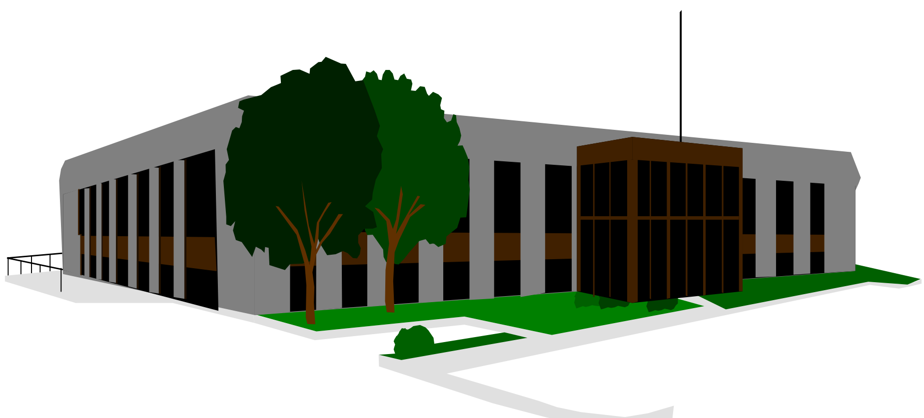
INDOOR AIR QUALITY ASSESSMENT

Holland Elementary School
28 Sturbridge Road
Holland, Massachusetts



Prepared by:
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Bureau of Environmental Health Assessment
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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Holland Elementary School (the school), 28 Sturbridge Road, Holland, Massachusetts. Concerns about indoor air quality and perceived increases in the incidence of symptoms prompted this report. On May 1, 2001, the school was visited by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air assessment.

The school was built in 1947 as a wood frame structure (see Picture 1). A wood frame addition was constructed at the rear of the original building during the 1960s (see Picture 2). A brick and steel frame addition was added to the east wall of the 1960s addition in 1975 (see Picture 3). The school contains general classrooms, library, gymnasium/cafeteria, and various offices. Classroom windows are openable. The 1947 and 1960s wings underwent renovations to render these sections energy efficient, but the date of these renovations was not available. The original siding on the 1947 and 1960s wings was replaced with vinyl siding. It also appears that the original window frames were replaced with energy efficient models. The air volume of each classroom in each of these wings was reduced by the installation of a suspended ceiling. Reducing classroom volume decreases the energy needed to heat an area.

A number of private consultants and government agencies have conducted indoor air quality assessments within this school. The Division of Occupational Hygiene (DOH) recommended that fresh air supply for the ventilation system in the old sections of the building (1947 and 1960’s) be provided or that windows and doors be opened to provide fresh air until the installation of a new ventilation system could be secured (MDLI, 1983). Ten years later, DOH made recommendations concerning roof leaks. DOH recommended the roof be repaired, water damaged ceiling tiles be discarded and all unit ventilator filters be replaced (MDLI, 1994). A consulting company (Mystic Air Quality Consultants, Inc.) was also contracted to conduct an indoor air quality assessment. The consultant recommended that 1) the exhaust ventilation system be evaluated for function, 2) use windows and portable fans to increase air circulation; 3) repair water leaks and 4) replace water damaged ceiling tiles (MAQCI, 1997). The consultant conducted further air testing on October 4, 2000. As a result of the air testing the consultant recommended: 1) reduce moisture/increase ventilation on crawlspace beneath older sections of the building to control musty odors; 2) replace water damaged carpet; 3) use a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner; 3) clean all non-porous surfaces with a biocide; 4) clean the interiors of unit ventilators (univents); 5) remove shrubbery from close proximity of fresh air intakes; 6) remove vinyl siding covering univent fresh air intakes; 7) remove blockage of univents fresh air diffusers; 8) repair exhaust vents; and clean exhaust vent grilles (MAQCI, 2000) A scope of work (NEMSI, 2000) and cost estimate (NEMSI, 2001) were submitted for repair of the ventilation system.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

This school has a student population of 290 and a staff of approximately 35. Tests were taken during normal operations at the school. Test results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 ppm (parts per million) in fourteen out of twenty one areas surveyed, which indicates an overall ventilation problem in this school. Of particular note was room 113, which had a carbon dioxide measurement of greater than 2000 ppm, indicating little or no air exchange. Fresh air in classrooms throughout the building was *originally* provided by unit ventilators (univents) (see Figure 1, Picture 4). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and draw return air through an air intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and heating coil and is then expelled from the univent by motorized fans through fresh air diffusers. For ease of discussion, comments concerning the ventilation system are divided by wing within the building (e.g., 1947, 1960s and 1974).

1947 wing

Ventilation in this section of the building was altered by reconfiguration of the original cafeteria/auditorium into a classroom and library as well as by the installation of vinyl siding on the exterior of this wing. Univent fresh air intakes for the rooms in the front of this wing were enclosed beneath the vinyl siding exterior (see Picture 5). Fresh air intakes for the library and classroom 106 were sealed with plywood (see Picture 6). Therefore, no fresh air can be provided for the areas using univents. Operation of univents would only serve as a radiant heat source. As univents operate, normally occurring indoor air pollutants would be entrained by each univent and reaerosolized, which can lead to pollutant build up. Sources of odors in each area would not be diluted and could be allowed to concentrate. Each room in this wing (with the exception of room 106) has exhaust vents. The exhaust vents were either drawing weekly or were blocked by boxes and other obstructions. The means to provide exhaust ventilation (either mechanically using fans or using rising, heated air) could not be determined, but are likely within cupolas located on the roof (see Picture 7). Since it appears that renovations to render this wing energy efficient were made, exhaust vents to the roof could either be blocked or deactivated in a manner similar to the univents. Roof exhaust vents were not examined because of difficulties in access to the peaked roof. Therefore, the sole means to creating airflow in this wing is through open windows. Rooms 105 (library) and 106 appear to be a former cafeteria/auditorium, which has been divided. Exhaust vents that serviced the entire original cafeteria/auditorium exist along the floor on the right side of the stage. The installation of the wall creating room 106 and the library separates room 106 from these exhaust vents. As configured, no means (with the exception of a single restroom exhaust vent) exists to provide exhaust ventilation for this room.

During summer months, ventilation in the school is controlled by the use of openable windows in classrooms. This section was configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. The hinged windows (called transoms) enable classroom occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open classroom transom, into the opposing classroom and finally exits the building on the leeward side (opposite the windward side) (see Figure 2). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or transoms are closed (see Figure 3). Most transoms in this wing were closed.

1960s wing

Fresh air is supplied by univents with open fresh air intakes that were installed through the vinyl siding (see Picture 8). Univents were deactivated. Exhaust ventilation is provided by ceiling mounted exhaust grilles. These exhaust vent grilles appear to be connected by ductwork to two exhaust vent fans on the roof (see Picture 9). Exhaust vents of this configuration typically are mechanical.

Roof exhaust vents were not examined because of difficulties in access to the peaked roof.

1975 Wing

Fresh air in these classrooms is supplied by a univent system. Obstructions to airflow, such as tables and boxes were seen in a number of classrooms. To function as designed, univents and univent returns must remain free of obstructions. More importantly, these units must be activated and allowed to operate. Exhaust ventilation in classrooms is provided by a mechanical exhaust system. The exhaust vents are located in the upper portions of coat closets in classrooms (see Picture 10). Classroom air is drawn over a shelf. This design allows for these vents to be easily blocked by stored materials on shelves beneath the exhaust vent. In a number of classrooms, these vents were blocked with books, book bags, boxes and other obstructions. Exhaust vents on the roof were deactivated and in one instance, disassembled (see Picture 11). A combination of restriction on fresh air intake by univents and deactivation of exhaust vents can serve to both restrict airflow and lead to accumulation of environmental pollutants.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, 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. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (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 design 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 Department of Public Health 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.

The BEHA recommends that indoor air temperatures be maintained in a range between 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. Temperature readings measured in the school ranged from 75^{o} F to 80^{o} F, exceeding the BEHA recommended range in several areas. This increase in temperature is most likely due to the energy conservation renovations and deactivation of the ventilation system as previously described. 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.

The relative humidity in all areas of the building ranged from 31 to 41 percent, which, for the most part, is below the BEHA recommended comfort range. Please note that the BEHA recommends a range of 40-60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. It is important to stress however, that relative humidity measured indoors exceeded outdoor measurements (range +11-21 percent). This increase in relative humidity can indicate that the exhaust system is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, individuals are more comfortable. Removal of moisture from the air, however, can also have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Concerns about musty odors and mold in the 1947 and 1960s wings are well documented. In response to concerns, ceiling tiles had previously been replaced in a number of areas and bioaerosol sampling was conducted. The consultant determined that "[a]ll Bioaerosols samples exhibited above normal growth for indoor environments. Indoor levels were above the comparable level outside) in response to acceptable growth" (MAQCI, 2000).

During the course of this assessment, BEHA staff did *not* detect musty/mold odors in any areas of this building. The 1947 and 1960s wing are built over a crawlspace. The floor of the crawlspace beneath the classrooms is dirt (see Picture 12). One passive air vent is located on the west foundation wall at ground level. This wing is covered with a peaked, shingled roof. It did not appear that the edges of either side of the roof were outfitted with rain gutters or downspouts (see Pictures 13 and 14). As a result, rainwater runs off the roof onto the ground at the base of the building. Over the years, this runoff has created a trench parallel to the base of the wall, which allowed rainwater and melting snow to pool against the foundation and the exterior wall of this wing. Pooling rainwater has accumulated in this area and has entered into the building through the crawlspace passive air vent. Several entrances to the crawlspace are located in these wings. A slight, musty odor was noted emanating from the crawlspace upon removal of a floor plug. A number of materials observed in the crawlspace can support mold growth, including its dirt floor (see Picture 12). It appears that no vapor barrier was installed on the wing floor. Air pathways from the crawlspace exist in both the 1947 and 1960s wings. Floor plug access doors and holes through the floor for plumbing and univents have spaces that can allow air and pollutants to migrate from the crawlspace into occupied areas. Elimination of these pathways would prevent musty odors reported in these wings.

There are a number of areas within the building that show signs of water-damage. Water penetration into the interior of a building can be a hallmark of potential microbial growth. As reported previously, water was noted on the interior of crawlspace walls. With increased moisture, materials in the crawlspace can serve as medium for mold growth. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that water damaged materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If moistened materials are not dried within this time frame, mold growth may occur.

The crawlspace is an unconditioned space. Air in the crawlspace will be colder than the rooms above, which can result in drafts from the crawlspace rising into the occupied spaces of the new wing through spaces in the floor and wall cavities. As airflow is created, odors and particulate matter from the crawlspace can accompany drafts into occupied spaces. It should also be noted that the floor plug is not airtight and also lacks a vapor barrier. Any seams in floor boards, exterior wall cavities, or holes in the floor for utilities can serve as pathways for air, mold spores and associated materials to move from the crawlspace into occupied areas in the newer wing. Certain individuals can be sensitive to mold exposure, which can result in irritation for the eyes, nose, throat or the respiratory system.

The 1947 and 1960s wings also have experienced significant water damage to ceiling tiles. This water damage can be attributed to the chronic development of ice dams on the roof of these wings. School personnel confirmed that ice dams are re-occurring problems. Ice dams occur when snow in contact with the roof melts to form water on the upper section of the roof which is then refrozen on the lower portion of the roof to form ice. The source of the heat is from the roof that is incidentally heated by air from the occupied spaces. The heated air gathers in the peak of the roof, which warms the roofing material above water's melting point (32^{o} F). As water rolls down the sloped roof, it freezes into ice when it come into contact with roof materials on the lower section of the roof that are below 32^{o} F. This ice creates a dam, which then collects and holds melting snow or rainwater against the roof shingles. Pooling water can then penetrate through the roof materials via cracks and crevices, resulting in wetting of the interior of the building. In order to prevent ice dams, a combination of methods are used. The floor of the attic space is insulated to prevent air movement and heat loss from the occupied space. Ridge vents (installed along the roof ridge) are installed to allow for free exhaust of heat from the attic space. Soffit vents (located beneath the eave in the roof) provide a source of cold outdoor air to replace the heated air that escapes through the ridge vent. This configuration allows for heat to escape so that the attic space has a temperature that is roughly equal to the outdoor temperature, so that the roof materials do not melt snow in contact with the roof. If attic insulation is inadequate, or ridge vents/soffit vents are sealed, then heat can accumulate in the roof peak and start the ice dam creation cycle. In this building, all existing soffit vents in the roof were sealed during the installation of the vinyl siding (see Picture 15). By cutting off the free flow of air through soffit vents, the draw of air from occupied areas through cracks and crevices in ceilings and walls can be increased, resulting in more heated air penetrating into the attic space. Another confounding problem is moistening of insulation resulting from these ice dams. The ability of insulation to prevent temperature transfer is decreased if the material becomes moistened. The loss of temperature control can result in more heat transfer into the attic space, creating larger ice dams and more water penetration. Water damaged ceiling tiles can be a mold growth medium. The conditions contributing to the creation of the ice dams should be corrected to prevent moisture problems.

Several classrooms have sinks that have a seam between the countertop and wall. Water penetration through this seam can result if not watertight. Water can penetrate the countertop seam and collect behind this board. Water penetration and chronic exposure to water on wood and plywood can cause these materials to swell and serve as a growth medium for mold.

Several classrooms contained a number of plants that are located over univent fresh air diffusers. Plant soil, standing water and drip pans can be potential sources of mold growth. Drip pans should be inspected periodically for mold growth and over watering should be avoided.

Other Concerns

Filters installed in univents provide minimal respirable dust filtration. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase of filtration, univents should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

Of note is the use of different volatile organic compound containing products in the building. The following materials were found in classrooms:

Lubricants-One classroom contained a spray can of WD-40®. This product contains aliphatic hydrocarbon distillates and petroleum based oils. The material safety data sheet indicates that irritation of the eyes, skin and upper respiratory system can occur if exposed to this product (WD 40 Company, 2001).

Permanent markers - Permanent markers can contain toluene (depending on the brand), which can be irritating to the eyes, nose and throat. Lack of ventilation can lead to an increase in perceived odors from these materials.

Dry Erase markers-Some classrooms contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Under the Labeling of Hazardous Art Materials Act (LHAMA), art supplies containing hazardous materials that can cause chronic health effects must be labeled as required by federal law (USC, 1988). The use of art supplies containing hazardous materials that can cause chronic health effects should be limited to times when students are not present and only when adequate exhaust ventilation is available. Other hazardous materials should not be used in classrooms during school hours or when children are present.

Also of note were the amount of materials stored inside classrooms. In classrooms throughout the school, items were seen piled on windowsills, tabletops, counters, bookcases and desks. The large amount of items stored in classrooms provides a means for dusts, dirt and other potential respiratory irritants to accumulate. Items stored in this manner, (e.g., papers, folders, boxes, etc.) make it difficult for custodial staff to clean around these areas. Dust can be irritating to the eyes, nose and respiratory tract. These items should be relocated and/or cleaned periodically to avoid excessive dust build up.

An emergency light was observed in the general library wing hallway (see Picture 16). A battery that requires periodic refilling to maintain its charge powers this emergency light. The battery solution would be expected to be a dilute sulfuric acid solution. This mixture evaporates over time and can form a vapor of sulfuric acid and water. Dilute sulfuric acid can be irritating to the eyes, nose and throat.

The library/room 106 univents sealed fresh air intakes are located next to a parking area. If these fresh air intakes are restored, vehicle exhaust can be entrained by the univents and distributed into these areas.

Natural rubber latex gloves were observed in use in the school (see Picture 17). The use of latex gloves aerosolizes proteins that are in glove powder. It is recommended that workers be provided with nonlatex gloves where there is little potential for contact with infectious materials (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix A.

Room 106 contained a guinea pig. The guinea pig cage contained wood shavings and accumulations of guinea pig wastes. Porous materials (i.e., wood shavings) can absorb animal wastes and can be a reservoir for mold and bacterial growth. Animal dander, fur and wastes can all be sources of respiratory irritants. Animals and animal cages should be cleaned regularly to avoid the aerosolization of allergenic materials and/or odors.

Conclusions/Recommendations

The indoor air quality conditions observed in the Holland Elementary School are somewhat complicated. The installation of the vinyl siding to the exterior of the 1947 and 1960s wings has created a number of problems. The sealing of soffit vents and removal of gutters and downspouts along the 1947 and 1960s addition have created conditions that contribute to water penetration through the roof as well as into the crawlspace. The reconfiguration of rooms, deactivation of exhaust vents and sealing of fresh air intakes have eliminated the means to both dilute and remove environmental pollutants from the 1947 and 1960s wings, with the exception of opening windows. The addition of vinyl siding and energy efficient windows have reduced/eliminated incidental airflow (infiltration and exfiltration), which renders opening of windows as the sole option for providing air to these wings. Therefore, conditions of minimized airflow by the ventilation system coupled with the existence of sources of microbial growth negatively influence indoor air quality in this section of the building. The deactivation/minimal operation of the 1975 wing ventilation system also serves to further degrade indoor air quality.

In order to address the conditions decribed in this report, recommendations to improve indoor air quality are divided into short-term and long-term corrective measures. The short-term recommendations can be implemented as soon as possible. Long-term solution measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns within this school.

In view of the findings at the time of the visit, the following short term recommendations are made:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Operate univents while classrooms are occupied. Check fresh air intakes for repair and increase the percentage of fresh air intake if necessary.
2. Repair exhaust vent fan motors. Operate exhaust vents during school hours.
3. Remove all blockages from univents and exhaust vents to facilitate airflow. Clear a three-foot space around all exhaust vents where feasible and reduce stored materials in classroom closets such that airflow is not impeded. Exhaust ventilation is necessary to remove pollutants from the interior of classrooms. If exhaust ventilation cannot be run continuously, adjust exhaust unit ventilator to have exhaust run to the extent that the equipment will allow.
4. Replace univent filters as per the manufacturer's instructions for all univents and air handling equipment.
5. Once fresh air supply is increased, the ventilation system should be balanced.
6. Examine building structural materials beneath the newer wing floor for mold colonization. Examine floorboards and joists for mold growth and disinfect with an appropriate antimicrobial. Remove debris from the floor of the newer wing crawlspace.
7. All wall and floor holes for building utilities should be rendered airtight. Install weather-stripping along the seam of all floor plug access doors in floors.
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. Increased dust control in the school would serve to reduce the number of airborne irritants. If acquisition of an HEPA filter equipped vacuum cleaner is not feasible, use a water soluble, odorless mop treatment to prevent the introduction of volatile organic solvents into the school. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

9. Move plants away from univents in classrooms. Examine drip pans for mold growth and disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants in certain areas.
10. Store chemicals and cleaning products properly.
11. Acquire current Material Safety Data Sheets for all products that contain hazardous materials and are used within the building, including office supplies, in conformance with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).
12. Consider replacing art and school supplies containing materials that require labeling under the Labeling of Hazardous Art Materials Act (LHAMA), with water-based materials to reduce VOCs in classrooms.
13. Remove materials blocking the fresh air diffusers or return vents of univents. Univents must remain clear of obstructions in order for the equipment to function properly.
14. Replace any remaining water-stained ceiling tiles and wall plaster. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.

15. Consider replacing the countertop over water-damaged cabinets. Consider using molded countertops to minimize seams where water and dirt can accumulate, thereby decreasing the chance of mold growth.
16. Replace latex gloves with nonlatex materials where appropriate.
17. Clean animal cages and change lining material on a regular basis.

The following long-term measures should be considered. A ventilation engineer should be consulted to resolve air supply/exhaust ventilation issues building-wide.

1. Consider installing a gutter/downspout system on the edge of the 1947 and 1960 wings' peaked roofs to direct water away from the base of each wing and its crawlspace vents. The installation of a drainage system may also be necessary to direct water away from the base of the foundation.
2. Restoration of the soffit vents sealed by the installation of the vinyl siding should be considered to remedy chronic creation of ice dams. The insulation in the crawlspace that has become moistened should be replaced with fresh insulation of a sufficient R-value that will prevent heat loss. Each ridge vent should be examined and repaired if necessary. Please note that any restoration effort must render the vinyl siding installation intact to prevent water penetration between the exterior siding and the original siding. Water accumulation behind vinyl siding can result in mold growth in building materials.
3. Consult a building engineer concerning the most appropriate method to provide active mechanical exhaust ventilation to place the crawlspace under negative pressure. Placing the crawlspace under negative pressure will reverse air penetration into occupied spaces. Please note that a crawlspace exhaust vent should not expel crawlspace air near univent fresh air intakes.

4. Consider consulting a building engineer to determine the most appropriate method to insulate and install a vapor barrier for the wing floor.
5. Consult a ventilation engineer to determine whether deactivated univents in the 1947 and 1960s wings can be repaired and restored to provide fresh air for classrooms. If not feasible, replacing the nonfunctioning univents should be considered.
6. Restore the fresh air intakes for the univents that were sealed by the vinyl siding installation after determining the feasibility of restoring the function of univents.
7. Examine the feasibility of providing exhaust ventilation for room 106.
8. Prohibit parking outside library/room 106 after fresh air intakes are restored to prevent vehicle exhaust entrainment.

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Figure 2 **Cross Ventilation in a Building Using Open Windows and Transoms**

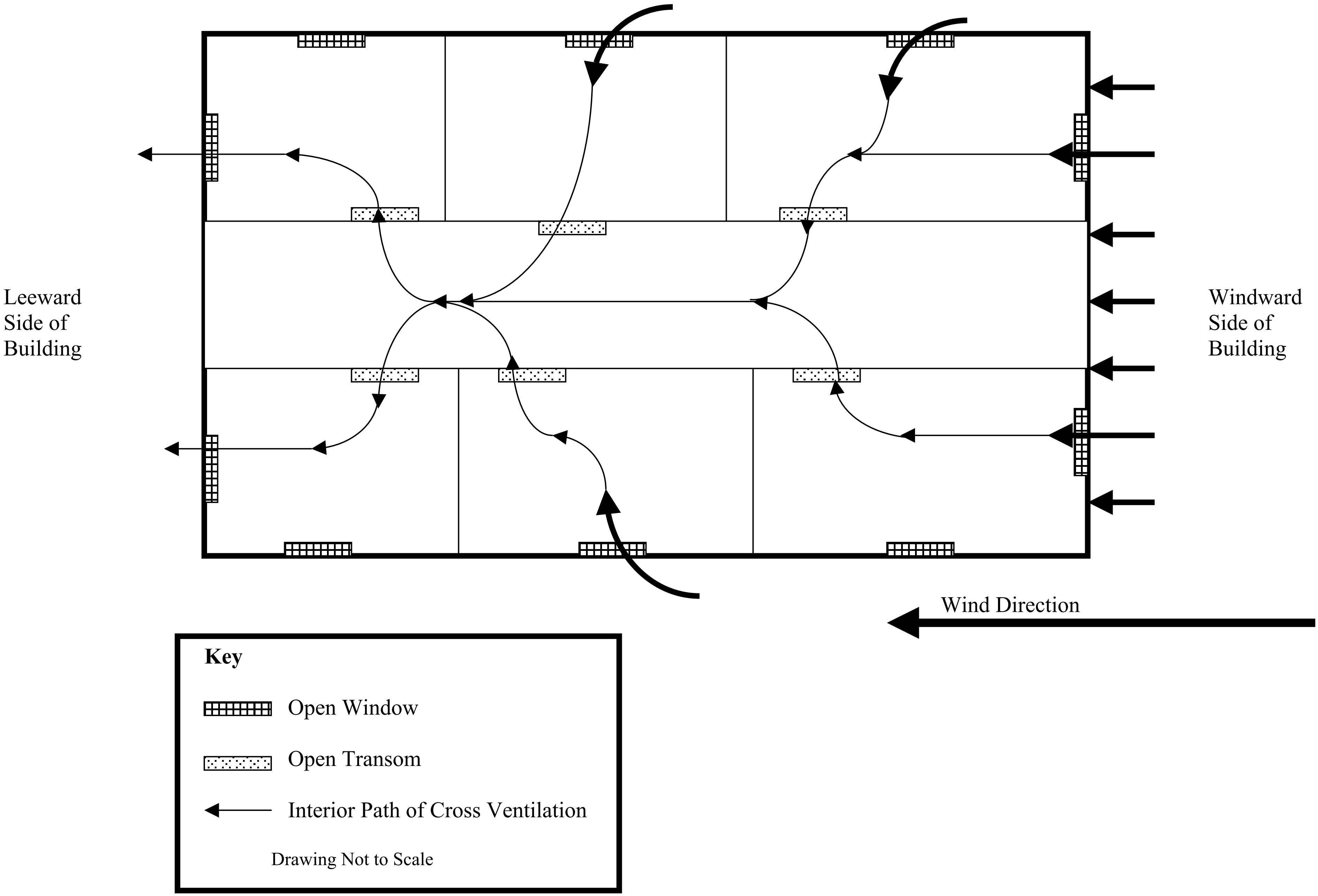
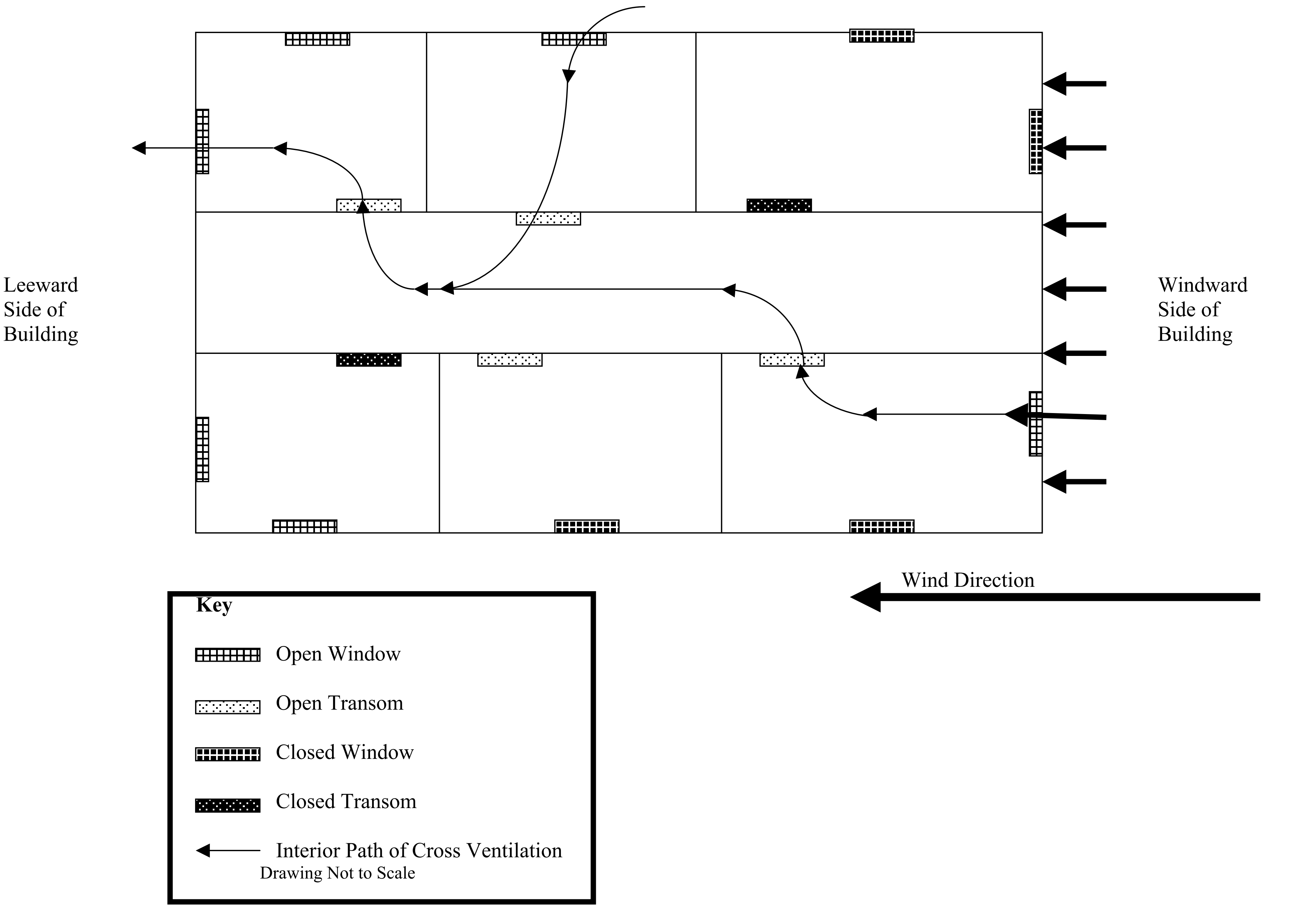


Figure 3 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



Picture 1

1947 Wing

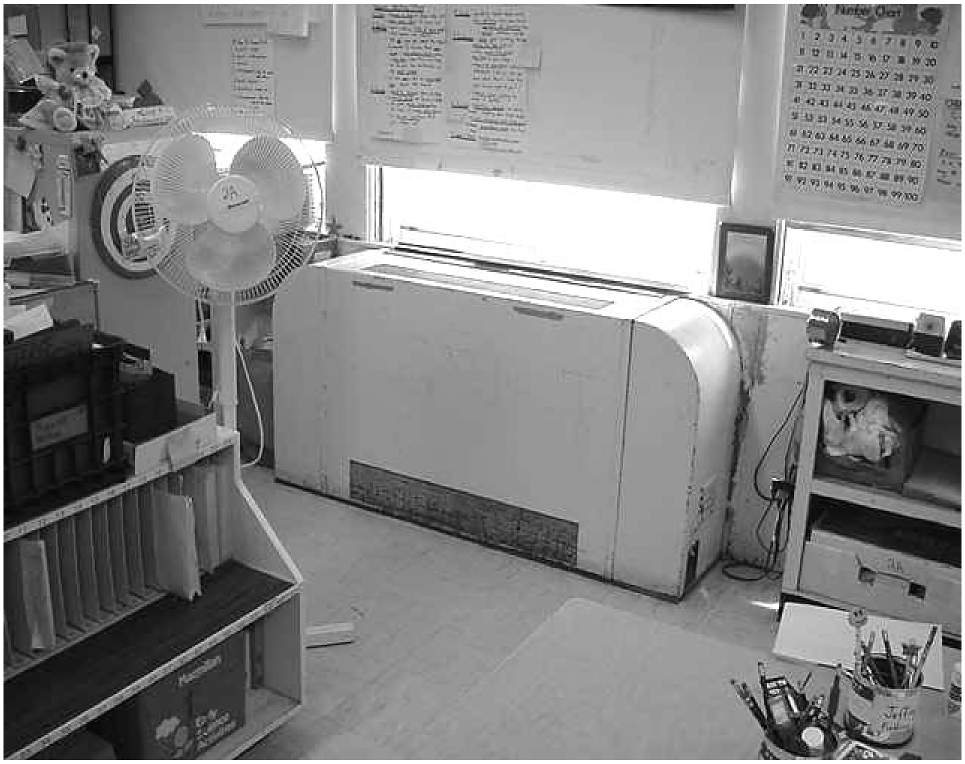
Picture 2

1960s Wing

Picture 3

1975 Wing

Picture 4



Univent in 1947 Wing

Picture 5

General Location of Univent Fresh Air Intake Sealed Inside Vinyl Siding

Picture 6

Sealed Univent Fresh Air Intakes for Library and Room 106

Picture 7

Rooftop Cupola That May Contain Exhaust Vent Terminus

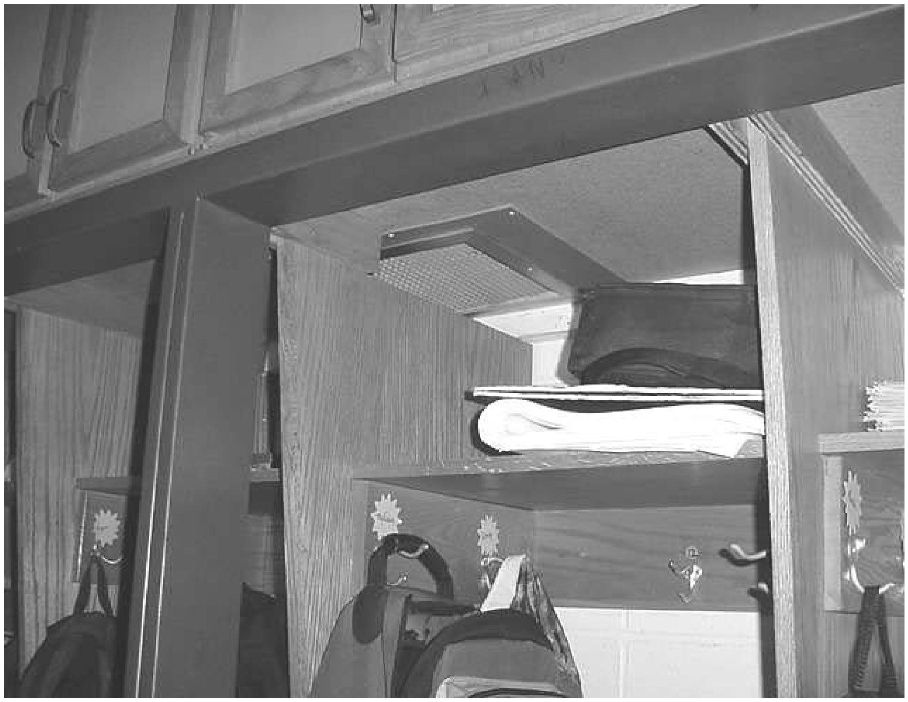
Picture 8

1960s Wing Univent Fresh Air Intake

Picture 9

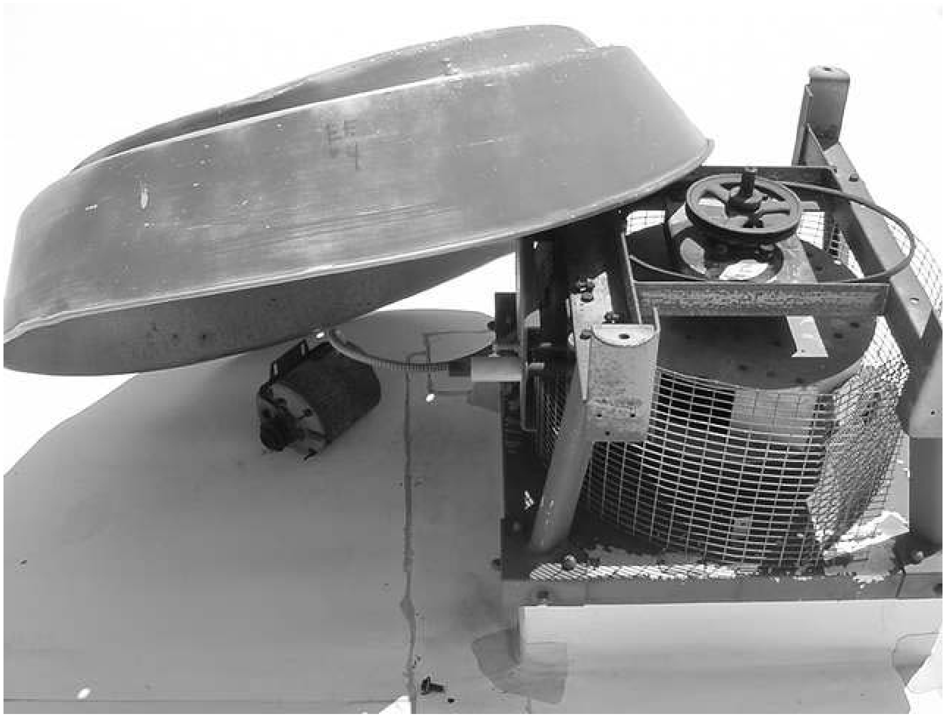
1960's Wing Rooftop Exhaust Vent Termini

Picture 10



Exhaust Vent Grilles Located in Ceiling of Closet in 1975 Wing

Picture 11



Disassembled Exhaust Vent Motor On 1975 Wing Roof

Picture 12

Floor Of Crawlspace beneath 1947 Wing

Picture 13

Edge Of Roof Missing Gutters over Crawlspace Vents

Picture 14

Edge Of Roof Missing Gutters

Picture 15

Vinyl Siding Soffit

Open Section of Vinyl Siding That Reveals Sealed Soffit Vents

Picture 16

Emergency Light Powered By Acid Battery

Picture 17

Box Of Latex Gloves, Note Warning

TABLE 1

Indoor Air Test Results – Holland Elementary School, 28 Sturbridge Road, Holland, MA – May 1, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	448	83	20					
118	872	78	34	21	Yes	Yes	Yes	Exhaust off, boxes/plant on univent-possible odor, floor fan, 4 computers, permanent markers
117	788	78	31	23	Yes	Yes	Yes	Window and door open, exhaust off
116	897	78	33	21	Yes	Yes	Yes	Exhaust off, window and door open, floor fans, latex gloves
115	767	78	31	20	Yes	Yes	Yes	Exhaust off, window and door open
114	1261	78	33	27	Yes	Yes	Yes	Univent and exhaust off-univent blocked by table, window open
113	2307	80	41	19	Yes	Yes	Yes	Exhaust off, floor fan
Boy's Restroom						No	Yes	
Hallway Emergency Lights								Acid batteries
Staff Lobby	1108	77	33	3	Yes	No	No	Toaster oven, refrigerator, door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

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%

TABLE 2

Indoor Air Test Results – Holland Elementary School, 28 Sturbridge Road, Holland, MA – May 1, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
112	867	79	32	17	Yes	Yes	Yes	Univent and exhaust off, window and door open
110/112 Restroom								Floor tile
111	964	79	32	21	Yes	Yes	Yes	Univent and exhaust off, window open
101 – Office	919	73	32	0	Yes	No	No	Window open, radiator
103	1350	75	36	17	Yes	Yes	Yes	Univent off, transom closed, clutter
102	895	77	31	20	Yes	Yes	Yes	Univent off, transom closed
104	1386	77	34	18	Yes	Yes	Yes	Univent and exhaust off-exhaust blocked by boxes, transom closed, door open
105 – Library	870	75	34	1	Yes	Yes	Yes	Univent and exhaust off-exhaust blocked by boxes
106	606	76	33	0	Yes	Yes	No	5+water damaged CT, ajar CT, guinea pig cage-odor-shavings on carpet
106 Restroom						No	Yes	Exhaust controlled by light switch, holes in floor-drawing air from

*** ppm = parts per million parts of air**
CT = ceiling tiles

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%

TABLE 3

Indoor Air Test Results – Holland Elementary School, 28 Sturbridge Road, Holland, MA – May 1, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
								crawlspace
Cafeteria/Gym	837	75	31	60+	No	Yes (2)	Yes	Exhaust off, 1 of 2 univents on, outside door open
107	732	78	31	12	Yes	Yes	Yes	Univent off-blocked by plants/table, exhaust blocked by box, clutter, window and door open
108	738	78	30	5	Yes	No	No	4 water damaged CT, outside door open
109	761	78	31	1	Yes	No	Yes	Exhaust blocked, radiator, door open
110	914	79	33	13	Yes	Yes	Yes	Univent and exhaust off-exhaust blocked by wood, door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

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%