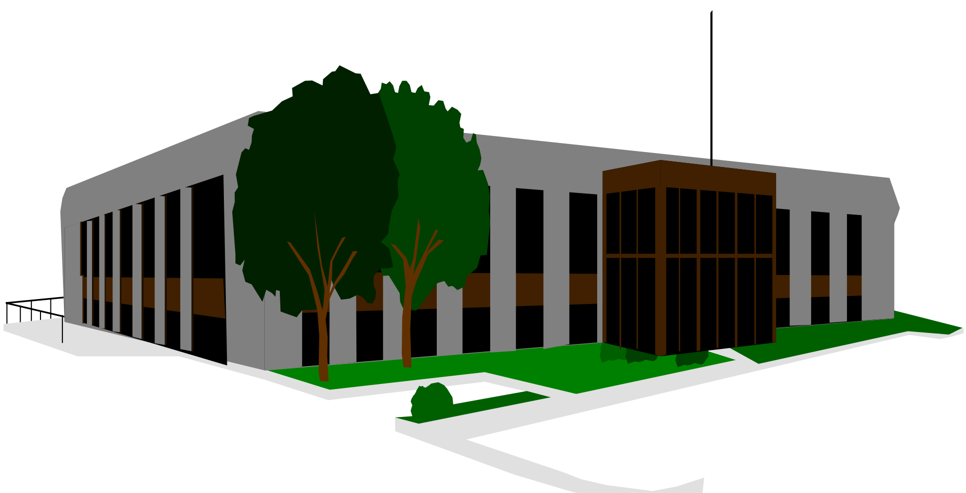
INDOOR AIR QUALITY ASSESSMENT

Hanover Middle School
Hanover School District
45 Whiting Street
Hanover, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Jeanmarie Joyce, Health Agent of the Hanover Board of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Hanover Middle School in Hanover, Massachusetts. Concerns about the effect of renovations on indoor air quality were raised by building occupants. Symptoms date back to the beginning of the current school year (September 1999). Symptoms reported by both teachers and students included headaches, respiratory and eye irritation. Reports of diesel exhaust inside the building were also reported.

On February 4, 2000, a visit was made to this school by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Ms. Joyce.

The school is a two-story brick building constructed in 1972. An addition to the north side of the building was under construction during the assessment. Other activities included renovation of the gymnasium and locker rooms. The school contains general classrooms, media center, art room, cafeteria, science classrooms and administration office. Windows in the school are openable. The office and media center are carpeted. The floor of the remainder of the building is covered with floor tile. Previous BEHA correspondence regarding recommendations for improved control measures to prevent renovation/construction generated pollutants from migrating into occupied areas of the building was provided (MDPH, 2000). This correspondence is included as Appendix A.

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 PTH8708 Thermo-Hygrometer.

Results

This school has a student population of over 630 and a staff of approximately 60. The tests were taken during normal operations at the school. Test results appear in the Tables 1-5.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million (ppm) in thirty-three of thirty-eight areas surveyed, which is indicative of an overall ventilation problem in the school. It should be noted that five of the rooms with carbon dioxide measurements below 800 ppm were sparsely populated, which can greatly reduce carbon dioxide levels.

Two different types of heating, ventilating, and air-conditioning (HVAC) systems supply fresh air to classrooms. Classrooms on exterior walls have fresh air supplied by a unit ventilator (univent) system. 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 its case (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 upper portion of the case. Univents were deactivated in several classrooms. Obstructions to airflow, such as books and paper, blocking univents were seen in several classrooms. In order for univents to provide fresh air as designed, fresh air diffusers and univent returns must be unblocked and remain free of obstructions. Exhaust ventilation in exterior classrooms is provided by a mechanical system consisting of ducted, wall-mounted vents. This system was found operating throughout the building.

The HVAC system in the central core areas consists of rooftop mounted air-handling units (AHUs). Fresh air is distributed to core rooms by ceiling-mounted air diffusers. A combination of wall and ceiling-mounted return vents is connected by ductwork to the rooftop AHUs. Both supply and return vents were operating during the assessment.

The central core AHUs provide air-conditioning during warm weather. Exterior classrooms with univents do not have air conditioning capacity. The central core AHUs are located in the center of the Unit B building roof. In close proximity to the fresh air intake is a pair of large exhaust vents (see Picture 1). Under certain wind and weather conditions it is possible that exhaust air from these vents can be entrained by the AHU. This condition can result in odors being distributed into the central core of the building.

The interior of a univent cabinet was examined. The cabinet cover is insulated with fiberglass insulation that is in a fraying, damaged condition (see Picture 2). Damaged fiberglass can become aerosolized and provide a source of respiratory and skin irritation. School officials report that univents will be replaced as part of the renovations during the summer.

In an effort to prevent renovation generated pollutants from being entrained by univents of classrooms 106, 108, 210 and 212, ductwork was installed over the fresh air intakes (see Pictures 3 and 4). This ductwork extends over the edge of the building and terminates on the roof. While this ductwork will prevent the entrainment of pollutants from the renovation, this passive ductwork may not be sufficient to provide fresh air for these classrooms. Airflow decreases as the length of ductwork increases from ventilation fans. In addition, airflow is decreased roughly in half by every 90^o angle that exists in ductwork. Most univents fans are approximately 3 feet from the fresh air intake. While these univents would be sufficient to draw air from this distance, the installation of ductwork over twenty feet from the univent fans would limit the draw of fresh air into these classrooms. In addition, this ductwork contains over 270^o of angles. If the draw of fresh air by the univents at the fresh air intake were 100 percent, the introduction of the angles of this ductwork would reduce that draw to approximately 12.5 percent. Therefore the length of this ductwork combined with the angles within the ductwork would tend to limit the amount of fresh air that can be drawn by univents in these classrooms without some mechanical aid at the rooftop fresh air intake vent.

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, these systems should also be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air. The date of the last balancing of these systems was not available at the time of the assessment.

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 (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 occurs, 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.

Temperature readings recorded during the assessment were in a range of 71 ^{o} F to 80 ^{o} F, which was slightly above BEHA's recommended comfort range in 3 classrooms and the gymnasium. 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.

Relative humidity measurements ranged from 5 to 17 percent, which is below BEHA comfort guidelines. 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 common problem during the heating season in the northeast part of the United States.

Moisture/Microbial Concerns

As noted previously, the center core rooms are equipped with air-conditioning, which is used during spring/summer months. Exterior classrooms do not have an air-conditioning capacity. As reported by building occupants, exterior windows are opened and univents operate during warm weather. This results in unconditioned air being introduced into the interior of the building. In an effort to create cross ventilation, exterior classroom hallway doors are opened. The air-conditioning of the central core classrooms creates a temperature differential with exterior classrooms. As this temperature differential increases, the creation of drafts by cold air moving to hot air increases.

Interviews with building occupants confirm the creation of drafts from the central core areas into exterior classrooms. This cold air penetration results in floor tiles and walls being cooled. With exterior classroom hallway doors open, moist air introduced by the univents and open windows also penetrates into hallways. This can result in the generation of condensation on floors and walls as moist air penetrates into the hallway. A condition noted that would confirm that condensation moistens floor tiles was observed in the hallway between the boy's locker room and classroom 108 (see Pictures 5 and 6). Stains along the seams of floor tiles indicate that moisture accumulates in this hallway. Due to the absence of supply and exhaust ventilation in this area, moistened air tends to linger resulting in the wetting of floor tiles. Introduction of moist air in unconditioned rooms in the building can result in repeated moistening of porous materials. A possible sign of moistening of porous materials is the musty odor noted in the administrative offices. These offices have wall-to-wall floor carpeting. Materials such as carpets and ceiling tiles can serve as a media for mold growth. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If moistened porous materials are not dried within this time frame, mold growth may occur. Mold colonized porous materials cannot be adequately disinfected and cleaned.

Several classrooms had a number of plants. In some classrooms, flowering plants were observed on univent air diffusers. Several classrooms contained plants in window planters without drip pans. Window planters are designed to be mounted on the outside of windows and therefore do not have drip pans. The lack of drip pans can lead to water pooling and mold growth on windowsills when used indoors. Moistened plant soil, drip pans and standing water can serve as a source of mold growth. Plants should be equipped with drip pans and over watering should be avoided. In addition, plants should be located away from univents to prevent aerosolization of dirt, pollen or mold.

Classroom 218A contained a water-damaged sink cabinet. Improper drainage or overflow could lead to water penetration of countertop wood and potential damage to the cabinet interior as well as materials stored therein. Water-damaged wood and standing water may also be a potential source of mold growth.

Other Concerns

With this building under renovation, the introduction of particulates, gases and vapors can adversely impact on indoor air quality in occupied areas of the school if not properly contained. Conditions noted by BEHA staff concerning containment of renovations were made in a previous correspondence (Appendix A). Conditions aside from the renovation in this building were noted during the assessment that can have an affect on indoor air quality.

Classrooms contained dry erase boards with dry erase board markers or chalkboards. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999). Some rooms were noted to have excessive chalk dust. Chalk dust and dry erase board markers and cleaners can be irritating to the eyes, nose and throat.

The home arts room 224 was equipped with a clothes washing machine. This equipment was removed, leaving the drainpipe for this equipment open (see Picture 7). Without draining water, the trap of this drain can dry out. This classroom also has a number of unused sinks. Drain traps are designed for a water seal in the pipe to prevent sewer gas from backing up into occupied areas. Sewer gas can contain hydrogen sulfide, which can be irritating to the eyes, nose and throat.

Three photocopiers were noted in the teacher's workroom. The interior wall of this room has a return vent (see Picture 8). Since the teacher's workroom is in the central core, this return vent would be ducted back to the rooftop AHU. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). Waste heat and other photocopier pollutants can be drawn into this vent and be distributed to other areas serviced by the AHU. Photocopiers should be located in a well-ventilated area and/or be equipped with local exhaust ventilation. Without mechanical exhaust ventilation, pollutants produced by office equipment can build up and in this case, be distributed to other areas of the second floor.

The administrative office contained window-mounted air conditioners (see Picture 9). The filters of this equipment do not appear to have been cleaned. Portable air-conditioning units are normally equipped with filters, which should be cleaned or changed as per the manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter.

Univents appear to be equipped with filter media that is cut to fit permanent metal racks (see Picture 10). Frequently, cut-to-fit filter media is not installed flush in racks. Air drawn into univents will bypass filters through spaces between filters and racks. This can result in dust, dirt and other debris to be distributed by the ventilation system. Air handling equipment is equipped with filters that strain particulates from airflow. 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 (ASHRAE, 1992, MEHRC, 1998). Note that increased filtration can reduce airflow produced by increased resistance. Prior to any increase of filtration, each piece of air-handling equipment (i.e., univents and AHUs) should be evaluated by a ventilation engineer to ascertain whether it can maintain function with more efficient filters.

A number of areas have ceiling tiles that are either missing or ajar (see Picture 11). The ceiling plenum is an unconditioned space, which can have a different temperature than the occupied space. This differentiation in temperature can create air movement, which can capture particulate matter in the air stream and distribute this material into occupied areas through open sections of the suspended ceiling system. Particulate matter can be irritating to the eyes, nose and respiratory system.

A fresh air intake is located above the loading dock (see Picture 12), which can result in the entrainment of vehicle exhaust into the building. M.G.L. chapter 90 section 16A prohibits the unnecessary operation of the engine of a motor vehicle for a foreseeable time in excess of five minutes (MGL, 1996).

Conclusions/Recommendations

The conditions noted at Hanover Middle School raise a number of complex issues. The combination of the renovations, building design, maintenance and other conditions in the building present factors that can influence indoor air quality in the building. For these reasons a two-phase approach is required, consisting of immediate measures **(short-term)** to improve air quality at Hanover Middle School and **long-term** measures that will require planning and resources to adequately address overall indoor air quality concerns. In view of the findings at the time of this visit, the following recommendations are made:

The following **short-term** measures should be considered for immediate implementation:

1. Implement the corrective actions recommended concerning renovations in the building (see Appendix A) (MDPH, 2000).
2. 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. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers school-wide. If

univents dampers cannot be readily adjusted, consider using windows to supplement fresh air in classrooms.

3. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
4. In order to enhance the draw of fresh air by univents in classrooms 106, 108, 210 and 212, consider installing an auxiliary fan in the mouth of the rooftop fresh air intake to force fresh air down the ductwork.
5. Install new disposable filters in classrooms that fit flush into racks.
6. Continue with plans to replace univents in the old building.
7. Once both the fresh air supply and the exhaust ventilation are functioning, the ventilation system should be balanced by an HVAC engineer.
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 relative humidity is low. Implement a dust control procedure. Institute wet mopping and wet wiping of horizontal surfaces (sweeping and dusting can stir up fine particulates). Consider using a vacuum cleaner equipped with a high efficiency particulate efficiency (HEPA) filter to reduce the aerosolization of respirable dusts. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
9. Clean air filters for window-mounted air conditioners in accordance with manufacturer's recommendations.
10. Have a chemical inventory done in all storage areas and classrooms. Discard hazardous materials or empty containers of hazardous materials in a manner consistent with

environmental statutes and regulations. Follow proper procedures for storing and securing hazardous materials. Obtain Material Safety Data Sheets (MSDS') for chemicals from manufacturers or suppliers.

11. Maintain MSDS' and train individuals in the science department in the proper use, storage and protective measures for each material in a manner consistent with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (M.G.L., 1983).
12. 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.
13. Seal openings in suspended ceiling to prevent dust and odor penetration into occupied areas.
14. Seal the washing machine drain in classroom 224. Run water into sinks in classroom to prevent drying of drain traps. If these sinks are not to be used, seal drains and disconnect water supply to these sinks.
15. Consider posting a sign at the loading dock to inform delivery drivers that engine should be shut off after five minutes as required by Massachusetts General Laws 90:16A.
16. Clean chalkboards and chalk trays regularly to prevent the build-up of excessive chalk dust.

The following **long-term** measures should be considered:

1. Consider consulting a ventilation engineer concerning the introduction of moisture into the building. The HVAC air conditioning system of the central core and exterior

classroom univents must be operated during warm weather in a manner to minimize the amount of moisture introduced into the building.

2. The ceiling tile system in both the hallway and exterior classrooms should be examined for microbial growth. If microbial growth is found in the ceiling plenum side of ceiling tiles, consider replacing contaminated materials.
3. Consider removing the carpeting in the administration office if determined to be moldy.

References

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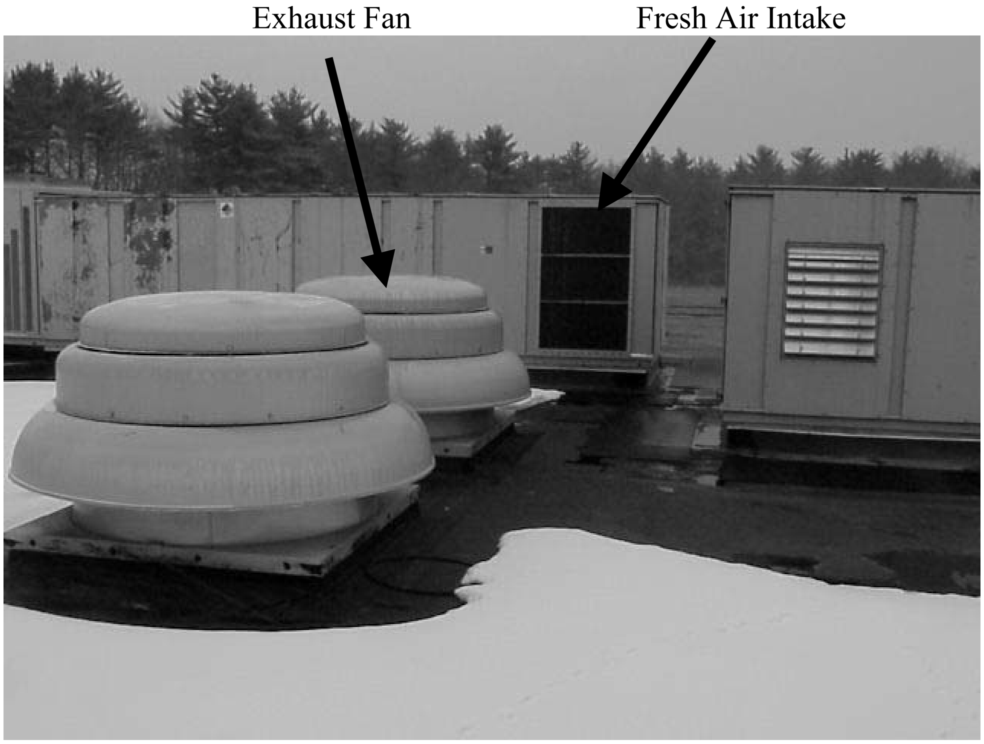
Picture 1



Exhaust Fans in Close Proximity to Fresh Air Intake of Central Core AHU

Picture 2

Frayed Fiberglass Insulation on Univent Cover

Picture 3

Ductwork Installed for Fresh Air Intakes of Classrooms 106, 108, 210 and 212

Picture 4

Ground View of Ductwork Installed for Fresh Air Intakes of Classrooms 106, 108, 210 and 212

Picture 5

Dried Residue in Cracks of Floor Tiles in the Small Hallway between the Boy's Locker Room and Classroom 108

Picture 6

Dried Residue in Cracks of Floor Tiles in the Threshold of Rear Hallway Door of Classroom 108

Picture 7

Open Clothes Washer Drainpipe in Classroom 224

Picture 8

Photocopiers in Teacher's Room

Picture 9

Window-Mounted Air Conditioner, Note Heavy Dust Accumulation on Filter

Picture 10

Metal Rack with Replaceable Filter Media

Picture 11

Plenum above Suspended Ceiling Pictured through Missing Ceiling Tiles

Picture 12

Loading Dock in Close Proximity to Fresh Air Intake

TABLE 1

Indoor Air Test Results –Hanover Middle School, Hanover, MA – February 4, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)								
214	1422	73	15	24	yes	yes	yes	
215	891	74	9	20	no	yes	yes	chalk dust
216	1061	73	11	21	yes	yes	yes	chalk dust, door open
217	851	72	11	19	no	yes	yes	
218A	1187	72	11	27	yes	yes	yes	water damage-sink cabinet, mold odor, dry erase board
218B	1010	80	12	23	yes	yes	yes	
219	829	75	9	30	no	yes	yes	dry erase board, door open
222	909	76	11	19	yes	yes	yes	door open
224	1019	76	9	0	no	yes	yes	univent and exhaust off, pipe open, sink traps, 1 missing ceiling tile
Cafeteria	989	73	12	2	yes	yes	yes	

*** 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 –Hanover Middle School, Hanover, MA – February 4, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
124	1045	71	12	25	yes	yes	yes	
201	974	72	9	24	no	yes	yes	3 ceiling tiles ajar, door open
202	1318	72	12	20	yes	yes	yes	univent and exhaust off, window open, 1 ceiling tile ajar, dry erase board, window mounted air conditioner-filter dirty, univent blocked by paper
203	981	72	12	0	no	yes	yes	univent and exhaust off, door open
204	1765	74	12	0	no	yes	yes	univent and exhaust off, door open
205	992	72	9	24	no	yes	yes	
206	1570	74	13	20	yes	yes	yes	univent off, door open, 1 ceiling tile ajar
208	1963	75	14	27	yes	yes	yes	univent off
208 Hallway					`			missing ceiling tile-odors
207	784	71	9	0	no	yes	yes	

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TABLE 3

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Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
210	1168	71	10	0	yes	yes	yes	hetanol, stored butane in gas bottles
Teachers' Workroom	791	78	5	7	yes	yes	yes	4 photocopiers
122	1150	72	15	21	yes	yes	yes	door open
Library	872	73	10	56	yes	yes	yes	
116	839	72	11	25	yes	yes	yes	
114	1030	74	13	26	yes	yes	yes	univent blocked by bookshelf, door open
112	1022	73	11	28	yes	yes	yes	univent blocked by paper, door open
110	1180	73	15	18	yes	yes	yes	univent blocked by paper
109	957	71	12	17	yes	yes	yes	chalk dust
108	749	72	10	0	yes	yes	yes	plants over univent, door open
106	1366	74	17	19	yes	yes	yes	exhaust blocked by stored items

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

TABLE 4

Indoor Air Test Results –Hanover Middle School, Hanover, MA – February 4, 2000

Remarks	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
104	1312	73	15	28	yes	yes	yes	univent off
102	1138	73	16	27	yes	yes	yes	univent off
105	751	73	11	25	yes	yes	yes	30 computers, door open
103	865	74	14	25	no	yes	yes	1 ceiling tile ajar, door open
Health	762	74	10	2	no	yes	yes	1 ceiling tile ajar
101	868	74	13	8	no	yes	yes	water damage, door open
111	753	73	9	1	no	yes	yes	missing ceiling tile
Listening Room	695	73	11	0	no	yes	yes	
Main Office	839	73	14	2	yes	no	no	

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