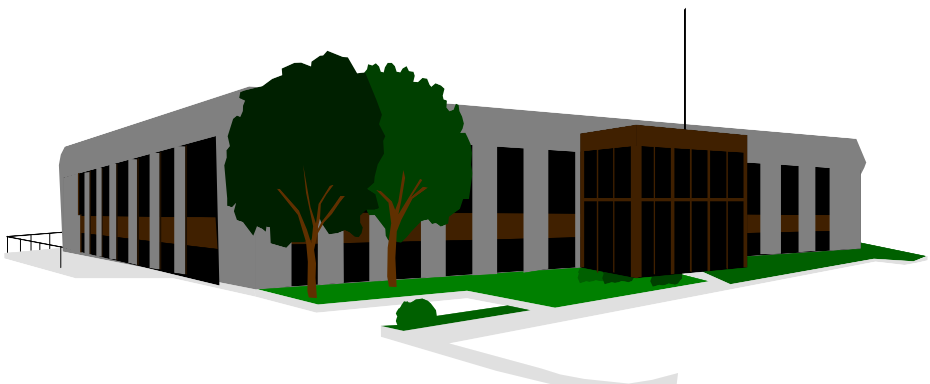
INDOOR AIR QUALITY ASSESSMENT

Aborn Elementary School
309 Eastern Ave.
Lynn, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment

June, 2000

Background/Introduction

At the request of the Lynn Board of Health an indoor air quality assessment was conducted at the Aborn Elementary School in Lynn, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA).

On March 29, 2000 Cory Holmes, Environmental Analyst of the Emergency Response/Indoor Air Quality (ER/IAQ) Program conducted an indoor air quality assessment. Mr. Holmes was accompanied by Steve Kolodziej of the Lynn Board of Heath and Allen Bract, Senior Custodian. Reports of poor indoor air quality related symptoms (e.g., chronic cough, congestion) and pigeon infestation prompted this request.

The school is a three-story red brick building, built in 1897. An addition containing four classrooms was added in the 1920's. A new roof was installed and downspouts and gutters were replaced in 1995. Windows are openable throughout the school.

The third floor contains a subdivided room currently used as the school library and computer room. The second floor consisted of general classrooms. The first floor contains the main office, nurse's office and general classrooms. Located on the basement level are kindergarten classrooms, custodian's office, the boiler room and storage areas.

ATC Associates, Inc. conducted microbiological testing prior to the BEHA assessment (ATC, 1999a, ATC, 1999b). Microbiological testing by ATC found elevated levels of bacteria and fungal growth in bulk wood samples taken from water-damaged wood trim and flooring, as well as in carpet dust in selected areas (ATC, 1999a). Based on microbiological testing ATC recommended: 1) that gravity feed ventilation shafts be thoroughly cleaned, 2) that water-damaged wood flooring and trim be replaced, and 3) that carpeting be replaced.

School officials' report that ventilation shafts were cleaned out in the fall of 1999 and chimneys were capped by school maintenance personnel to prevent an entryway for birds into the building.

Methods

Air tests for carbon dioxide were taken with the Telaire, Carbon Dioxide Monitor and tests for temperature and relative humidity were taken with the Mannix, TH Pen Thermo-Hygrometer.

Results

This school has a student population of 300 and a staff of approximately 26. The tests were taken under normal operating conditions. Test results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in all areas surveyed, indicating an overall ventilation problem in the school. It should also be noted that seven classrooms had windows open, which can greatly reduce carbon dioxide levels. Classroom 8 had a carbon dioxide level in excess of 2,000 ppm, which indicates little or no air movement. Windows are reportedly very difficult to open, which may discourage some occupants from opening them to improve airflow.

This building does not have a modern mechanical ventilation system (with the exception of classroom 13), but uses a natural/gravity ventilation system to provide airflow to classrooms in combination with openable windows. Ventilation is provided by a series of louvered vents. Each classroom has an approximately 3' x 3' grated air vent in the center of an interior wall near the ceiling (see Picture 1) which is connected by a ventilation shaft to a vault-like room in the basement (see Picture 2). A corresponding 3' x 3' vent exists in each room near the classroom doorway that is connected to an exhaust ventilation shaft that runs from the roof to the basement. Some of these vents were sealed with plywood, reportedly to prevent reoccurring odors from entering occupied areas. Most vents are not sealed (see Picture 3). Some classrooms and hallway areas contain open floor vents that are also connected to the ventilation shaft in the basement (see Picture 4). Classrooms were constructed around these shafts to provide exhaust ventilation.

Air movement is provided by the stack effect. Heating elements located in the base of the ventilation shaft (see Picture 5) warm the air, which rises up the hot air ventilation shafts. As the heated air rises, negative pressure is created, which draws cold air from the basement area into the heating elements. This system was designed to draw air from two sources in the basement: fresh air from a hinged window-pulley system on the exterior wall of the building (see Picture 5) and return air from the exhaust ventilation shafts. These sources of air mix in the vault prior to being drawn into the heating elements. The percentage of fresh air to return air is controlled by the hinged window-pulley system. The chains of the pulley system were designed to be set to lock the hinged window at a desired angle to limit fresh air intake. The remains of the chain and pulley system were noted in the ventilation vault. Non-openable windows have replaced the hinged window-pulley system; therefore no fresh, cool air can be introduced into the system.

The negative pressure created by the fresh air supply system also provides classroom exhaust ventilation. Each classroom is connected by ventilation shafts to the basement beneath the heating elements in a hearth-like structure. As the heating elements draw air into the hot air ducts, return air is drawn from the "hearths" at the bottom of the exhaust ventilation shafts. Negative pressure is created in these shafts, which in turn draw air into the exhaust vents of each classroom. The draw of air into these cool air vents is controlled by a draw chain pulley system. As mentioned previously, some of these vents were sealed in classrooms, therefore no means of exhaust ventilation exists.

In addition, many of the control mechanisms for the natural ventilation system are not operable or are missing (i.e., pull chains and louvers) and the window systems that provided fresh air in the basement are unopenable. Unless the ventilation system is restored to its original design by restoring control systems, openable basement windows and unsealing of exhaust vents, the sole source of ventilation in this building is openable windows.

Basement classroom 13 contained a ceiling-mounted unit ventilator (univent), which was not operating during the inspection (see Picture 6). A univent draws fresh air from a vent on the exterior of the building and air from the classroom (called return air) through a vent in the base of the unit (see Figure 1). Fresh air and return air are mixed, filtered, heated and expelled into the classroom through a fresh air diffuser located in the top of the unit. To function as designed, univents must be activated to provide a mechanical means of fresh air. No mechanical exhaust ventilation was noted in this area.

The Massachusetts Building Code requires a minimum mechanical ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (BOCA, 1993, SBBRS, 1997). 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.

Temperature readings on the day of the assessment were within a range of 69^{o} F to 77^{o} F, which was slightly below the BEHA recommended range for comfort. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. 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. Heat complaints in a number of areas were reported to BEHA staff. Temperature control is difficult in an old building without a functioning ventilation system or properly working windows.

The relative humidity in the building was below the BEHA recommended comfort range in all areas sampled, with the exception of room 13. Relative humidity measurements ranged from 17 to 40 percent. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. 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.

Moisture/Microbial Concerns

Several classrooms had water-damaged ceiling tiles, which can indicate leaks from either the roof or plumbing system. Water-damaged ceiling tiles can provide a medium for mold and mildew growth and should be replaced after a water leak is discovered and repaired.

Water-damaged wall plaster was also noted on walls and windows in a number of areas in the building (see Tables), which may be evidence of a current or historic roof or plumbing leak. Water intrusion was evident by the presence of efflorescence (e.g., mineral deposits) and water-damaged plaster. Efflorescence is a characteristic sign of water damage to brick and mortar, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds in bricks and mortar dissolve, creating a solution. As this solution moves to the surface of the brick or mortar, the water evaporates, leaving behind white, powdery mineral deposits. Water-damaged wall plaster, if wetted repeatedly, can be a medium for mold growth. Water damage was especially prevalent in the northeast corner of the building (see Picture 7). A perimeter inspection of the exterior of the building also revealed missing, damaged and crumbling mortar around brickwork. These conditions are breaches of the building envelope and provide a means for water entry into the building.

As indicated in the ATC report, water damaged wood trim and flooring was evident in a number of areas in the school (see Tables). Wet, porous material (i.e., wood flooring and trim) can provide a medium for mold growth, especially if wetted repeatedly.

The building's roof drainage system collects water and directs it into a series of downspouts into an underground drainage system beneath the school. The downspout on the northeast side of the building was clogged and several inches of standing water was noted in the gutter outside of the third floor computer room. In addition the drainage pipe was cracked and water stains on the pavement at ground level, indicated leakage. These conditions undermine the ability of the drainage system to remove water from the base of the building and may be an indirect source of water penetration.

The floor of the ventilation shaft was heavily coated with dirt, dust and accumulated debris. With the addition of water or humid air, these materials can serve as a medium for mold growth. Under certain conditions the ventilation shaft can serve as a means to transport mold throughout the building. No evidence of bird infestation was noted by BEHA personnel during the assessment.

Several classrooms contained plants. Plant soil and drip pans can serve as a source of mold growth. Plants in classroom 6 were stationed on cardboard boxes. Cardboard is a porous material where if wetted repeatedly can also provide a source of mold growth.

Other Concerns

Several other conditions were noted during the assessment which can affect indoor air quality. A number of areas had open utility holes around pipes. Open utility holes can provide a means of egress for odors, fumes, dusts and vapors between rooms and floors.

Several classrooms had excessive amounts of chalk dust. Chalk dust is a fine particulate which can become easily aerosolized and serve as a source of eye and respiratory irritation. Many classrooms contained dry erase boards and dry erase board 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 also be irritating to the eyes, nose and throat.

Also of note was 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 amounts of items stored in classrooms provide a source for dusts to accumulate. Many of these items, (e.g. papers, folders, boxes, etc.) are difficult to clean and therefore make it difficult for custodial staff to clean around these areas. Household dust can be irritating to eyes, nose and respiratory tract. These items should be relocated and/or should be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

Symptoms and complaints reported to the BEHA are consistent with what might be expected in an environment with a poorly operating or non-existent ventilation system. The absence of a mechanical supply and exhaust ventilation system prevents the dilution and/or removal of environmental pollutants from the building. This can result in a buildup of dust, dirt, odors and other pollutants in the indoor environment. In order to provide ventilation, windows are used to introduce air into the building. If windows are shut, no ventilation exists. In view of the findings at the time of this visit, the following recommendations are made:

1. 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. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
2. Consider consulting a ventilation engineer concerning the feasibility of restoring the original gravity feed ventilation system. This may entail repair or replacement of heating elements located in ventilation shafts; repair of broken or missing warm air and cool air pulley chain/louver door systems to provide ventilation in this building as designed; repair of the hinged-pulley system and/or installation of openable windows in basement area to provide fresh air to classrooms.
3. Examine univent in classroom 13 for proper function, ensure fresh air intake louvers are operable, repair/replace as needed. Operate univent during periods of school occupancy.
4. Regulate airflow in these classrooms with the use openable windows to control for comfort. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding. Contact the window manufacturer concerning proper operation/maintenance of window systems.
5. Ensure building is entirely cleaned of all bird wastes. Inspect chimney caps periodically for proper seal to prevent backdrafting and reoccupation by birds.

6. Consider having exterior brick repointed and waterproofed to prevent further water intrusion. Repair water damaged ceilings, walls and wall-plaster as necessary.
7. Repair any existing water leaks and replace any remaining water-stained ceiling tiles, wooden flooring and wood trim. Examine the areas above and around these tiles for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial as needed.
8. Unclog downspouts and repair/replace cracked drainpipe to provide proper drainage.
9. Ensure plants are equipped with drip pans. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial where necessary. Remove plants from on top of cardboard boxes in classroom 6.
10. Seal utility holes to avoid the aerosolization of dirt, dust and particulates in occupied areas.
11. 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.

References

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Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

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Picture 1

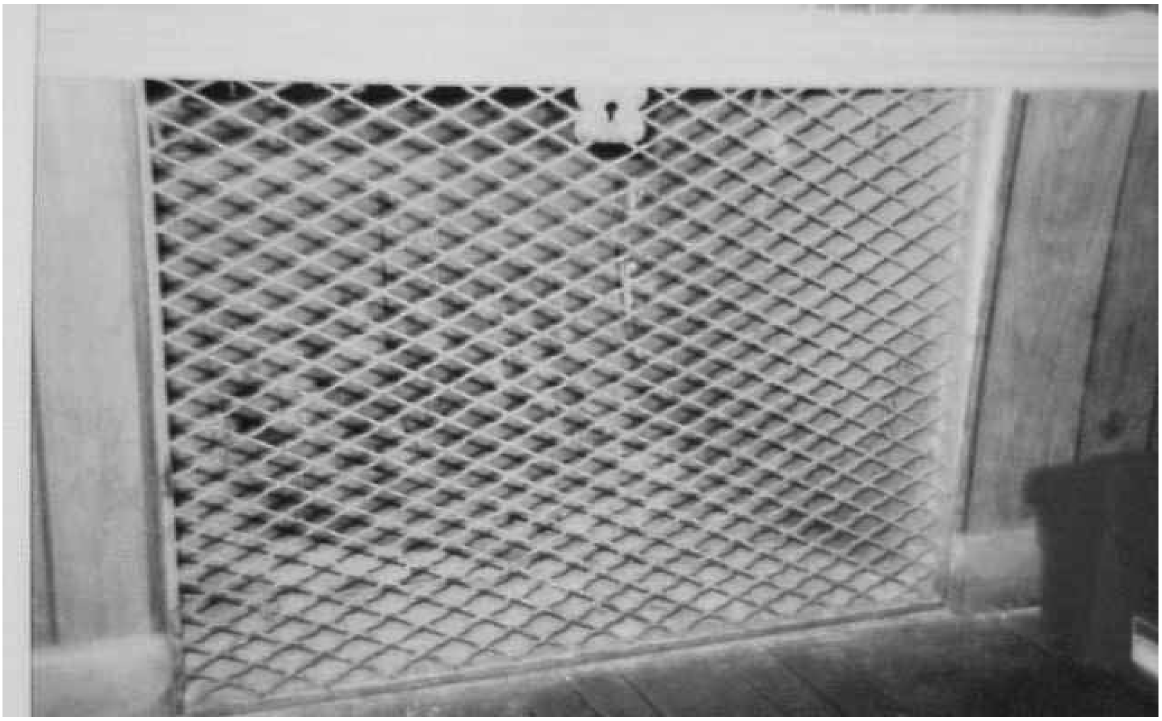
Classroom Natural Gravity Feed Supply/Heat Vent Note Vent Is Not Sealed

Picture 2

Vault Door

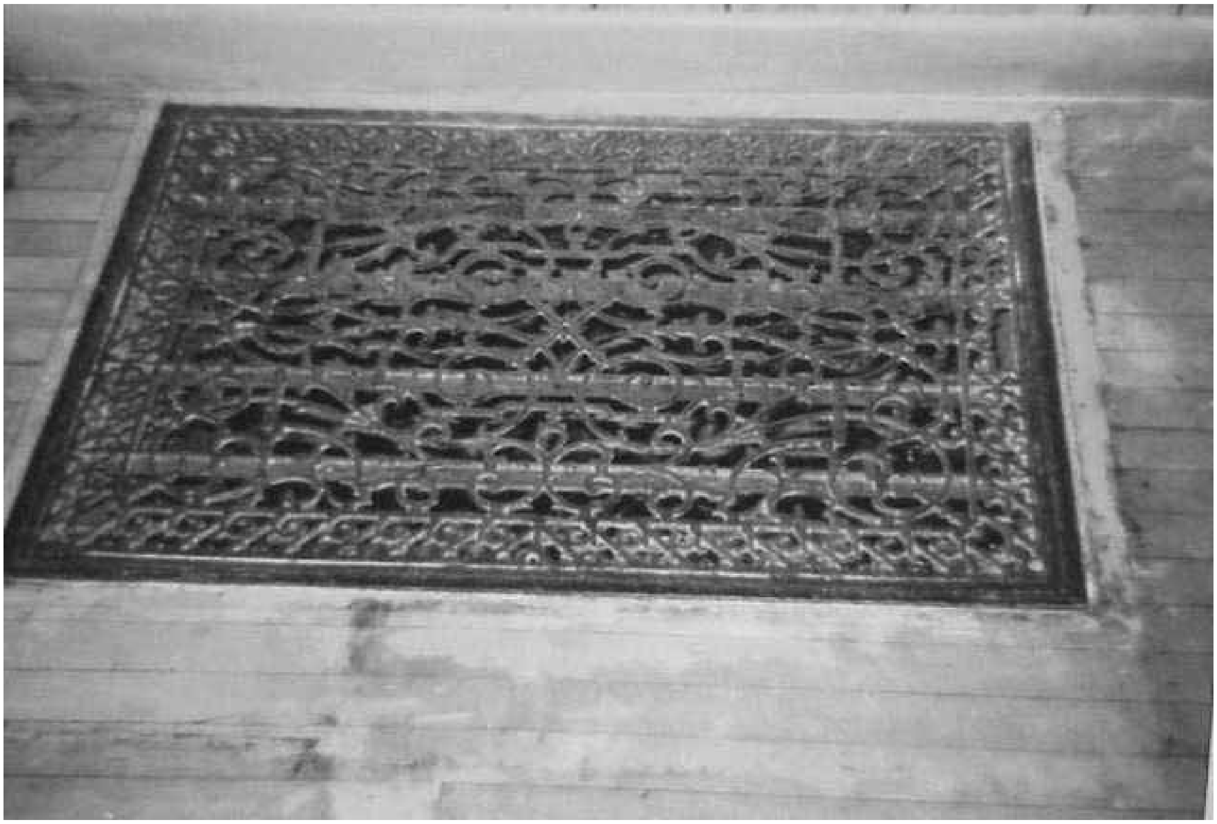
Doorway to Ventilation Room (Vault) in Basement

Picture 3



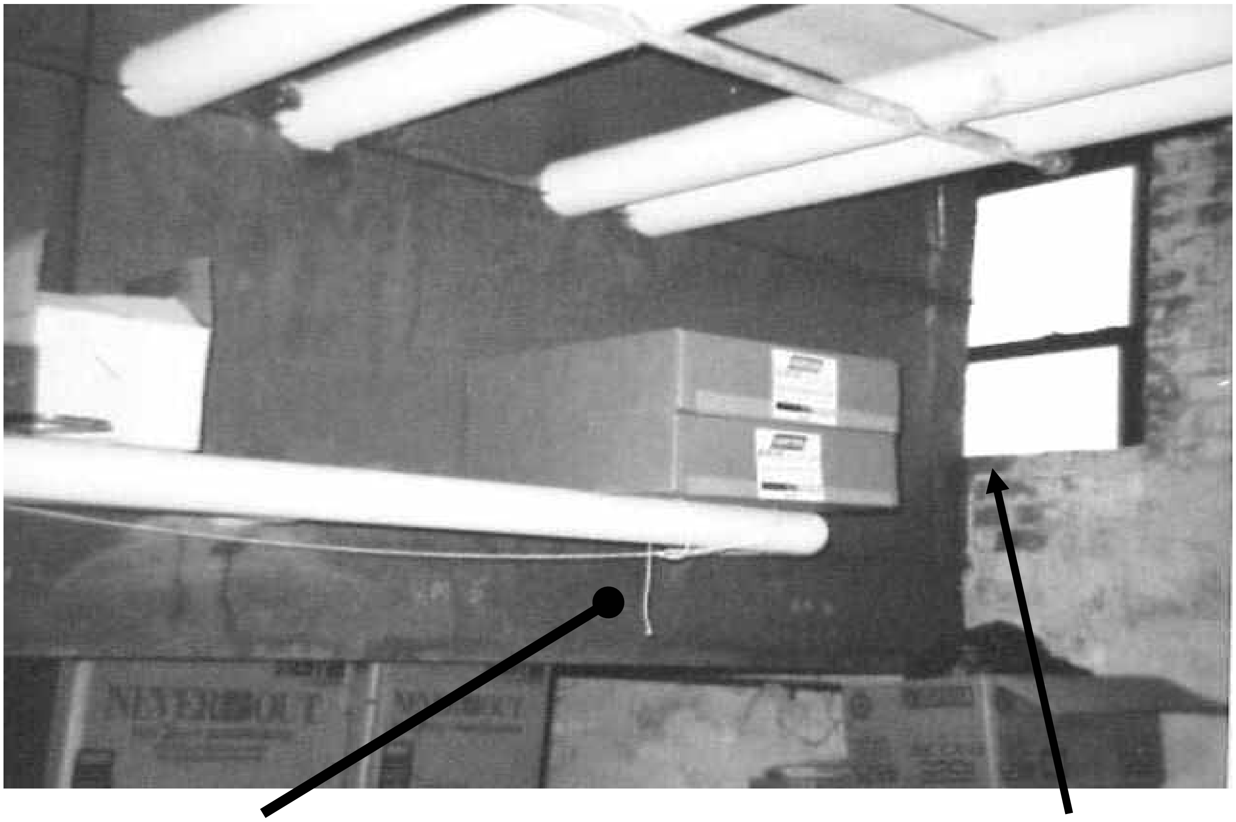
Unsealed Classroom Natural Gravity Feed Exhaust Vent

Picture 4



Natural Gravity Feed Supply/Heat Floor Vent

Picture 5



Heating Element/Radiator in Ventilation Room (Vault) in Basement Note Window Originally Designed to Introduce Fresh Air into the System

Picture 6

Ceiling-Mounted Univent Noted in Classroom 13

Picture 7

Water-Damaged Ceiling Tiles and Wall Plaster Noted in Northeast Classroom

TABLE 1

Indoor Air Test Results –Aborn Elementary School, Lynn, MA – March 21, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Outside (Background)	409	59	52					weather conditions: sunny, light breeze
Vent room East/West						no	no	gravity feed vent system, window open, new insulation on pipes, open shafts to classrooms, dirt/dust-dry stored items, air currents
Room 13	1512	69	40	17	yes	no	no	hole in wall, univent off, water damaged exterior door, spaces around exterior door
Room 14	800	72	31	18	yes	no	no	10+ CT-near sprinkler system, water damaged exterior door, water damaged (wood) ceiling near exit
Room 5	944	77	27	21	yes	no	no	window open, pull chain to louver broken, louver disconnected-resting on bottom of shaft, dirt/dust/debris
Room 4	1196	76	37	0	yes	no	no	severe water damage-NE corner, 20+ CT, ~15 occupants gone 5 min., open floor vent
Room 6	1307	76	26	22	yes	no	no	broken/missing pull chains, 8 plants-plants on cardboard boxes
Room 1	976	71	26	17	yes	no	no	10+ CT, floor vent covered with floor board, water damaged plaster/wooden

*** ppm = parts per million parts of air**
CT = water-damaged 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 –Aborn Elementary School, Lynn, MA – March 21, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
								window frames
Room 2	944	71	26	19	yes	no	no	6 CT, floor vent covered, door open
Room 3	876	73	25	22	yes	no	no	window open
Room 10	1222	76	34	21	yes	no	no	water damage-NE corner/floor boards/wall plaster, exhaust vent sealed with plywood, 8 CT
Room 11	840	75	21	22	yes	no	no	window open, exhaust grate broken, broken pull chain
Room 9	968	76	26	19	yes	no	no	water damaged wall plaster-efflorescence, floor vent open, window open, 5+ CT
Room 12	864	75	17	17	yes	no	no	window open, vent shaft sealed with trash bag & tape, 7 plants, chalk dust, pull chain missing, 5+ CT
Room 8	2000+	76	34	19	yes	no	no	2 plants, chalk dust, floor vent covered
Room 7	1640	75	27	19	yes	no	no	window open, water damaged wall plaster/wooden window frames, efflorescence

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Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results –Aborn Elementary School, Lynn, MA – March 21, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Teacher's Room	1044	76	32	7	yes	no	no	water damaged wallpaper/wooden windowsills
Library/Computer Room	1071	74	26	25+	yes	no	no	exterior door open, air conditioner, 20+ CT
Building Exterior								gutter system clogged, standing water in gutters-downspout blocked with debris, missing mortar, cracked drain pipe (from freezing)

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