clearly labeled. Where food products are used in art, the artwork should be stored/displayed in a container or the food components should be treated in a manner that does not attract pests (i.e., non-toxic white glue sealant or other clear coat product). Reuse of food containers is not recommended, since food residue adhering to the surface may serve as an attractant to pests.

Health Concerns

As mentioned, BEH received reports of health concerns among employees working at the HMS. BEH/CAP conducted interviews with HMS staff at the time of the IAQ inspection. The type and frequency of the symptoms experienced by some HMS employees were obtained through administration of a questionnaire by BEH/CAP staff. The questionnaire elicited information on those symptoms that have been reported in the scientific/medical literature as commonly experienced in buildings with indoor air quality problems. These types of questionnaires are used to systematically collect building-related health and environmental complaints. The information collected, in conjunction with the assessment of the indoor environment, can be used to evaluate possible associations between indoor air quality and health and to recommend appropriate follow-up if warranted.

The questionnaire was developed by BEH to assess the types of symptoms reported among a group of concerned employees of the HMS. The questionnaire was closely modeled on surveys used previously by BEH as well as those used by the National Institute of Occupational Safety and Health (NIOSH) and the U.S. Environmental Protection Agency (US EPA). It included questions on specific symptoms (those commonly experienced by occupants of buildings with indoor air problems), on perceived air quality and other behavioral/medical factors.

The HMS has an employee population of approximately 45 individuals. On December 6 and December 16, 2011 and January 13, 2012, BEH staff conducted in-person interviews with HMS employees who expressed interest in participating. In addition, two individuals who were not available to meet on those days were interviewed via telephone by BEH staff. A total of 27 HMS employees were interviewed as part of this investigation. The interviews took approximately 30 minutes each. All clinical information/symptoms reported were reviewed to determine the frequency of occurrence, and whether any unusual patterns emerged suggestive of a possible association between reported health problem and indoor environmental conditions in the HMS (Appendix B).

Employee Interview Results

Information from the 27 individuals (representing roughly 60% of the HMS employees) is summarized below. Under both state and federal regulations, personally-identifying information is confidential; therefore, the following discussion provides summary information only.

Health Effects

Of the 27 employees interviewed, 21 were female and six were male. The average age of the employees was approximately 49 years old and the average length of employment with HMS was 7 years. Smoking status was obtained in the interviews due to the role of smoking in respiratory health. Two people reported that they were current smokers, ten people reported that they were a former smoker, and 15 people reported that they have never smoked.

The most commonly reported symptoms (with at least 15 of the 27 employees reporting that they experienced the symptom at least once since the beginning of the school year) were: headaches (n=19); sore, hoarse or dry throat (n=18); unusual tiredness, fatigue, or drowsiness (n=18); itchy, runny or watery eyes (n=15); stuffy or runny nose and sinus congestion (n=16); and coughing (n=15). Most of these employees reported that their symptoms were worse while inside the building and their symptoms did improve once they left the building.

Other symptoms that were reported by at least ten of the 27 employees to have been experienced at least once since the beginning of the school year included the following: skin irritation, dryness, redness or rash (n=12); dizziness, lightheadedness or loss of balance (n=11); difficulty remembering things or concentrating (n=10); sneezing (n=10); pain or stiffness in the back, shoulders or neck (n=10); and wheezing in the chest (n=10). Respondents were asked if there was a particular time of day or week when their symptoms usually became worse or more frequent; nine of the 27 individuals reported that their symptoms appeared to get worse in the afternoons. Most employees reported no pattern during the week.

Employees who participated in the MDPH interview were also asked if they had been diagnosed by a doctor with any of the following conditions: asthma, eczema, hay fever/allergies, or migraine headaches. Of the 27 participating employees, seven reported being diagnosed with asthma, seven with hay fever, six with migraine headaches, and six with eczema. Four of the seven individuals reporting a diagnosis of asthma reported to MDPH that they had been diagnosed with their condition prior to working at HMS. Six of the seven individuals reported to MDPH with a reported diagnosis of hay fever/allergies reported to MDPH that they had been diagnosed with their condition prior to working at HMS. The majority of the individuals who reported a diagnosis of either migraine headaches or eczema also reported that they were diagnosed prior to starting at HMS.

Building Concerns

The 27 HMS employees were also asked about their perceptions of environmental conditions in their work environment. Their responses were as follows:

- 26 reported that the air is too stuffy
- 24 reported that the air was too dry
- 24 reported that the indoor temperature was too hot
- 20 reported unusual or unpleasant dust
- 17 reported musty or moldy smells

Of the 24 employees who reported that the indoor temperature was too hot, 11 also reported that the indoor temperature was consistently too cold, indicating that the indoor temperature is inconsistent and variable by season.

Other Reported Concerns

When individuals who participated in the interview were asked if they had any other building or health-related concerns at the HMS that had not yet been discussed, a number of other concerns were discussed. Staff were worried about potential exposures from the closed area of the school, asbestos, carbon monoxide and the school's drinking water. More general concerns about poor air quality, black dust and clogged vents were mentioned. Staff also mentioned concerns about water damage in the building and leaks in the roof.

Medical Record Review Findings

As part of this investigation, MDPH offered to have Dr. Jon Burstein, BEH's staff physician, review medical records for any individual who was interested in participating in this portion of the investigation. Consent forms were distributed to individuals at the time of the interviews. For the two individuals who were interviewed via telephone, consent forms were provided via U.S. mail. MDPH received consent forms from one individual. Due to the low response, the results of Dr. Burstein's review cannot be included here, but will be sent directly to this individual.

Conclusions/Recommendations

Health Discussion/Conclusions

The respiratory/irritant and other symptoms reported among participants in this health investigation are generally those most commonly experienced in buildings with indoor air quality problems. These included sore, hoarse or dry throat; dry, itchy eyes; sneezing, stuffy or runny nose; unusual tiredness, fatigue, or drowsiness; coughing; and headaches. Such symptoms are commonly associated with ventilation problems in buildings, although other factors (e.g., odors, microbiological contamination) may also contribute (Passarelli 2009; Norbäck 2009; Burge 2004; Stolwijk et al. 1991).

During BEH's inspections on December 6 and 16, 2011, carbon dioxide was found above 800 ppm in many of the test locations. As mentioned, carbon dioxide is not a problem in and of itself, however, it is used as an indicator of the adequacy of the fresh air supply. Ten of the 27 individuals reported having asthma and/or allergies. The onset of allergic reactions to mold/moisture can be either immediate or delayed. Allergic responses include hay fever-type symptoms such as runny nose and red eyes. The majority of the individuals were diagnosed with these conditions prior to working at the HMS; however, exposure to irritants (e.g., mold/moisture, dust) as well as low relative humidity environments can exacerbate pre-existing symptoms. It is likely that some individuals may be impacted differently than the general population.

IAQ Conclusions

Based on the information in the AECOM report (AECOM, 2011) and findings by MDPH staff, HVAC equipment at the HMS appears to consist of univents that have exceeded their expected service lifespan and an exhaust ventilation system that is non-functional. In occupied classrooms, normally-occurring environmental pollutants and excess heat can build up and lead to indoor air/comfort complaints. The existing capacity of mechanical ventilation equipment to provide adequate fresh air and exhaust to classrooms is limited, as evidenced by air testing (i.e., carbon dioxide levels above 800 ppm). Based on the condition of the exhaust system in the building, repair of the existing system would not likely be feasible. Problems existing with the HVAC system are compounded by the documented water issues in the crawlspace, as well as other structural concerns.

To remedy building problems, two sets of recommendations are made, including short-term measures that may be implemented as soon as practicable and long-term measures that will require planning and resources to address overall IAQ concerns. It is important to note that any renovation project is a dynamic process; therefore it is important to have measures in place to promptly deal with issues likely to arise. The MDPH guidance "Methods Used to Reduce/Prevent Exposure to Construction/Renovation Generated Pollutants in Occupied Buildings" should be consulted (Appendix C). The MDPH has prepared this guidance document in order to prevent/reduce the migration of renovation-generated pollutants into occupied areas.

Short Term Recommendations

1. Use openable windows in conjunction with mechanical ventilation to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes in the winter.
2. Examine each univent for function. Survey classrooms for univent function to ascertain if adequate air supply exists for each room.
3. Where operable, operate both supply and exhaust ventilation continuously during periods of school occupancy independent of classroom thermostat control to maximize air exchange.
4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
5. Determine the purpose of the ducted vent in office 158 (Picture 5). Measures should be taken to determine whether this vent is operable to create air movement in this office, if not feasible, permanently seal.
6. Change filters for air-handling equipment (e.g., univents, AHUs and ACs) per manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces allowing bypass of unfiltered air into the unit.
7. Monitor all beams and walls for any changes in size of gaps on a monthly basis and after any appreciable snowstorm.
8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance

(HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

9. Ensure roof/plumbing leaks are repaired and remove/replace any remaining water-damaged *non asbestos-containing* ceiling tiles. Repair interior water-damaged surfaces.

10. Install gutters/downspout system to direct water away from the building to prevent water from pooling at the base of the school.

11. Seal open utility holes to prevent water penetration and block insect and rodent pathways into the building.

12. Repair cracks in the exterior cement walls and brick work

13. Seal open utility holes around plumbing fixtures beneath sinks.

14. Seal holes in univent cabinets.

15. Make adjustments/repairs to crawlspace accesses to render airtight (as possible) to prevent odor/moisture infiltration into occupied areas.

16. Ensure plants have drip pans and avoid over-watering. Examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary. Remove plants from univent air diffusers.

17. Store cleaning products properly and out of reach of students. Ensure spray bottles are properly labeled. All cleaning products used at the facility should be approved by the school department with MSDS' available at a central location.

18. Refrain from using air fresheners or other air deodorizers.

19. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

20. Clean personal fans, univent air diffusers, return vents and exhaust vents periodically of accumulated dust.

21. Refrain from using food as an art material. Where this is unavoidable, ensure projects are sealed/stored in a manner that prevents pests/rodents attraction.

22. Consider adopting the US EPA (2000) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

23. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/iaq.

Long Term Recommendations

Given the observed conditions at the HMS, a number of costly capital repairs are likely necessary in order to restore the unoccupied wing. Compounding these repairs is the presence of asbestos containing materials (ACM) in the crawlspace (AECOM, 2011). Repair work addressing water vapor damage to the crawlspace below the unoccupied wing includes:

1. Remediation of water sources in the crawlspace:
    a. Complete remediation of ACM in the crawlspace;
    b. Leaking steam pipes;
    c. Leaking roof drain pipes; and

d. Arrestance of water penetration into the crawlspace foundation walls on both sides of the building.

2. Provision for a means to remove water vapor from the crawlspace by either:

   a. Installation of a series of mechanical exhaust vents to remove water vapor; or

   b. Excavation of the crawlspace/foundation walls to cut in sufficient passive air vents similar to those found in the occupied wings crawlspace/foundation walls.

3. Reestablishing the integrity of the cement structure in the crawlspaces, *if feasible*. Consultation with a building engineer on methods to complete this work and the cost is strongly recommended.

4. Repair work to the roof would likely require a means to support the underside of each joint for each beam (not beneath a load bearing interior wall), in addition to the bolt connected the end to the roof. In each of these remedies, an engineering firm should be retained in order to examine the feasibility and cost of rendering the unoccupied wing safe for occupancy. The possible options may include, but are not limited to the following possibilities:

   a. Installation of posts beneath each joint (assuming the floor can accommodate the additional load from the roof);

   b. Installation of a beam installed beneath the beam junction that rests on classroom interior walls;

   c. Installation of a support system over the roof to transfer the load to the ground around the unoccupied wing; or

   d. Retrofitting each joint that would transfer the load of the exterior wall beam to the hallway beam as if the beams were self-supporting.

5. Complying with all relevant Massachusetts building related codes, especially if the option of renovating the existing building is considered. A cost estimate comparing renovations compared to replacement should be considered as well as the legal requirements for such a project. The relevant codes/regulations that may have to be addressed in a renovation project likely include but are not limited to:

   a. Disabled access (Architectural access board);
   b. Plumbing/gas;
   c. Electrical code;
   d. Fire code;
   e. Building code;
   f. State and/or Federal asbestos remediation and hazardous waste disposal laws;
   g. State energy code;
   h. Earthquake code; and
   i. School building requirements under 963 CMR 2.04: General Site and School Construction Standards

6. Contact an HVAC engineering firm for an assessment of the ventilation system's control system (e.g., controls, air intake louvers, ductwork, thermostats). Based on the age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing the equipment.

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Figure 1: Schematic of Hunking Middle School

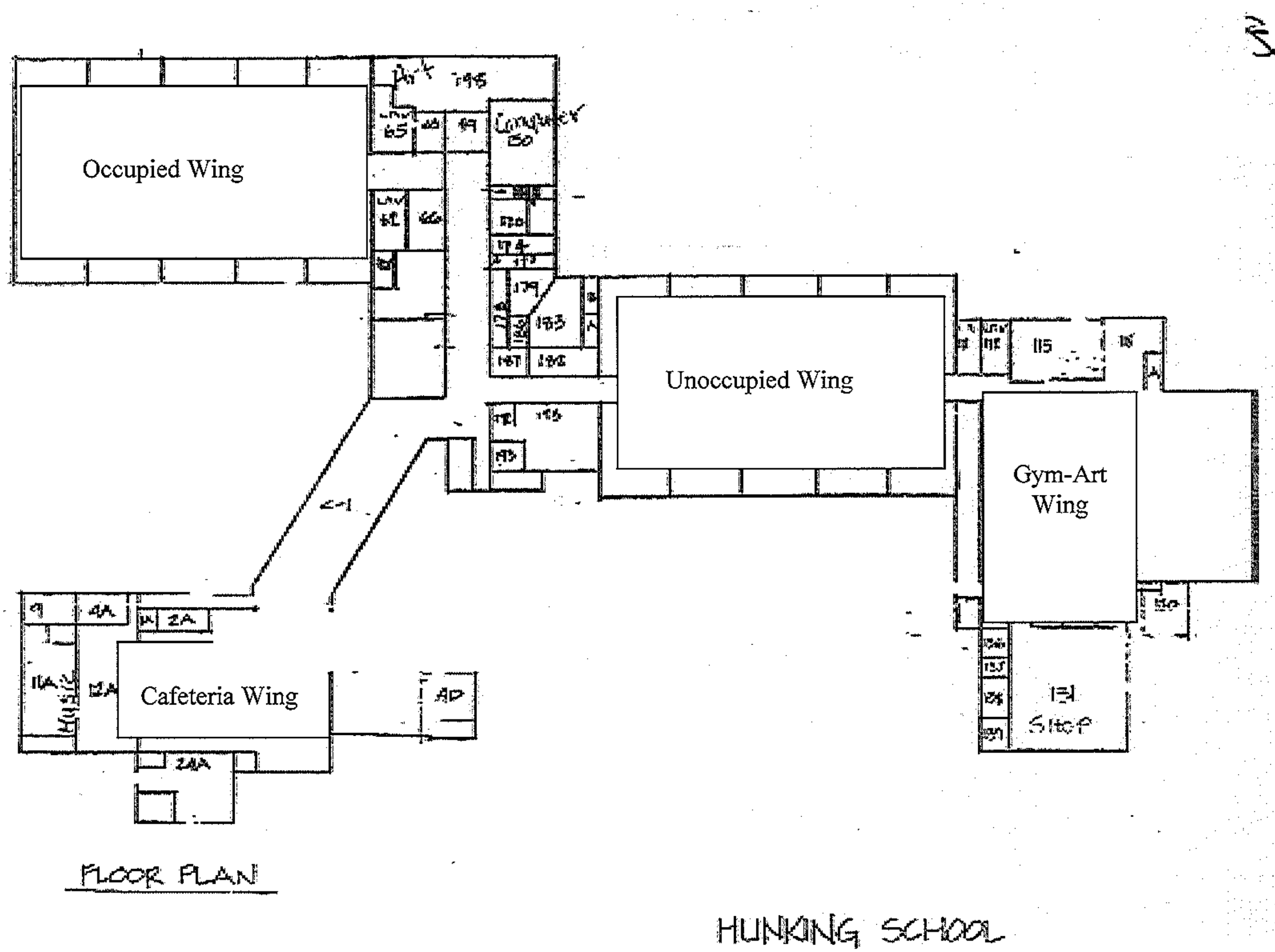


Figure 2: Unit Ventilator (Univent)

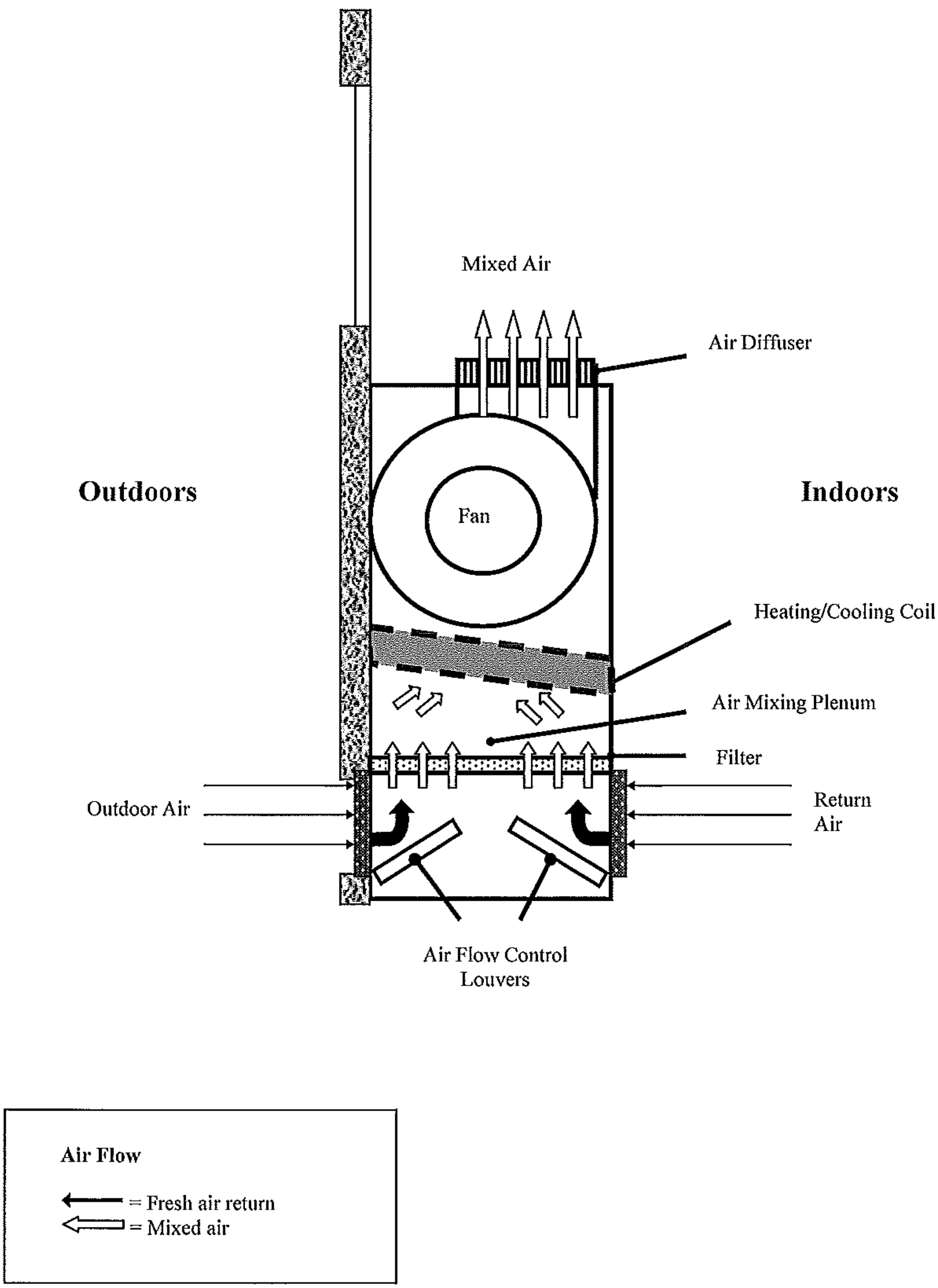


Figure 3: Location of Installed Crawlspace Passive Vents

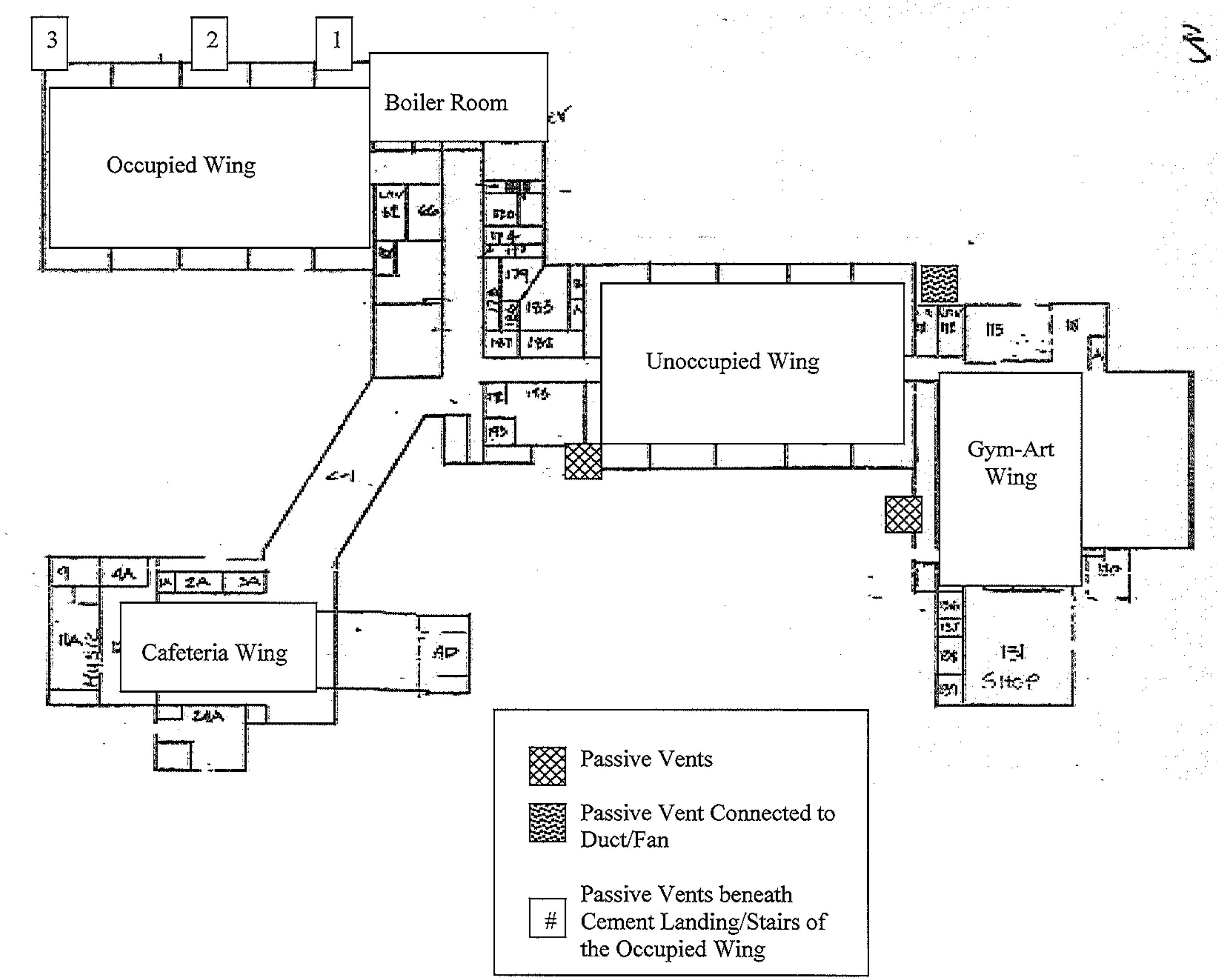


Figure 4: Theoretical Orientation of How Roof Beams Should Have Been Installed to Provide Support for Entire Roof Deck

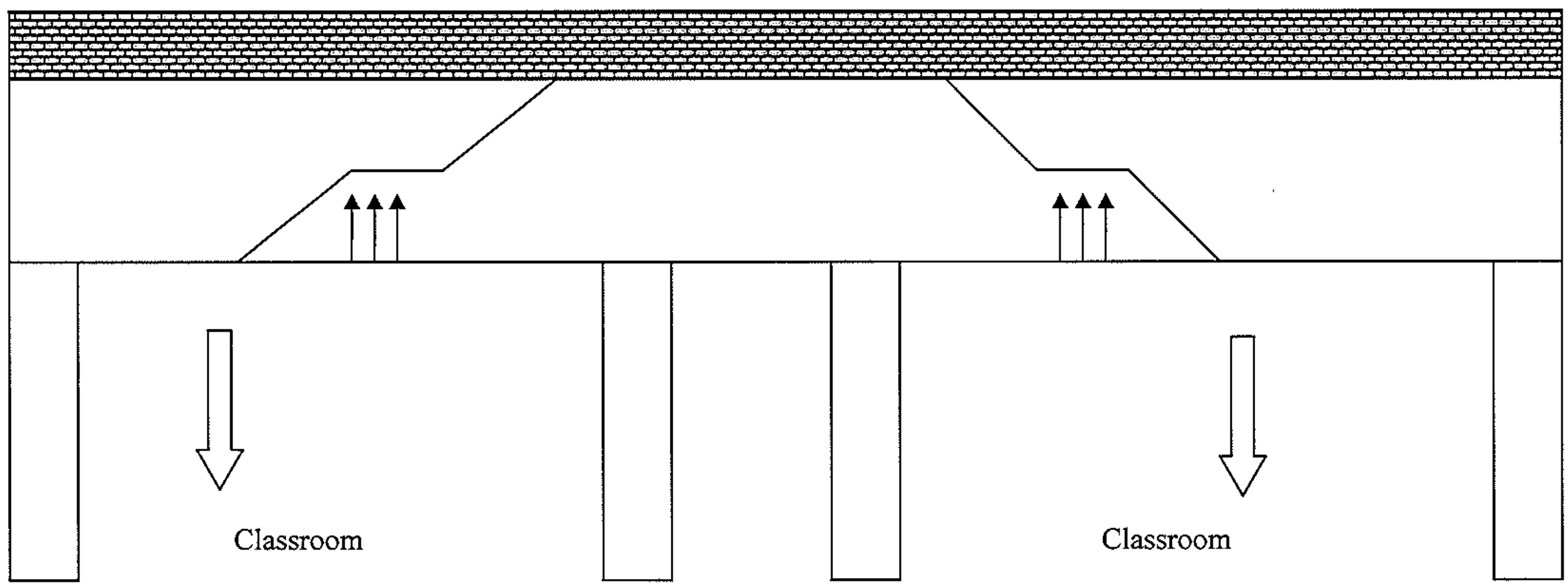
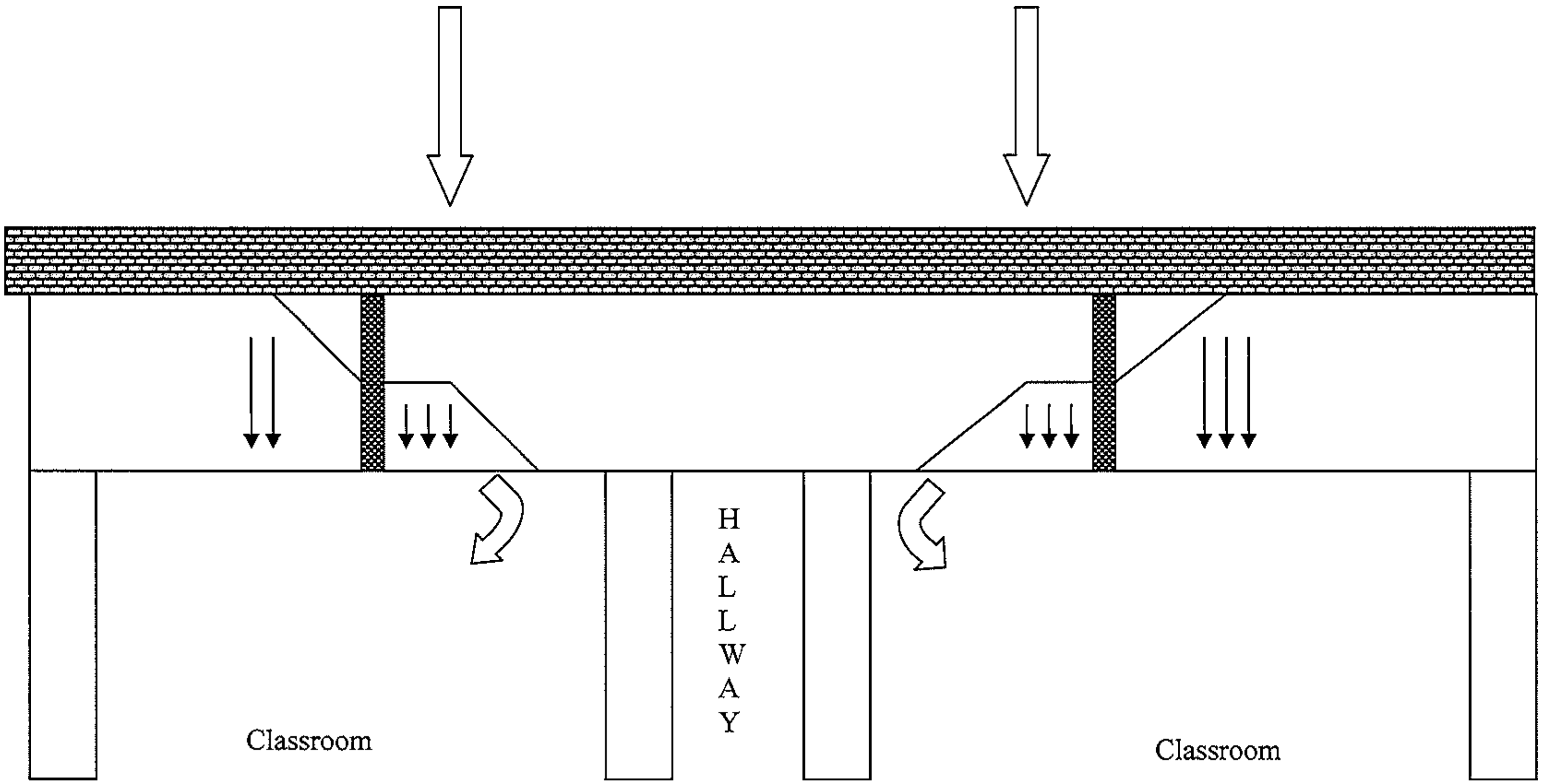
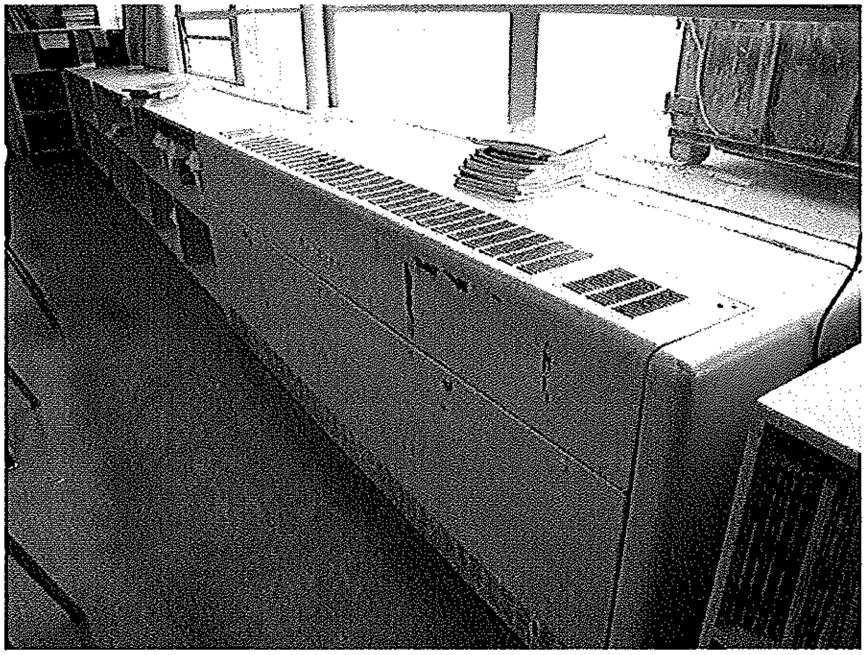


Figure 5: Roof Beam Exterior Wall Beams Are Not Supported by Beam Traversing the Hallway Walls, Load is Shifted to Roof via Bolts Allow for Exterior Wall Beam Rotation

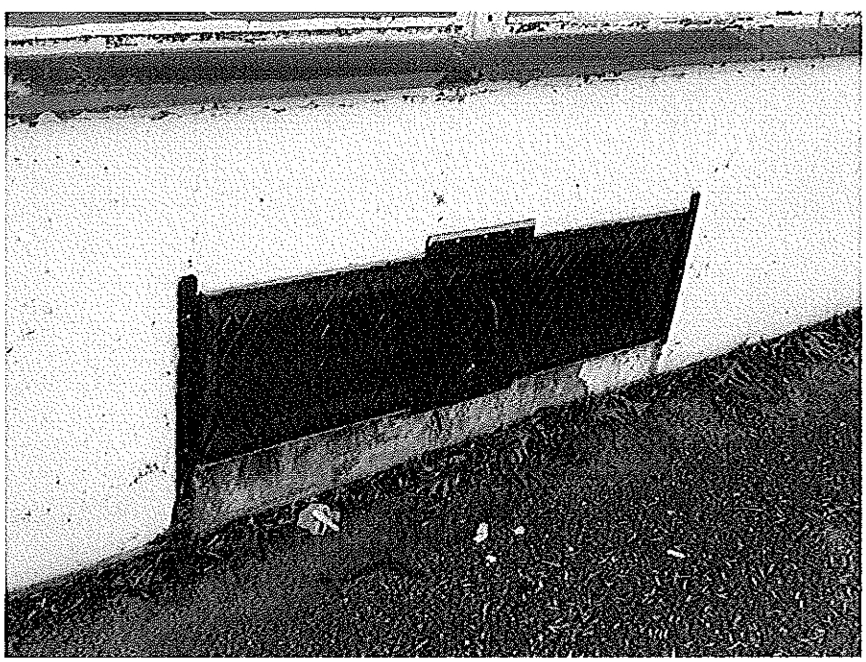


Picture 1



Classroom univent

Picture 2

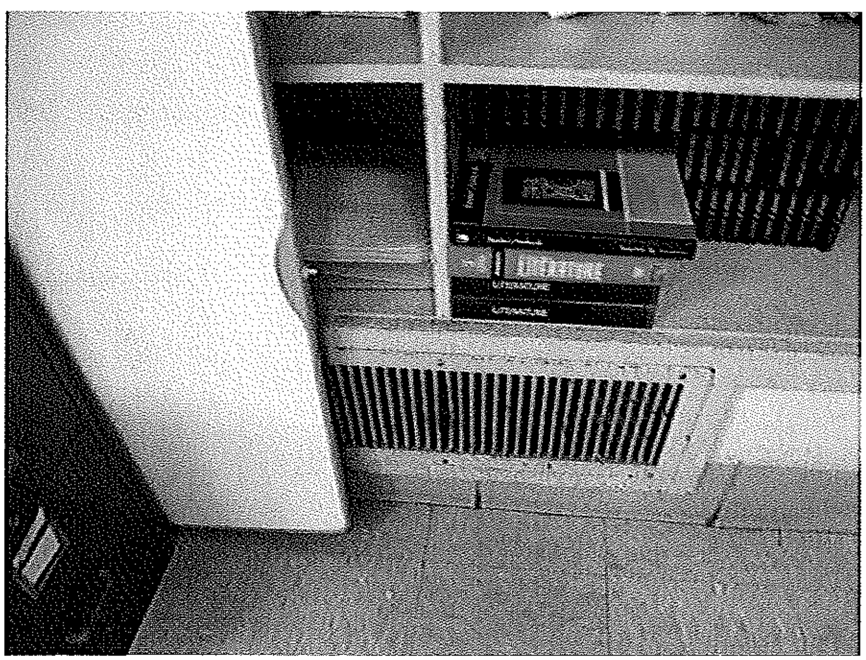


Univent fresh air intake on exterior wall of building

Picture 3

Plants and other items placed on univent

Picture 4

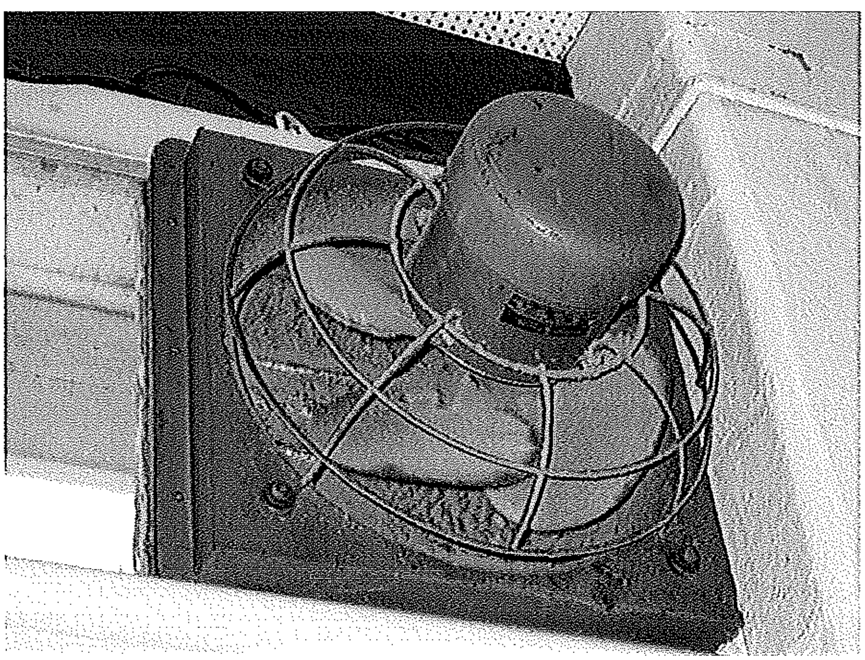


Classroom exhaust vent

Picture 5

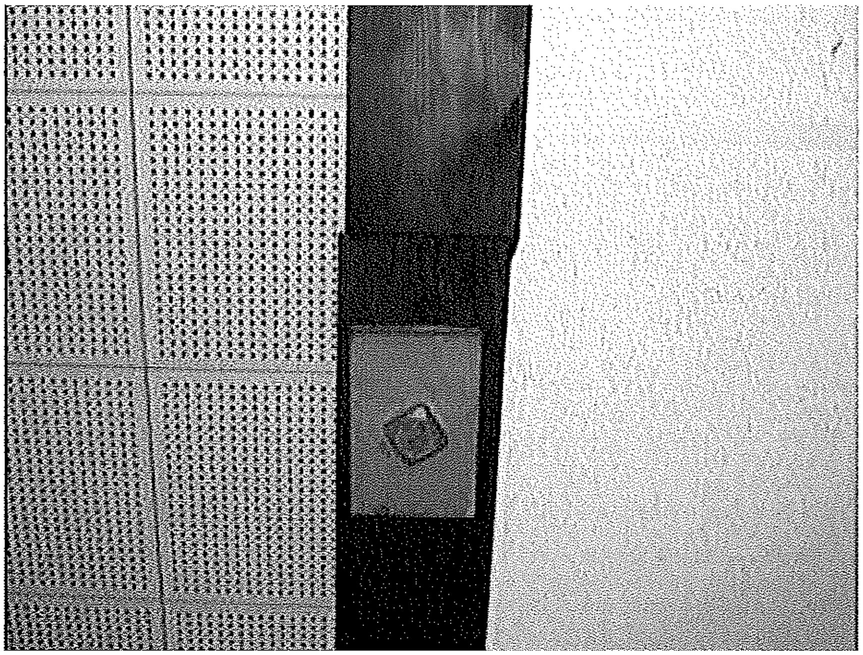
Cardstock-sealed vent, note water-damaged interlocking ceiling tiles

Picture 6



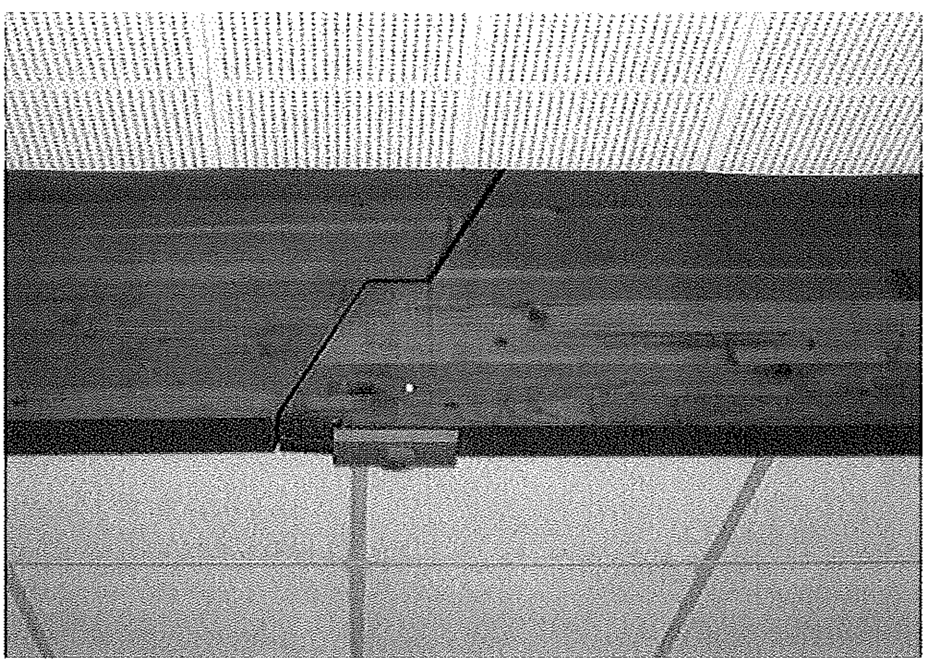
Switch-activated exhaust fan, note occlusion with dust

Picture 7



Horizontal movement of load-supporting beam

Picture 8

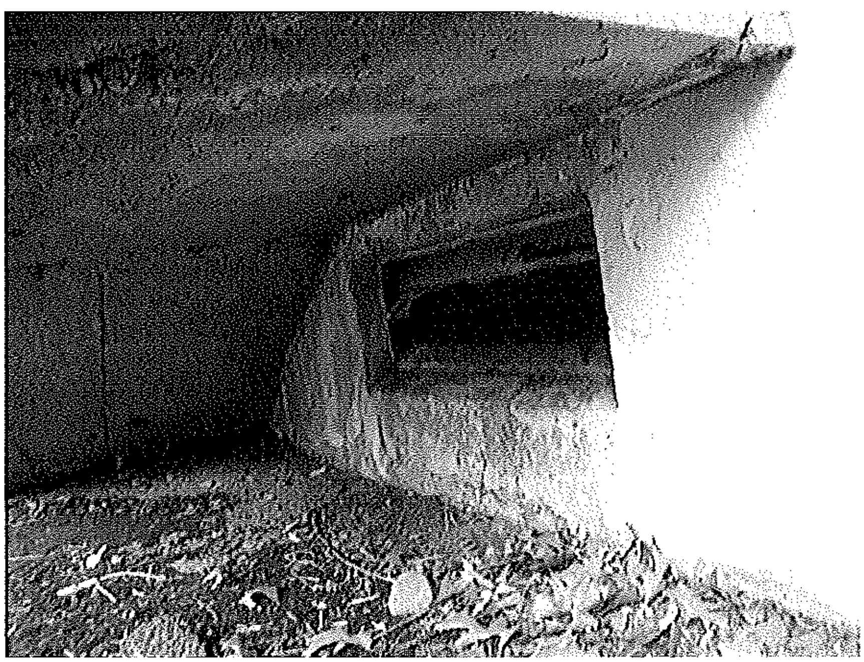


Vertical movement of load-supporting beam

Picture 9

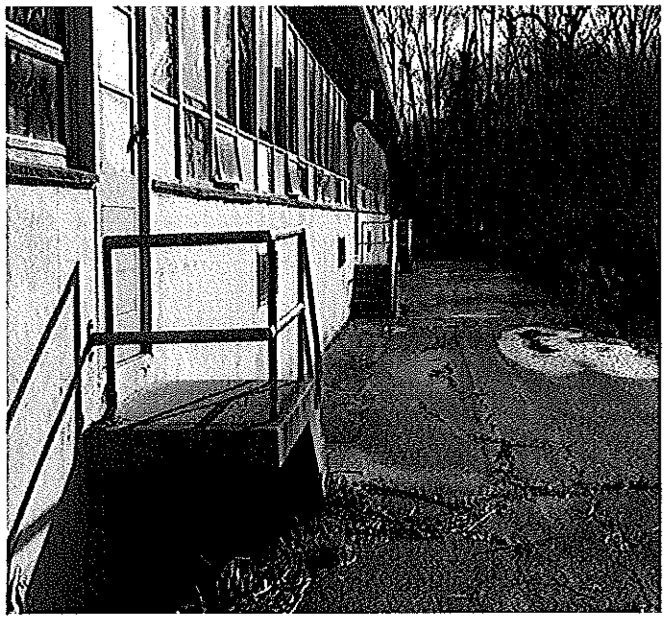
Depression in soil near footing to building
(note level of grass in foreground and lack of visibility of feet in background)

Picture 10



Crawlspace exhaust vent below staircase

Picture 11

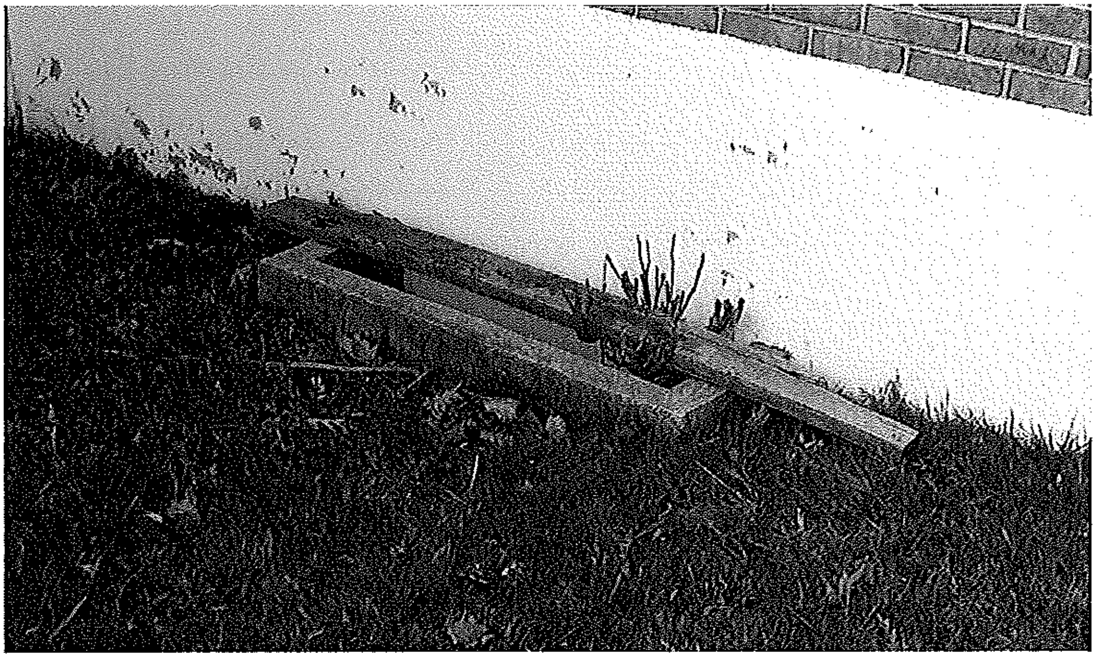


Crawlspace exhaust vents below staircases, note orientation of staircase 1 (foreground) and staircases 2 and 3 (background)

Picture 12

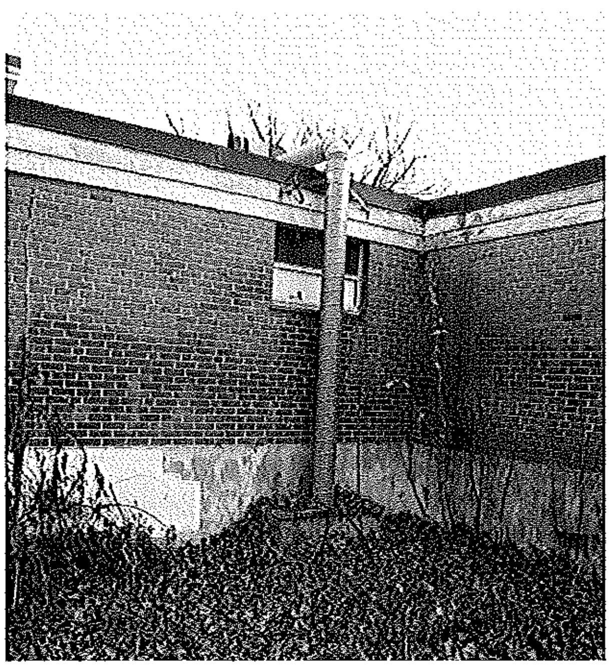
Sealed crawlspace vent near gymnasium

Picture 13



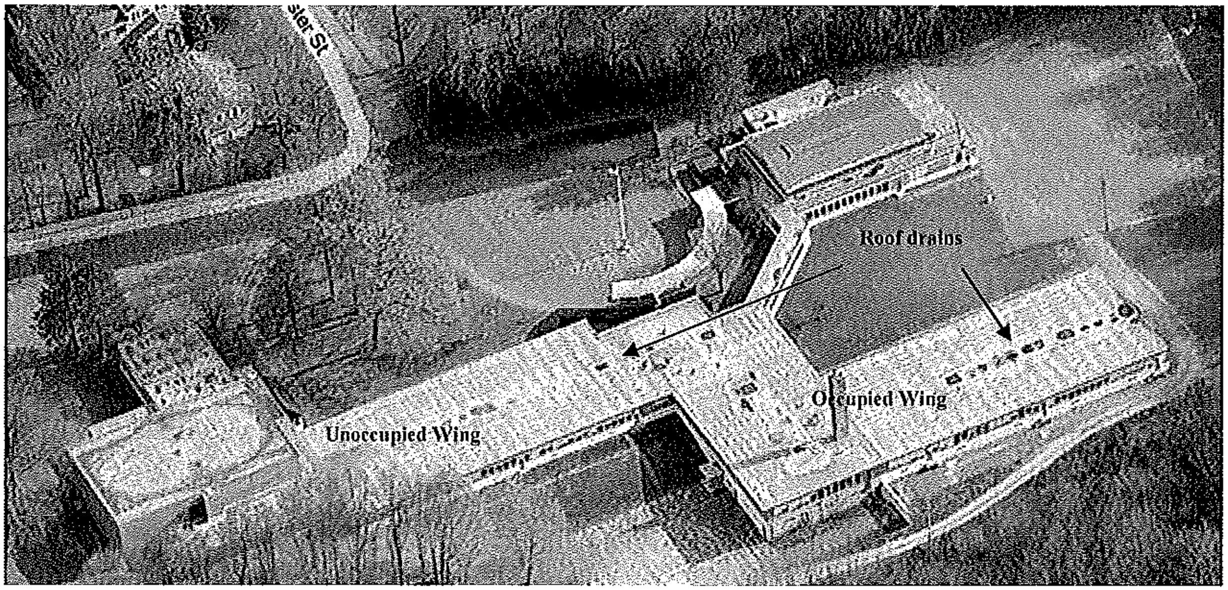
Sealed crawlspace vent near building entrance

Picture 14



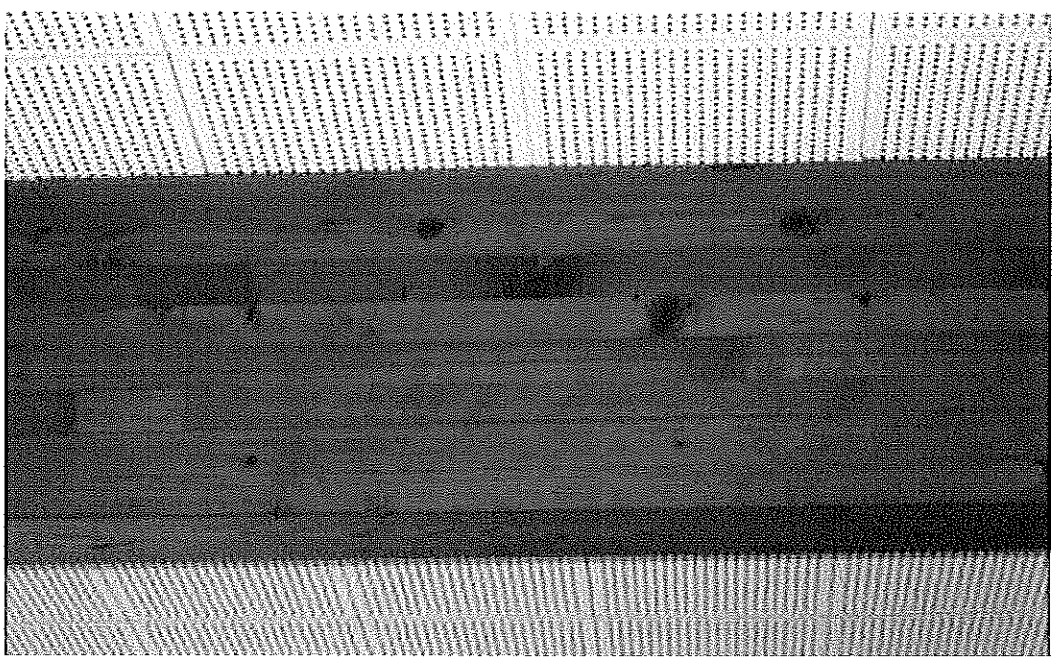
Ductwork connecting exhaust fan to passive vent

Picture 15



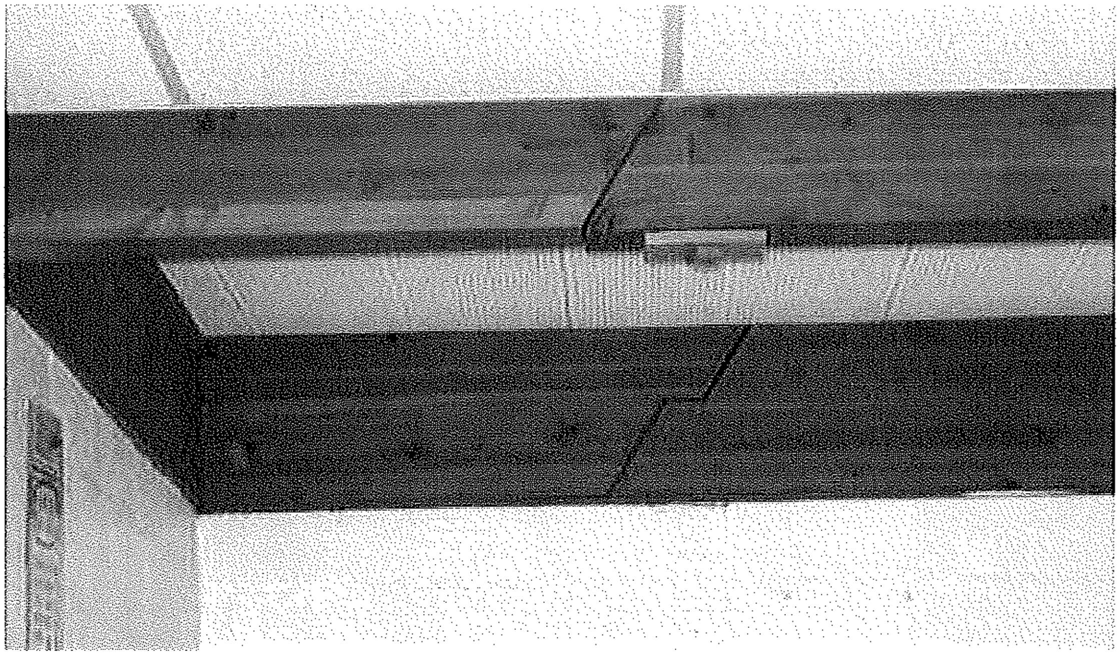
Roof drains located at the center of roof (i.e., along hallway) of each wing. A roof is typically pitched to move water towards the drain, indicating that the roof is convex. (Image source: Bing.com/Maps)

Picture 16



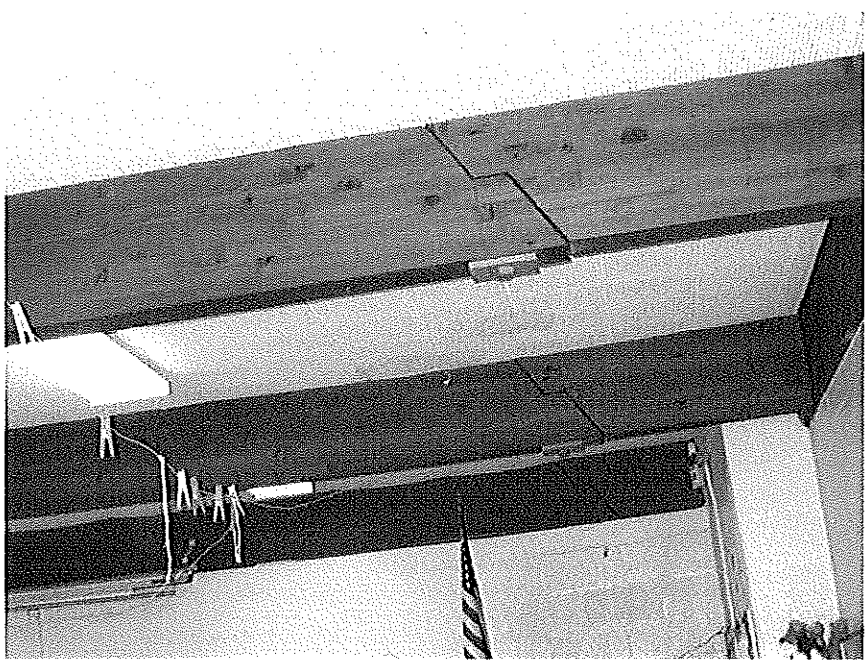
Eight layers of engineered wood glued together to form a laminated beam

Picture 17



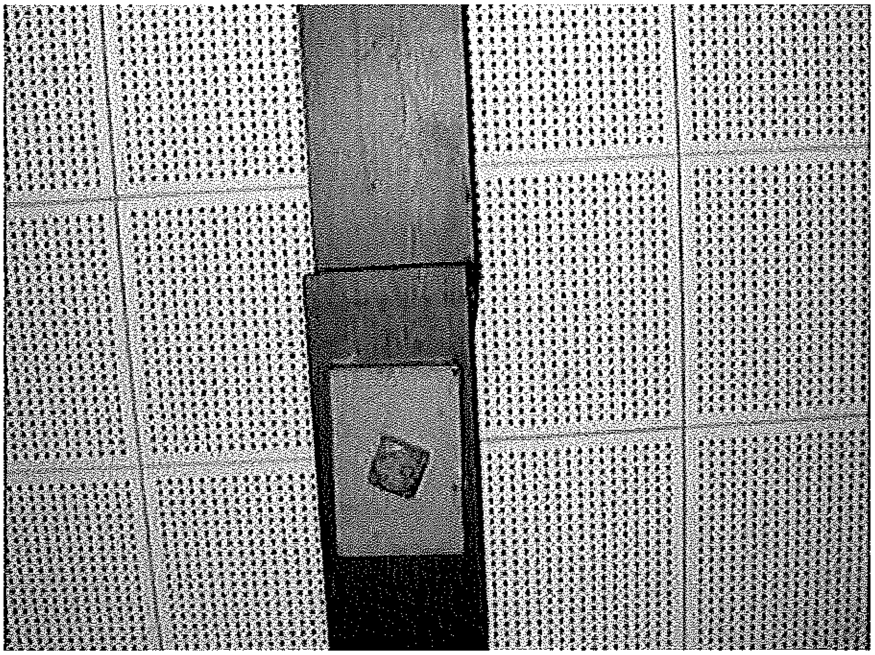
Wooden bolt joining hallway beam (left) to classroom beam (right)

Picture 18



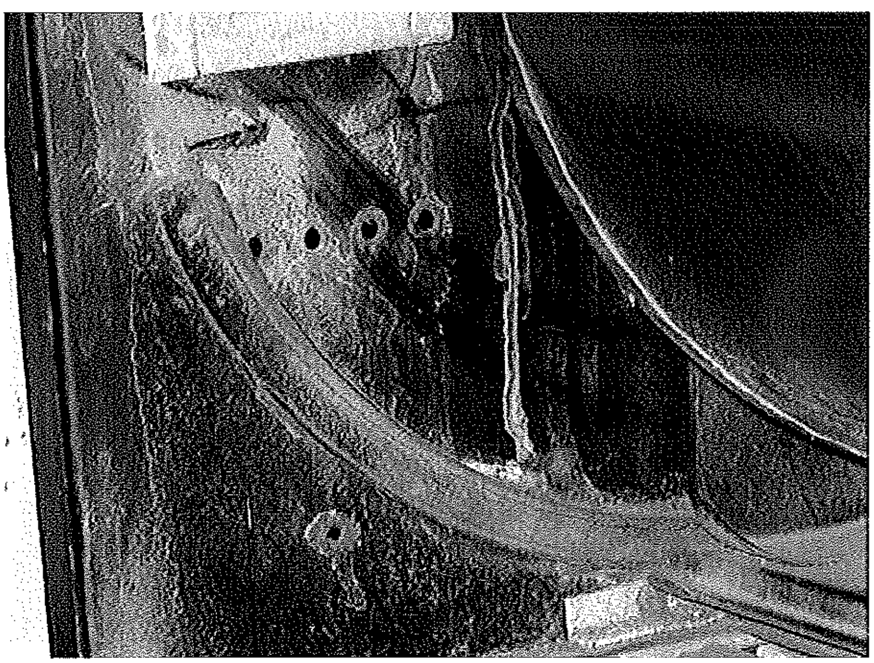
Vertical shift (downwards movement) creating space between two roof beams

Picture 19



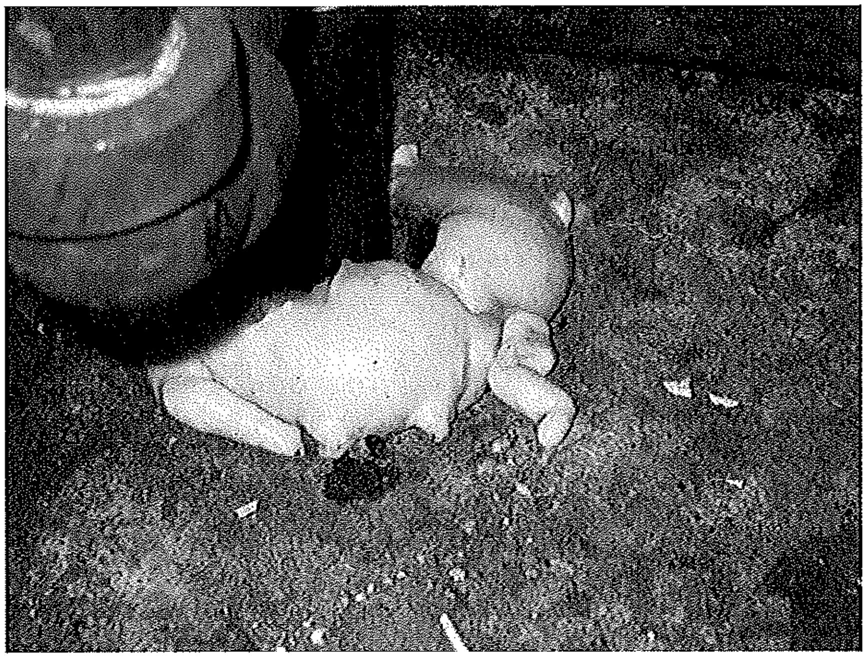
Horizontal shift (left and right movement) of roof beams

Picture 20



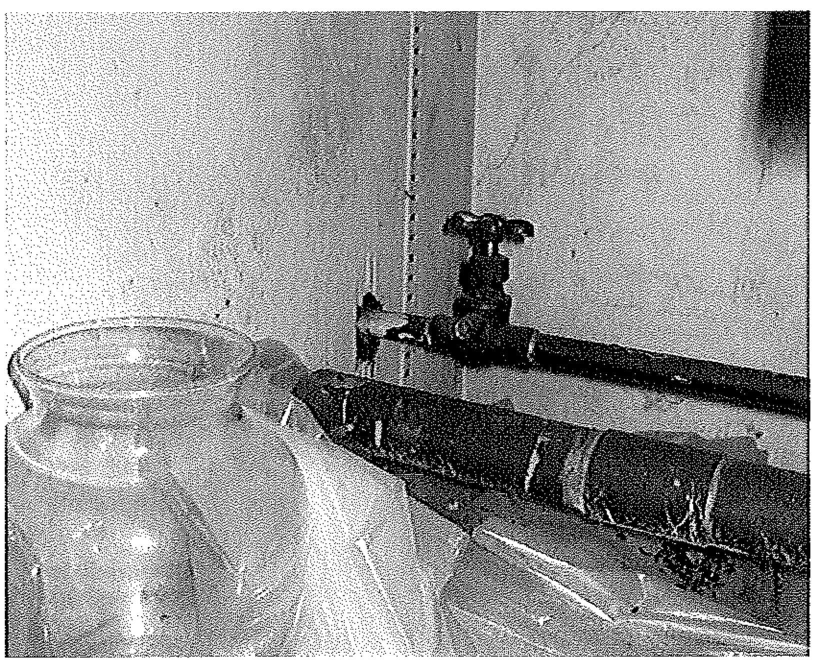
Holes in univent cabinet wall

Picture 21



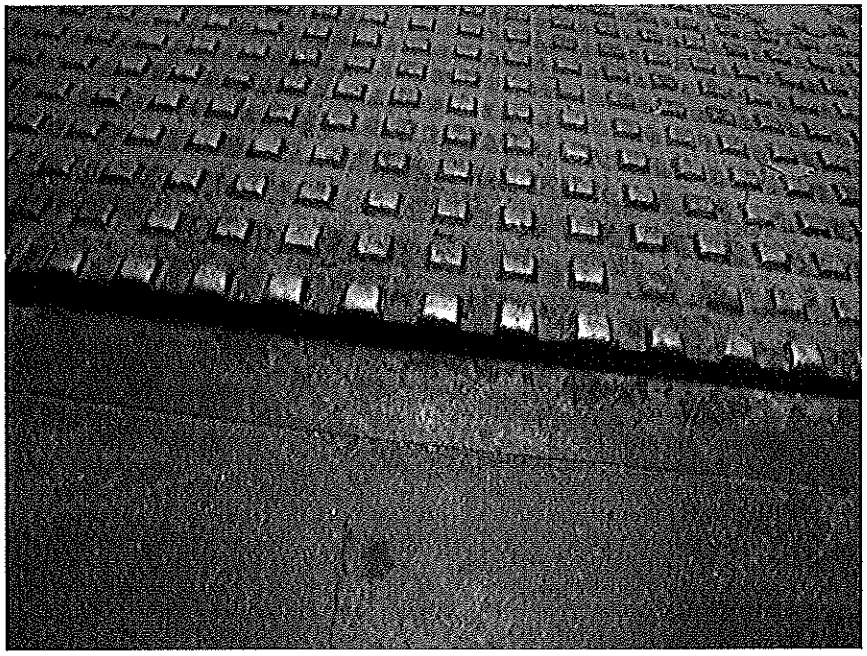
Space around pipe (with deteriorating old spray foam)

Picture 22



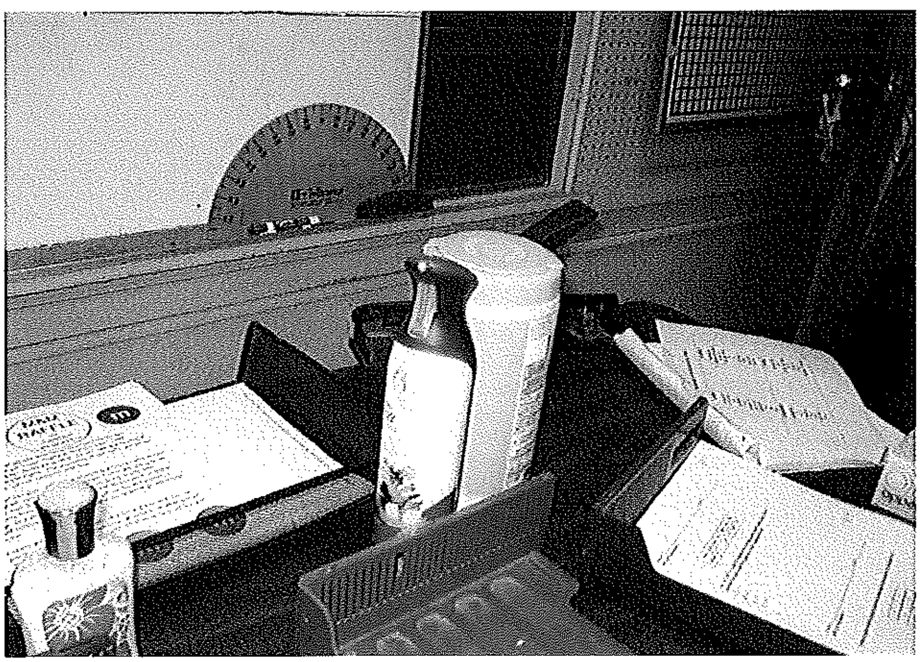
Space around sink pipe

Picture 23



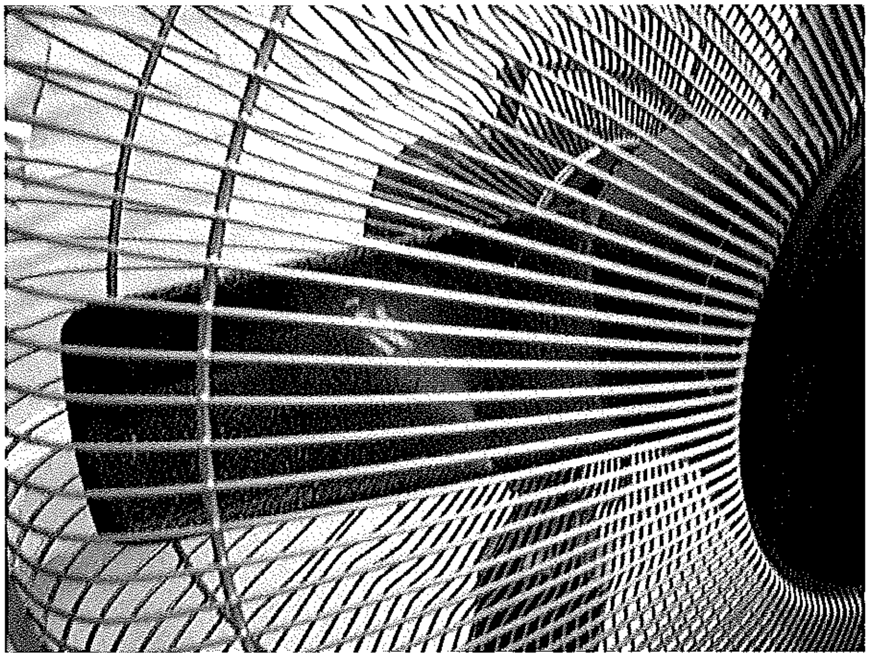
Crawlspace access not flush

Picture 24



Cleaning products and air deodorizers

Picture 25

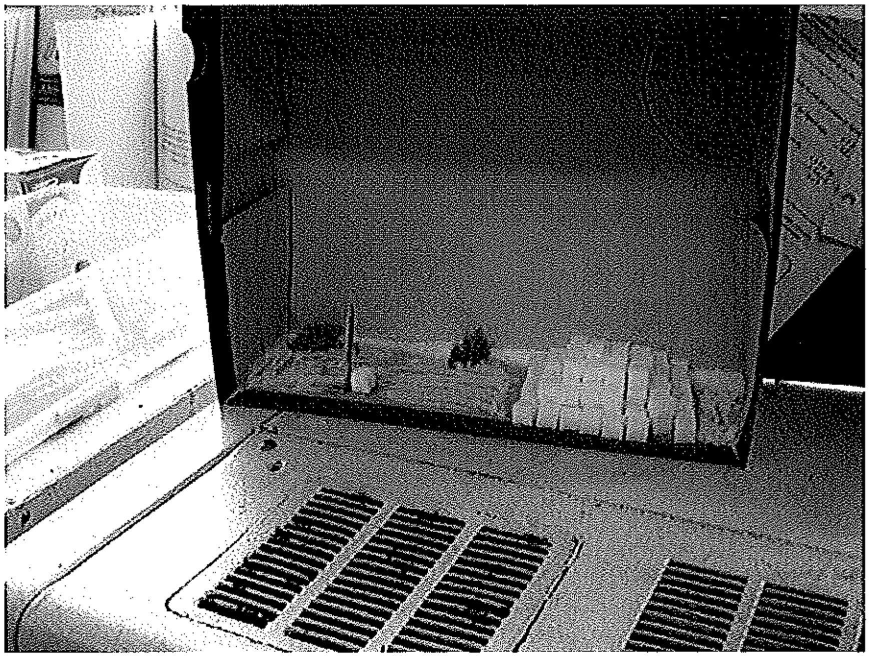


Dust on fan blade

Picture 26

Air-conditioner occluded with dust

Picture 27



Food as art; note placement on univent, which can distribute dried food particles throughout room

Location: Hunking Middle School

Address: 98 Winchester St. , Haverhill, MA

Table 1

Indoor Air Results

Date: 12-6-2011

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background/ Outdoors	349	ND	62	50	12					
Music	791	ND	78	48	7	2	Y	Y Off, items	N	DO, WD-CT, PF, DEM,
Platts	521	ND	78	46	6	1	Y 1/2 open	N	N	
Cafeteria	1025	ND	79	48	12	150	Y	Y	Y off	
Yes Program	676	ND	78	48	8	4	Y 1/2 open	N	N	PF/heater
Teacher's room	710	ND	74	42	6	6	Y	N	N	AC, AV equipment
178/guidance	790	ND	78	44	7	2	N	N	N	DO, inter-room DO
177/Nurse	536	ND	77	46	7	2	Y 1/2 open	N	N	
Copy room		ND					N	N	N	PC, 2 WD-CT, water staining on walls, inter-room DO
AV		ND	80	43	6		N	N	N	Crawlspace access - not flush, musty odors, DEM, stored items (CPs, toner/ink cartridges)

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect

AC = air conditioner
PF = personal fan
AP = air purifier

DO = door open
CPs = cleaning products
CT = ceiling tile

DEM = dry erase materials
PC = photocopier

WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: Hunking Middle School | **Indoor Air Results**

Address: 98 Winchester St., Haverhill, MA | **Table 1 (continued)** | **Date: 12-6-2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Office	713	ND	79	47	5	3	N	N	N	DO, CF, AP, CPs, WD-CTs
Gym	533	ND	76	45	11	80	N	Y	Y	Exterior DO
Obrien	523	ND	78	45	5	3	Y	Y	Y	Fridge, WD-CT
Art	851	ND	76	51	9	27	Y	N	N	APs, breaches in exterior DO
Vaughn	792	ND	76	49	7	1	Y	N	Y	Exhaust switch activated
Conference room	695	ND	78	40	8	1	Y	N	N	AC
Principal	482	ND	79	43	5	2	Y	N	N	CF, PF
Grade 8/164	764	ND	77	47	6	13	Y 1/2 open	N	N	AC, PF, DEM
Library/Room 5	671	ND	77	49	12	23	Y 4/8 open	Y Off	N	DEM, AC, CPs
51	530	ND	73	54	6	17	Y 2/6 open	Y Items, off	Y Off	Exterior DO, DEM
52	1096	ND	75	55	10	24	Y 1/4 open	Y Off	Y Off	DO, CPs, DEM, PF

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect

AC = air conditioner
PF = personal fan
AP = air purifier

DO = door open
CPs = cleaning products
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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (μg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
53	874	ND	75	53	8	25	Y 2/4 open	Y Off	Y Off	Exterior DO, DEM, CPs, plants, items
54	1499	ND	76	52	15	26	Y 2/4 open	Y Off, items	Y Off	DEM odors, sink breach, CPs, PF
55	912	ND	77	49	9	13	Y 2/4 open	Y Off, items	Y Off	CPs, AC, Dem, 2 WD-CT
56	666	ND	74	54	8	1	Y 2/4 open	Y Off	Y Off	Over 30 WD-CT, DEM
57	1109	ND	75	54	8	2	Y 2/4 open	Y Items, off	Y off	WD-CT, Dem, CPs, food art, AP
58	2069	ND	75	59	15	29	Y	Y Off	Y Off	DO, plants, AC, CPs
59	1259	ND	74	56	14	1	Y 2/4 open	Y Off	Y off	
60	2046	ND	74	58	13	21	Y	Y Off	Y Off	AC- dusty, plants, DEM
148	581	ND	76	48	6	17	Y 2/8 open	Y Off	N	Sink breach/WD-cabinet; CPs, DEM, WD-CTs, water staining on walls
150 Computer lab	580	ND	80	44	6	0	Y	N	Y	27 computers, PF, AC, exhaust-switch activated
174	532	ND	77	47	6	7	Y	N	N	CPs, DO, inter-room DO

ppm = parts per million
μg/m³ = micrograms per cubic meter
ND = non detect
AC = air conditioner
PF = personal fan
AP = air purifier
DO = door open
CPs = cleaning products
CT = ceiling tile
DEM = dry erase materials
PC = photocopier
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 (µg/m³)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
179	827	ND	78	37	5	0	Y	N	N	AC, CPs
196	839	ND	79	39	8	0	N	N	N	Sealed skylight, AP, water staining on walls

ppm = parts per million
µg/m³ = micrograms per cubic meter
ND = non detect
AC = air conditioner
PF = personal fan
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DO = door open
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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: Hunking Middle School **Indoor Air Results**

Address: 98 Winchester St., Haverhill, MA **Table 2** **Date: 12-16-2011**

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Background (Outdoors)	366	ND	52	30	1					
Mrs. Concannon	986	ND	73	33	2	9	Y	Y	N	
Computer	699	ND	73	30	5	0	Y	N	N	20 computers, floor fans
Mrs. Obrien	661	ND	74	24	1	0	Y	N	N	
Health	830	ND	74	30	2	2	Y	N	N	
Music Room	766	ND	75	28	4	7	Y	Y Off	Y Off	DO
Cafeteria	573	ND	75	28	2	0	Y	Y	Y	DO
Gym	388	ND	68	24	1	1	N	Y	Y	
Art room	480	ND	68	30	4	2	N	N	N	DO
Art classroom	869	ND	68	35	4	11	Y	N	N	
5	915	ND	75	28	6	10	Y Open	Y Off	N	

ppm = parts per million

$\mu g/m^3$ = micrograms per cubic meter

DO = door open

ND = non detect

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	Temp (°F)	Relative Humidity (%)	PM2.5 ($\mu g/m^3$)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Grade 8	1041	ND	75	30	6	6	Y	N	N	DO
44	2037	ND	72	38	4	24	Y	Y	Y Off	
51	1147	ND	70	32	4	27	Y	Y	Y Off, blocked	
52	1652	ND	70	36	4	23	Y	Y	Y Off	DO
53	1305	ND	70	33	4	21	Y	Y	Y Off	
54	1050	ND	70	31	3	27	Y	Y	Y Off	
56	1281	ND	71	34	4	17	Y	Y	Y Off	
57	1462	ND	71	35	4	26	Y	Y	Y Off, blocked	
58	1196	ND	71	32	3	18	Y	Y	Y Off	DO
59	1521	ND	70	35	6	15	Y	Y	Y Off	
60	1311	ND	70	36	2	30	Y	Y	Y Off	DO, Plants

ppm = parts per million

$\mu g/m^3$ = micrograms per cubic meter

DO = door open

ND = non detect

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Appendix A

Carbon Dioxide and its Use in Evaluating Adequacy of Ventilation in Buildings

The Bureau of Environmental Health's (BEH) Indoor Air Quality (IAQ) Program examines indoor air quality conditions that may have an effect on building occupants. The status of the ventilation system, potential moisture problems/microbial growth and identification of respiratory irritants are examined in detail, which are described in the attached report. In order to examine the function of the ventilation system, measurements for carbon dioxide, temperature and relative humidity are taken. Carbon dioxide measurements are commonly used to assess the adequacy of ventilation within an indoor environment.

Carbon dioxide is an odorless, colorless gas. It is found naturally in the environment and is produced in the respiration process of living beings. Another source of carbon dioxide is the burning of fossil fuels. Carbon dioxide concentration in the atmosphere is approximately 250-600 ppm (Beard, 1982; NIOSH, 1987).

Carbon dioxide measurements within an occupied building are a standard method used to gauge the adequacy of ventilation systems. Carbon dioxide is used in this process for a number of reasons. Any occupied building will have normally occurring environmental pollutants in its interior. Human beings produce waste heat, moisture and carbon dioxide as by-products of the respiration process. Equipment, plants, cleaning products or supplies normally found in any building can produce gases, vapors, fumes or dusts when in use. If a building has an adequately operating mechanical ventilation system, these normally occurring environmental pollutants will be diluted and removed from the interior of the building. The introduction of fresh air both increases the comfort of the occupants and serves to dilute normally occurring environmental pollutants.

An operating exhaust ventilation system physically removes air from a room and thereby removes environmental pollutants. The operation of supply in conjunction with the exhaust ventilation system creates airflow through a room, which increases the comfort of the occupants. If all or part of the ventilation system becomes non-functional, a build up of normally occurring environmental pollutants may occur, resulting in an increase in the discomfort of occupants.

The MDPH approach to resolving indoor air quality problems in schools and public buildings is generally two-fold: 1) improving ventilation to dilute and remove environmental pollutants and 2) reducing or eliminating exposure opportunities from materials that may be adversely affecting indoor air quality. In the case of an odor complaint of unknown origin, it is common for BEH staff to receive several descriptions from building occupants. A description of odor is subjective, based on the individual's life experiences and perception. Rather than test for a potential series of thousands of chemicals to identify the unknown material, carbon dioxide is used to judge the adequacy of airflow as it both dilutes and removes indoor air environmental pollutants.

As previously mentioned, carbon dioxide is used as a diagnostic tool to evaluate air exchange by building ventilation systems. The presence of increased levels of carbon dioxide in indoor air of buildings is attributed to occupancy. As individuals breathe, carbon dioxide is exhaled. The greater the number of occupants, the greater the amount of carbon dioxide produced. Carbon dioxide concentration build up in indoor environments is attributed to inefficient or non-functioning ventilation systems. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

Carbon dioxide can be a hazard within enclosed areas with **no air supply**. These types of enclosed areas are known as confined spaces. Manholes, mines and sewer systems are examples of confined spaces. An ordinary building is not considered a confined space. Carbon dioxide air exposure limits for employees and the general public have been established by a number of governmental health and industrial safety groups. Each of these standards of air concentrations is expressed in parts per million (ppm). *Table 1* is a listing of carbon dioxide air concentrations and related health effects and standards.

The MDPH uses a guideline of 800 ppm for publicly occupied buildings (Burge et al., 1990; Gold, 1992; Norback, 1990; OSHA, 1994; Redlich, 1997; Rosenstock, 1996; SMACNA, 1998). A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Several sources indicate that indoor air problems *are significantly reduced* at 600 ppm or less of carbon dioxide (ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH, 1987). Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Air levels for carbon dioxide that indicate that indoor air quality may be a problem have been established by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). Above 1,000 ppm of carbon dioxide, ASHRAE recommends adjustment of the building's ventilation system (ASHRAE, 1989). In 2001, ASHRAE modified their standard to indicate that no more than 700 ppm above the outdoor air concentration; however 800 ppm is the level where further investigation will occur.

Carbon dioxide itself has no acute (short-term) health effects associated with low level exposure (below 5,000 ppm). The main effect of carbon dioxide involves its ability to displace oxygen for the air in a confined space. As oxygen is inhaled, carbon dioxide levels build up in the confined space, with a decrease in oxygen content in the available air. This displacement of oxygen makes carbon dioxide a simple asphyxiant. At carbon dioxide levels of 30,000 ppm, severe headaches, diffuse sweating, and labored breathing have been reported. No **chronic** health effects are reported at air levels below 5,000 ppm.

Air testing is one method used to determine whether carbon dioxide levels exceed the comfort levels recommended. If carbon dioxide levels are over 800-1,000 ppm, the MDPH recommends adjustment of the building's ventilation system. The MDPH recommends that corrective measures be taken at levels above 800 ppm of carbon dioxide in office buildings or schools. (Please note that carbon dioxide levels measured below 800 ppm may not decrease indoor air quality complaints). Sources of environmental pollutants indoors can often induce symptoms in exposed individuals regardless of the adequacy of the ventilation system. As an example, an idling bus outside a building may have minimal effect on carbon dioxide levels, but can be a source of carbon monoxide, particulates and odors via the ventilation system.

Therefore, the MDPH strategy of adequate ventilation coupled with pollutant source reduction/removal serves to improve indoor air quality in a building. Please note that each table included in the IAQ assessment lists BEH comfort levels for carbon dioxide levels at the bottom (i.e. carbon dioxide levels between 600 ppm to 800 ppm are acceptable and <600 ppm is preferable). While carbon dioxide levels are important, focusing on these air measurements in isolation to all other recommendations is a misinterpretation of the recommendations made in these assessments.

Table 1: Carbon Dioxide Air Level Standards

Carbon Dioxide Level	Health Effects	Standards or Use of Concentration	Reference
250-600 ppm	None	Concentrations in ambient air	Beard, R.R., 1982 NIOSH, 1987
600 ppm	None	Most indoor air complaints eliminated, used as reference for air exchange for protection of children	ACGIH, 1998; Bright et al., 1992; Hill, 1992; NIOSH 1987
800 ppm	None	Used as an indicator of ventilation inadequacy in schools and public buildings, used as reference for air exchange for protection of children	Mendler, 2003 Bell, A. A., 2000; NCOSP, 1998; SMACNA, 1998; EA, 1997; Redlich, 1997; Rosenstock, 1996; OSHA, 1994; Gold, 1992; Burge et al., 1990; Norback, 1990 ; IDPH, Unknown
1000 ppm	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1989
950-1300 ppm*	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 1999
700 ppm (over background)	None	Used as an indicator of ventilation inadequacy concerning removal of odors from the interior of building.	ASHRAE, 2001
5000 ppm	No acute (short term) or chronic (long-term) health effects	Permissible Exposure Limit/Threshold Limit Value	ACGIH, 1999 OSHA, 1997
30,000 ppm	Severe headaches, diffuse sweating, and labored breathing	Short-term Exposure Limit	ACGIH, 1999 ACGIH. 1986

* outdoor carbon dioxide measurement +700 ppm

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Appendix B

Skin Irritation, Dryness, Redness or Rashes

Response	Number	Percent
Yes	12	44%
No	15	56%
Total	27	100%

Difficulty Remembering Things or Concentrating

Response	Number	Percent
Yes	10	37%
No	17	63%
Total	27	100%

Itchy, Runny or Watery Eyes

Response	Number	Percent
Yes	15	56%
No	12	44%
Total	27	100%

Nausea or Upset Stomach

Response	Number	Percent
Yes	5	19%
No	22	81%
Total	27	100%

Stuffy or Runny Nose and Sinus congestion not related to an Infection

Response	Number	Percent
Yes	16	59%
No	11	41%
Total	27	100%

Unusual Tiredness, Fatigue or Drowsiness

Response	Number	Percent
Yes	18	67%
No	9	33%
Total	27	100%

Pain or Stiffness in your Neck, Shoulders or Back

Response	Number	Percent
Yes	10	37%
No	17	63%
Total	27	100%

Wheezing in your Chest

Response	Number	Percent
Yes	10	37%
No	17	63%
Total	27	100%

Sore, Hoarse or Dry Throat

Response	Number	Percent
Yes	18	67%
No	9	33%
Total	27	100%

Tightness in your Chest

Response	Number	Percent
Yes	8	30%
No	19	70%
Total	27	100%

Tingling in the Hands and Feet

Response	Number	Percent
Yes	2	7%
No	25	93%
Total	27	100%

Coughing

Response	Number	Percent
Yes	15	56%
No	12	44%
Total	27	100%

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Appendix C

Commonwealth of Massachusetts
Department of Public Health
Helping People Lead Healthy Lives In Healthy Communities

BUREAU OF ENVIRONMENTAL HEALTH

Indoor Air Quality Program

Methods Used to Reduce/Prevent Exposure to Construction/Renovation Generated Pollutants in Occupied Buildings

November 2006

Among the most serious indoor air quality health issues is the potential exposure to construction/renovation-generated pollutants in occupied buildings. The renovation of occupied buildings provides a number of potential exposure opportunities to pollutants. Demolition of the building materials can provide exposure to mold, asbestos, lead, bird waste and other respiratory irritants. The application of tile adhesive, roofing materials, paints and other products used during renovations provide point sources of volatile organic compounds (VOCs) and other irritating chemicals. Contractors frequently use fossil fueled construction and heating equipment in indoor areas undergoing renovations. Combustion products (e.g. carbon monoxide) can migrate into occupied areas. The impact of construction/renovation pollutants on occupied areas can be evaluated through air monitoring for VOCs, airborne particles and products of combustion. Preventing and/or minimizing exposure to construction/renovation-generated pollutants is essential to reduce indoor air-related symptoms in building occupants.

In 1999, the State Department of Education (DOE) amended their regulations to require that state funded construction projects follow established guidelines to prevent exposure of building occupants to construction/renovation pollutants. Subsequently, Chapter 208 of the Acts of 2004 transferred responsibility for the School Building Assistance Program from the DOE to the Massachusetts School Building Authority (MSBA). On September 6, 2006, the MSBA enacted regulations that require that schools receiving funds under the program for construction or renovation projects must confer with the most current edition of the "IAQ Guidelines for Occupied Buildings Under Construction" published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA) 963 CMR 2.04(2)(c),(d).

The MDPH has prepared this guidance in order to prevent/reduce the migration of renovation-generated pollutants into occupied areas and their potential impact on indoor air quality. The MDPH suggests that the following steps be taken on any renovation project within a public building.

Physical Isolation of Occupied Areas from Renovation Areas

Renovations of buildings should be separated from occupied areas by constructing temporary