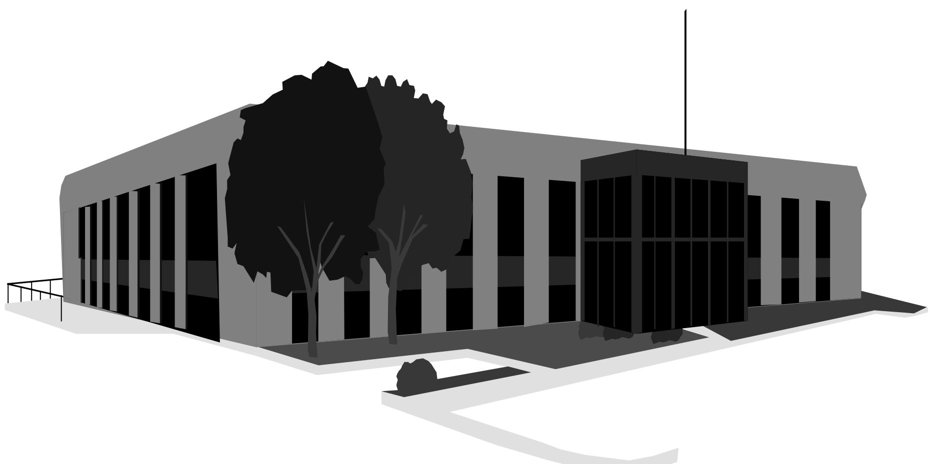
INDOOR AIR QUALITY ASSESSMENT

North Andover Fire Department
124 Main Street
North Andover, Massachusetts



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
June, 2001

Background/Introduction

At the request of Deputy Chief Edward Morgan, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at North Andover Fire Station (the firehouse), 124 Main Street, North Andover, Massachusetts. On February 22, 2001, a visit was made to the firehouse by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA to conduct an indoor air quality assessment. During the visit BEHA staff received complaints from building occupants of vehicle exhaust odors from the operation of fire engines.

The firehouse is a two-story red brick building constructed in 1909 (see Picture 1). This building is joined to the North Andover Town Hall, which was built in the 1920's. The indoor air quality assessment for the North Andover Town Hall is subject of a separate report. The North Andover Fire Department second floor has offices, a meeting room, bunkroom and kitchen. The first floor contains three engine bays, reception and credit union office. The basement contains a workout room, furnace, equipment storage and garage used to store fossil fuel-powered equipment. Windows are openable and consist of single paned glass in wooden window frames. The front of the building has three garage doors that enclose the engine bays. Two stairwells connect the garage to rooms on the second floor.

Methods

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

Results

The building has an employee population of approximately 10. The tests were taken under normal operating conditions. Test results appear in Tables 1-2.

Discussion

Ventilation

It can be seen from the tables that the carbon dioxide levels were below 800 parts per million of air (ppm) in all areas sampled, which indicates adequate air exchange. No general mechanical ventilation systems exists in the building, with the exception of the basement locker room and weight room. The mechanical system in the basement does not have a fresh air supply. Each room has a radiator beneath the window that provides heat. The sole source of fresh air is the openable windows. Offices and restrooms do not have mechanical exhaust ventilation. With the lack of exhaust ventilation, pollutants that exist in the interior space can build up and remain inside the building.

A mechanical exhaust ventilation system was installed in the engine bays to remove carbon monoxide and other products of combustion from vehicles. A flexible hose is connected to the tailpipe of each vehicle. Each flexible hose is connected to a motorized fan located on the rear of the building (see Picture 2). As motors operate, engine combustion products are drawn into the vent system and released into a chimney that terminates above the edge of the roof.

During summer months, ventilation in the firehouse is controlled by the use of openable windows. The firehouse 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. This hinged window (called a transom) enables occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window (windward side), pass through a room, pass through the open transom, enter the hallway, pass through the opposing open room transom, into the opposing room and exit the building on the leeward side (opposite the windward side) (see Figure 1). 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 2). Transoms were rendered inoperable by the installation of a suspended ceiling system. Therefore, in order to create cross-ventilation, office doors would need to remain open.

The Massachusetts Building Code requires a minimum ventilation rate of 20 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.

Temperature readings were measured in a range of 67^{o} F to 73^{o} F, which were close to the BEHA recommended comfort range. 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.

The relative humidity in this building was below the BEHA recommended comfort range of 40 to 60 percent in all areas sampled on the day of the assessment. Relative humidity measurements ranged from 30 to 39 percent. The sensation of dryness and irritation is common in a low relative humidity environment. For buildings in New England, periods of low relative humidity during the winter are often unavoidable.

Microbial/Moisture Concerns

A refrigerator drip pan in room 207 was encrusted with dried material. Drip pans should be examined on a periodic basis and cleaned with an appropriate antimicrobial agent as necessary.

Other Concerns

Under normal conditions, a firehouse can have several sources of environmental pollutants present from the operation of fire vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds;
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Residues from fires on vehicles, hoses and fire-turnout gear.

Of particular interest is vehicle exhaust. The firehouse is equipped with a mechanical exhaust system to remove exhaust from the engine bays during vehicle idling. As discussed previously, each fire engine is connected to the mechanical ventilation exhaust system by a vehicle tailpipe exhaust system using a flexible hose. As the mechanical exhaust vent system operates, vehicle exhaust is drawn to a fan motor outside the building and ejected through a chimney above the edge of the roof. Once fire vehicles are warmed up, the flexible hose is disconnected from the tailpipe and the engine exits the firehouse. On return to the firehouse, fire vehicles are backed into the engine bays.

Since moving vehicles cannot be connected to the mechanical exhaust system, vehicle exhaust is released into the interior of the firehouse as fire apparatus exit and re-enter the engine bays. Once vehicle exhaust enters the interior of the firehouse, there exist a number of pathways for vehicle exhaust and other pollutants to move from the first floor into the second floor. These include:

- The door to the front stairwell does not fit flush with its doorframe, resulting in the creation of spaces around the door (see Picture 3). The top door hinge appears to be worn, resulting in the door fitting loosely in the frame. The loosening of the door could have resulted from the hinge screws stripping the wood of the doorframe over time.
- The door to the rear stairwell also has spaces around the doorframe.
- Open seams in walls around the rear stairwell can allow air penetration (see Picture 4).
- Two fire pole holes exist in the ceiling of the engine bays. One fire pole hole has space around its door (see Picture 5).
- The ceiling of the engine bays is penetrated by holes for utilities. These holes are not sealed (see Picture 6).

Each of these conditions presents a pathway for air to move from the engine bays to the second floor. In order to explain how engine bay pollutants may be impacting the second floor, the following concepts concerning heated air and creation of air movement must be understood.

1. Heated air will create upward air movement (called the stack effect).
2. Cold air moves to hot air, which creates drafts.

3. As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
4. Airflow is created, intended or otherwise, from items that produce heat (e.g., vehicle engines).
5. Combusted fossil fuels contain heat, gasses and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
6. Airflow created by the stack effect or drafts can draw particulates into the air stream.

Each of these concepts has influence on the movement of odors to the second floor. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bays can place the garage under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, spaces around utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, sealing of the pollutant pathways to the second floor should be considered.

The use of mechanical exhaust ventilation to create negative air pressure in engine bays while the fire station is occupied can serve to prevent/limit odor penetration into the second floor. For garages the Massachusetts Building Code requires a minimum ventilation rate of 1.5 cubic feet per minute (cfm) per square foot of floor space of fresh outside air (SBBRS, 1997; BOCA, 1993).

During the course of the assessment, detectable levels of carbon monoxide were measured in the kitchen (1-2 ppm). The kitchen has a natural gas stove with a pilot light. No local exhaust ventilation exists in the kitchen. The process of combustion of natural gas can produce a number of pollutants, including carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a correction 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 the rink, that operator must take actions to reduce carbon monoxide levels. (MDPH, 1997). The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 1999). No carbon monoxide levels measured in the firehouse exceeded the MDPH ice rink correction levels or NAAQS. However, without local exhaust ventilation for the stove, combustion of natural gas would continue to be expected to be a source of carbon monoxide production in the kitchen.

The fire station and the town hall share an adjoining wall. While the first and second floors appear to have minimal air pathways, a hole for access to a crawlspace beneath the town hall exists in the basement of the fire station (see Picture 7). Stored in the basement are several pieces of fossil fuel powered equipment, including the emergency electrical generator. The opening between the buildings can serve as a means for odors to move from the fire station basement into the town hall crawlspace. Once in the crawlspace, pollutants could potentially move into the ground and first floor through spaces in floor or walls.

Conclusions/Recommendations

In view of the findings at the time of the visit, health and building complaints are consistent with what might be encountered in a building with various pollutant sources, that lacks mechanical ventilation. In order to improve indoor air quality the following recommendations are made:

1. Operate the vehicle exhaust ventilation system on a continuous basis to create negative air pressure in the engine bays.
2. Seal utility holes in the ceiling of the engine bays. Continue with plans to seal the remaining fire pole hole. Caulk the seam around the plywood plugs placed over the fire pole holes.
3. Refit the hinges of the front stairwell door. Install weather stripping along the doorframe and a door sweep on the underside of all doors that access the engine bays.
4. Render the walls along the back stairwell airtight. Installing gypsum wallboard over the original walls and sealing the seams with caulking may be the most cost-effective method to create an airtight barrier.
5. Consider installing local exhaust ventilation for the natural gas stove in the kitchen.
6. 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 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).

References

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

US EPA. 1999. National Primary Ambient Air Standards for carbon monoxide. 40 CFR 50.8.

Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

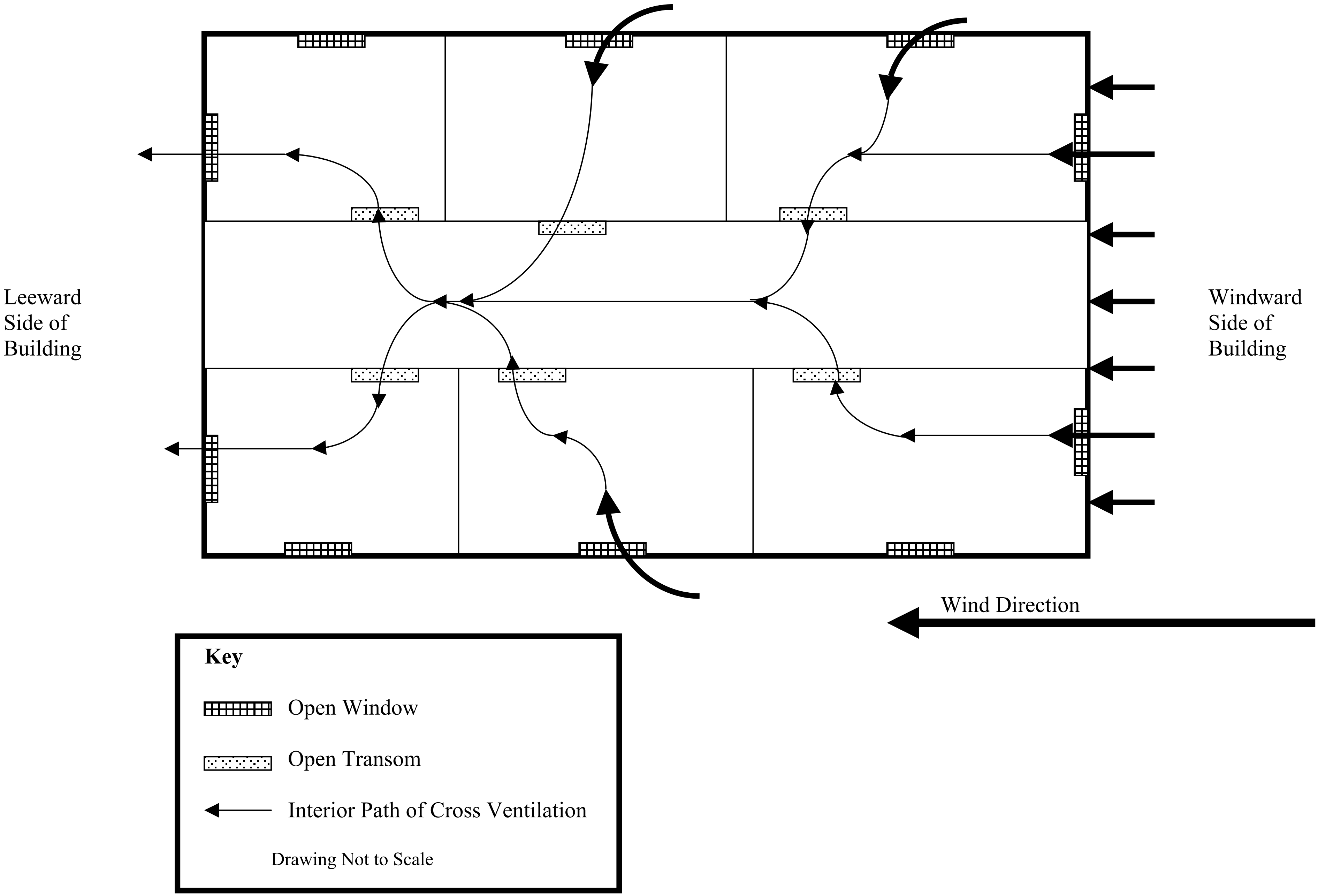
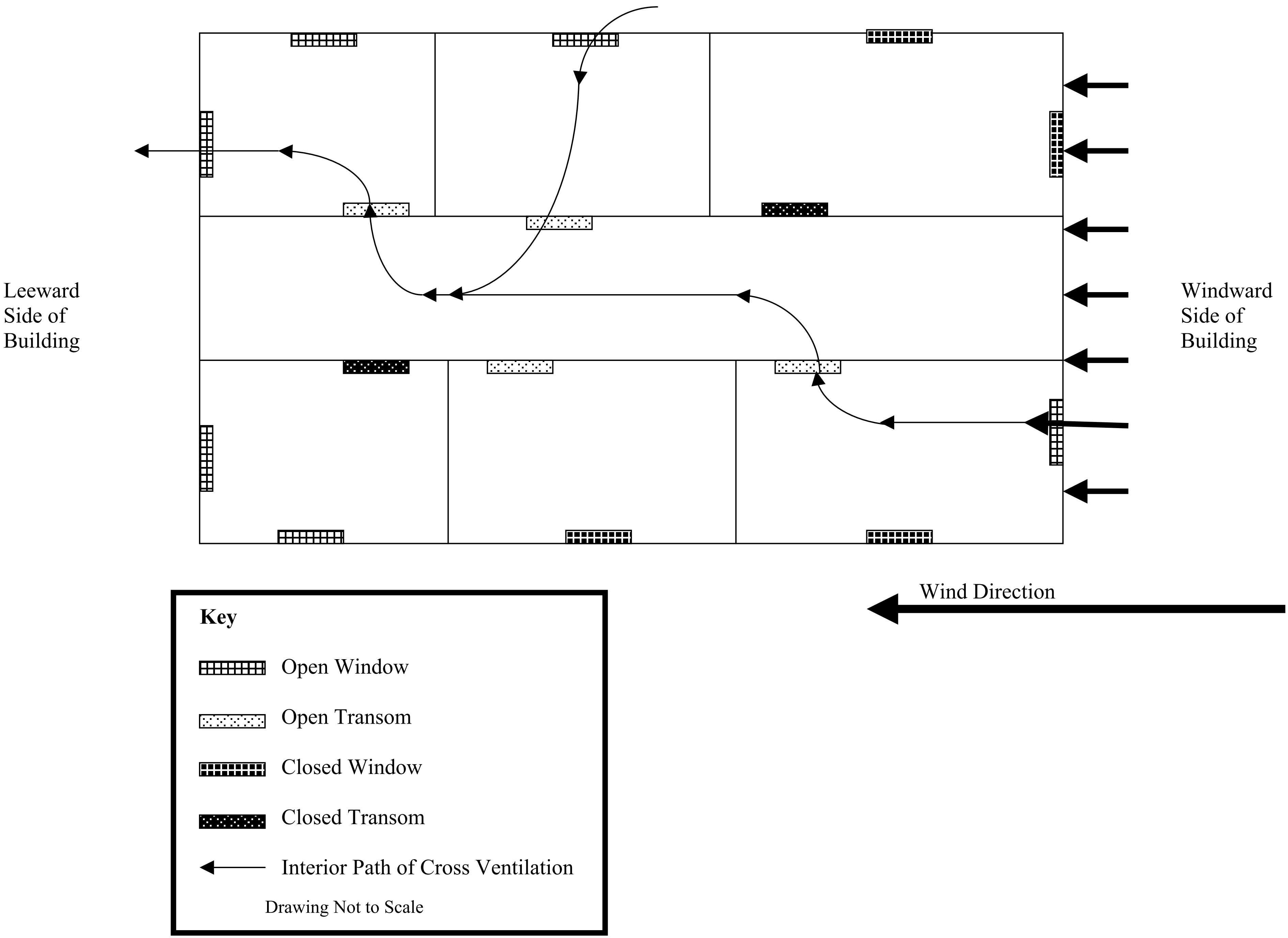


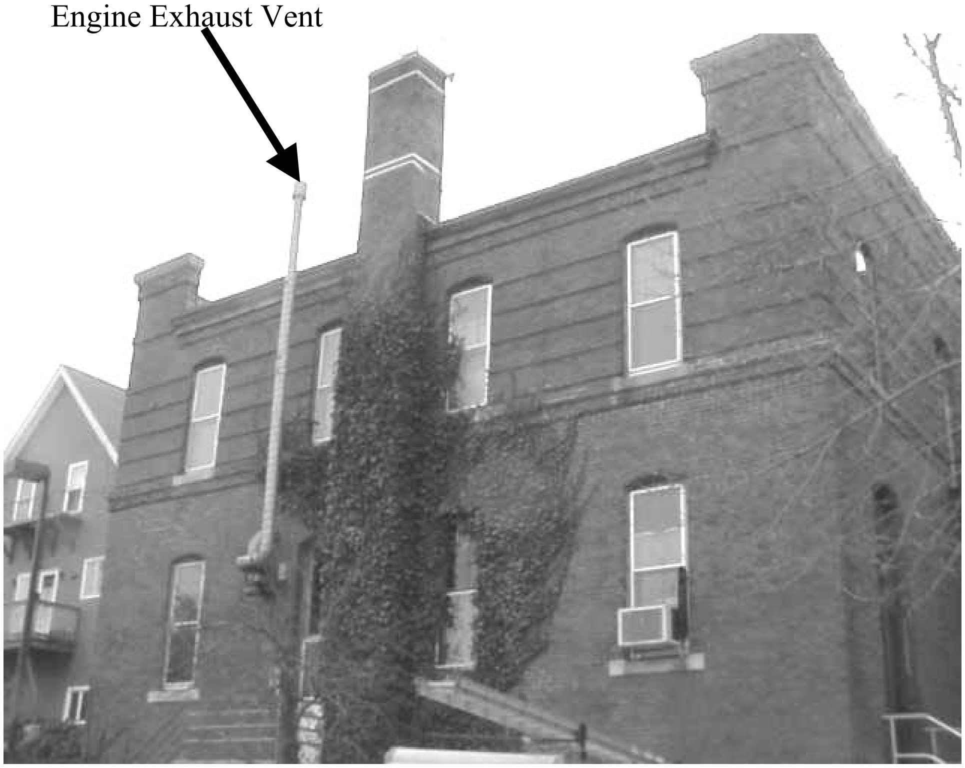
Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



Picture 1

North Andover Fire Station

Picture 2



Exhaust Vent for Fire Engines

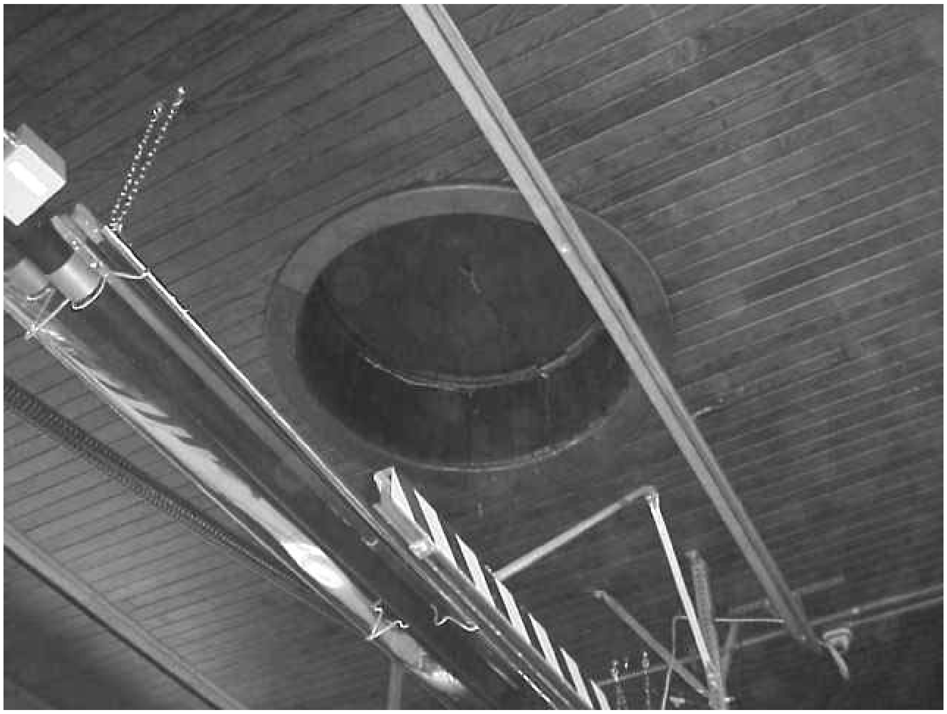
Picture 3

Space in Doorframe Adjacent to Engine Bays

Picture 4

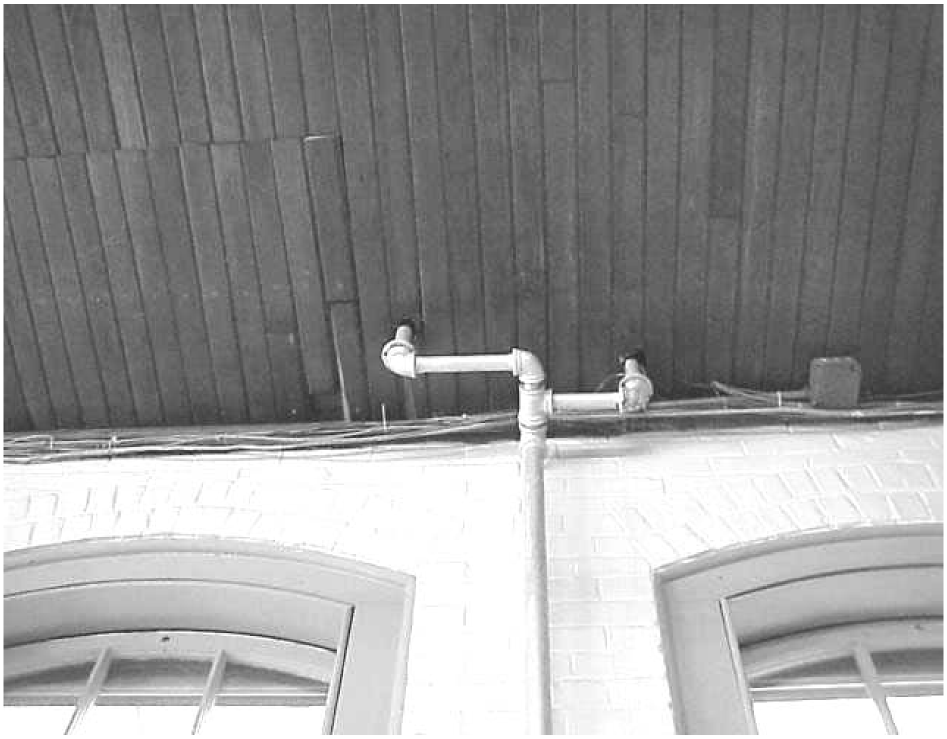
Spaces in Wall around Back Stairwell Wall

Picture 5



Fire Pole Hole in Ceiling

Picture 6



Utility Holes in Ceiling of Engine Bays

Picture 7

Hole in Fire Station/Town Hall Shared Wall

TABLE 2

Indoor Air Test Results – North Andover Fire Department, North Andover, MA – February 15, 2001

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Outside (Background)	398		41	26					
Town Manager – Reception						Yes			2 water damaged CT, transom open, door open
Fire Station-Cell 4	484	0	68	30	2	No	No	No	Entrance to crawlspace to town hall
Garage	553	0	68	36	3	Yes	No	No	Holes in ceiling
Credit Union	1115	0	73	36	2	No	No	No	Window mounted A/C, plant/dirt
Secretary	586	0	71	31	1	Yes	No	No	Photocopier
Deputy Chief's Office	754	0	70	32	0	Yes	No	No	Door open
Lt. Office	760	0	69	33	0	Yes	No	No	Water damaged CT-fiberglass, door open
Fire Prevention	781	1	69	35	0	Yes	No	No	Door open
Pole Room									Hole to garage-truck odor

*** 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 – North Andover Fire Department, North Andover, MA – February 15, 2001

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Intake	Exhaust	
Front Sleeping Quarters	1090		67	38	0	Yes	No	No	Door open
Company Room	1125		68	39	7	Yes	No	No	Door open
Kitchen	1025		69	39	0	Yes	No	No	Gas odor, un-vented gas stove, 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%