INDOOR AIR QUALITY ASSESSMENT

Natick Fire Department
22 East Central Street
Natick, Massachusetts

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

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Background/Introduction

At the request of Jim White, Senior Environmental Health Specialist, Natick Public Health Department, an indoor air quality assessment was done at the Natick Fire Department Headquarters (NFD) on 22 East Central Street in Natick, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA). The request was prompted by concerns of potential mold growth resulting from water damage and occupant complaints of reoccurring sinus infections and cold/flu-like symptoms.

On December 26, 2002, a visit was made to the NFD by Cory Holmes, of BEHA's Emergency Response/ Indoor Air Quality (ER/IAQ) Program to conduct an indoor air quality assessment. The station is a two-story red brick building that was constructed in 1998. The first floor contains the engine bay, a locker room for turnout gear, administrative offices, a classroom and the watch desk, which is directly off the engine bay. The second floor contains the bunkhouse (for overnight staff), weight room, several recreation rooms, cafeteria and office space. Windows are openable throughout the building. The front of the building has four garage doors that enclose the engine bay. A stairwell off the engine bay connects the bay to the day room on the second floor. Several fire poles connecting the second floor to the engine bay are located in the second floor main hallway.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525.

Results

The station is staffed 24 hours a day/seven days a week and has an employee population of approximately 40 (eight per shift). The station is visited by approximately 10-15 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results for general air quality parameters (i.e., carbon dioxide, temperature and relative humidity) appear in Tables 1-2. Test results for ultrafine particulates and carbon monoxide are listed in Table 3.

Discussion

Ventilation

It can be seen from the tables that the carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, which indicates adequate air exchange by the ventilation system. Ventilation is provided by a number of rooftop air handling units (AHUs). AHUs are connected to wall mounted air diffusers by ducts. Return vents located throughout the building draw air from interior areas back to each AHU via ductwork. These systems were in operation during the assessment.

A vehicle exhaust ventilation system is installed in the engine bays to remove carbon monoxide and other products of combustion. This system is discussed in detail in the **Other Concerns** section of this report.

To maximize air exchange, the BEHA recommends that the general ventilation system operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the system 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 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 firehouses 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 63^{o} F to 72^{o} F, which were below the

BEHA recommended comfort range in some areas. 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 22 to 41 percent, with most areas being below the BEHA recommended comfort guidelines. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. During winter months outdoor relative humidity levels tend to drop. 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 northern part of the United States.

Microbial/Moisture Concerns

The building has experienced problems with water penetration, most notably the second floor ceiling (see Tables/Picture 1). Water-damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered. BEHA staff observed conditions in the ceiling plenum above ceiling tiles in a number of areas where water damage was noted. No visible microbial growth and/or associated mold-like odors were detected nor were any obvious sources of interior moisture problems identified.

Vehicle Exhaust

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 importance is vehicle exhaust. In order to assess whether contaminants generated by diesel engines were migrating into occupied areas of the station, measurement for airborne particulates in combination with carbon monoxide measurements were used to pinpoint the source of combustion products.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include 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 corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within 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, 2000). No carbon monoxide measurements taken during the assessment exceeded the NAAQS.

The combustion of fossil fuels can produce particulate matter that is of a small diameter (10 μm), which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas. Inhaled particles can cause respiratory irritation.

Air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, in that it can be used as a tracker to identify the source of airborne pollutants by counting the actual number of airborne particles. The source can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increase as the UPC is moved closer to the source of particle production.

While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or that particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether the NAAQS PM_{10} standard was exceeded. The primary purpose of these tests at the fire station was to identify and reduce/prevent pollutant pathways. Air monitoring for ultrafine particles was conducted around each door with access to the engine bay as well as within each room in the station (e.g., offices, berthing areas). Several sets of readings were taken prior to and during diesel engine operation. As expected, the highest readings for ultrafine particulates were taken in the engine bay during diesel engine operation.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bays during vehicle idling. The system is designed with a pressurized cuff attached to flexible hose that fits directly over the exhaust pipe of fire apparatus (see Picture 2). As vehicles exit the engine bay the hose slides down a runner tripping a switch that depressurizes and releases the cuff (see Picture 3). When vehicles return to the firehouse, the flexible hoses are manually reattached.

As demonstrated by the particle counts shown in Table 3, a number of pathways for vehicle exhaust and other pollutants to move from the engine bay into occupied areas on both the first and second floors were identified by BEHA staff (see Figure 1). The watch desk office directly off the engine bay had a large gap beneath the engine bay door (see Picture 4). A similar space in which light could be seen penetrating was observed beneath the door to the stairwell (also off the engine bay) leading to the upstairs (see Picture 5). During engine operation an ultrafine particulate reading of 50,000 particles/cc of air was taken at the bottom of the door inside the watch desk office as compared to a measurement of 6,600 particles/cc prior to vehicle operation. Similar readings were recorded in the stairwell and above spaces in second floor fire pole dampers (see Tables/Picture 6). These results demonstrate that breaches are serving as pathways for diesel exhaust and particulates to move from the engine bay into other areas of the station.

Another possible mechanism for exhaust emissions is through utility holes. The ceiling/walls of the engine bay are penetrated by holes for utilities. These holes can present potential pathways into occupied areas if they are not sealed airtight.

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

- ♦ Heated air will create upward air movement (called the stack effect).

- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of odors to the second floor and watch desk office. 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 bay can place the garage under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the adjacent areas, sealing of these pollutant pathways should be considered.

Other Concerns

NFD staff could not identify the date of the last HVAC filter change or if a preventative maintenance program for HVAC equipment was in place. BEHA staff removed the access plates from several of the rooftop AHUs to examine filters. AHUs were equipped with high efficiency pleated filters. Several filters were saturated with dirt and debris (see Pictures 7 & 8). A clogged filter can obstruct airflow through the filters, and may serve as a reservoir of particulates that can be re-aerosolized and distributed to occupied areas via the ventilation system.

Missing/dislodged ceiling tiles were observed in several areas. A number of supply and return vents were coated with dirt/dust (see Picture 9). The activation of the HVAC system or the movement of ceiling tiles can introduce dirt, dust and particulate matter into occupied areas. These materials can be irritating to certain individuals.

Conclusions/Recommendations

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

1. Ensure doors around engine bay fit completely flush with threshold. Seal doors on all sides with foam tape and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
2. Examine ways to prevent leakage around fire pole dampers or consider installing local exhaust ventilation directly over fire poles to remove lingering exhaust fumes.
3. Ensure all utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.
4. Continue to work with Natick Town Officials to develop a preventative maintenance program for all HVAC equipment including local exhaust system for the engine bay.
5. Change filters for AHU equipment as per the manufacturer's instructions or more frequently if needed.
6. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of building occupancy independent of thermostat control (excluding engine bay exhaust system).

7. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994). Consult a ventilation engineer concerning re-balancing of the ventilation systems.
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 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).
9. Continue working with Natick Town Officials to identify and address building leaks. Once repaired, replace any remaining water-stained ceiling tiles. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.
10. Clean air diffusers and return vents periodically of accumulated dirt/dust build-up.
11. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

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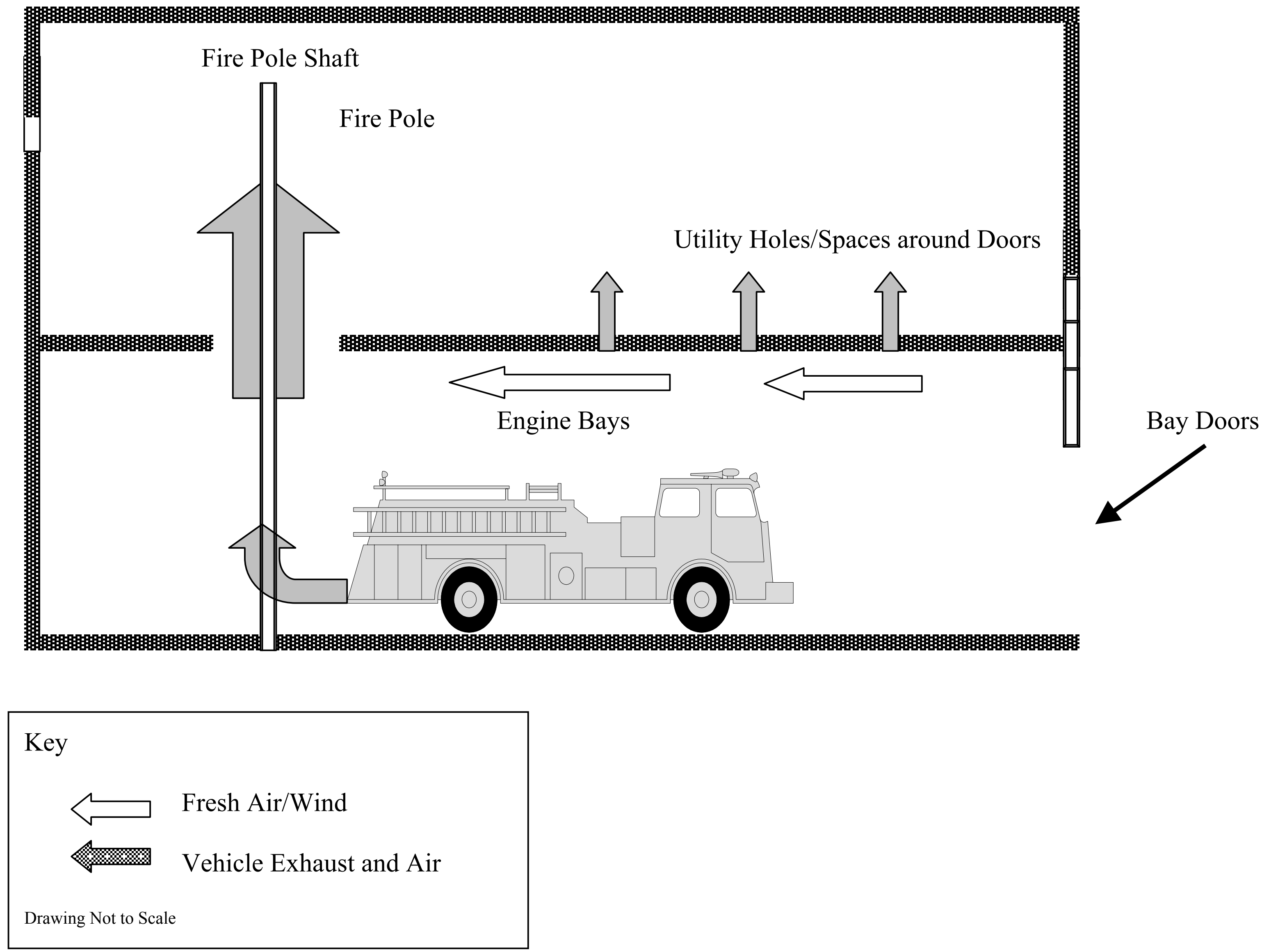
Figure 1 **Potential Pathways of Air and Pollutant Movement from Engine Bays through Holes in Ceilings and Spaces around Door Frames**



Picture 1

Water Damaged Ceiling Tiles

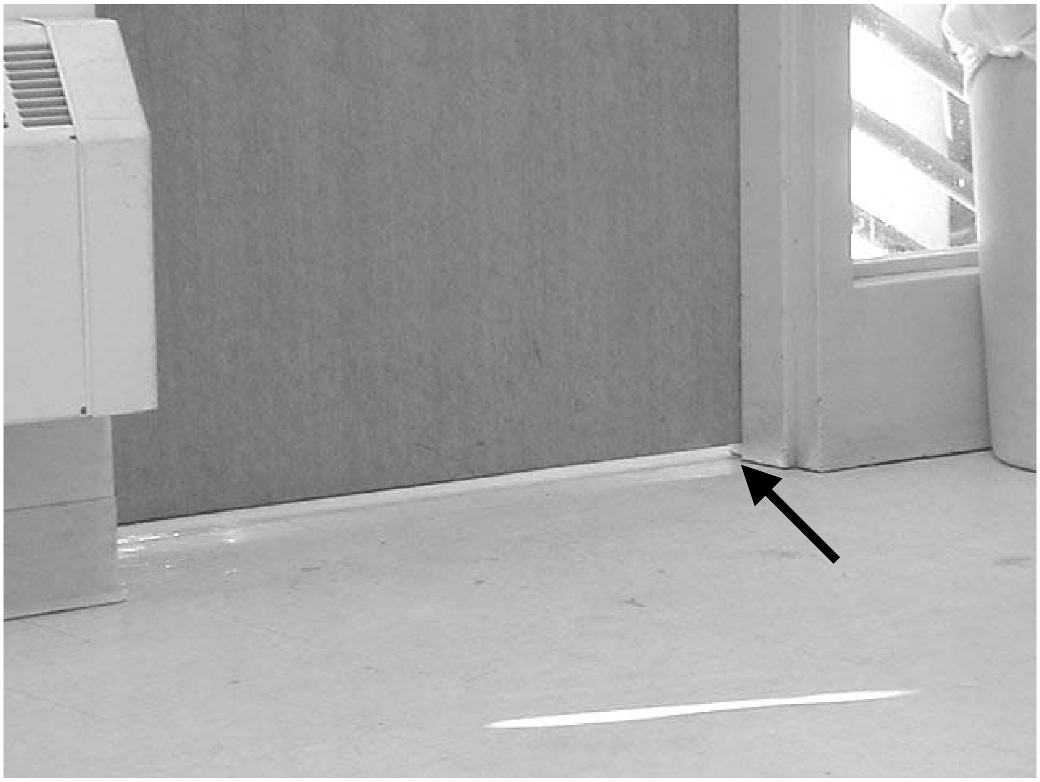
Picture 2

Pressurized Cuff/Flexible Hose for Local Exhaust System in Engine Bay

Picture 3

Runner Attached to Flexible Hose for Local Exhaust System in Engine Bay

Picture 4

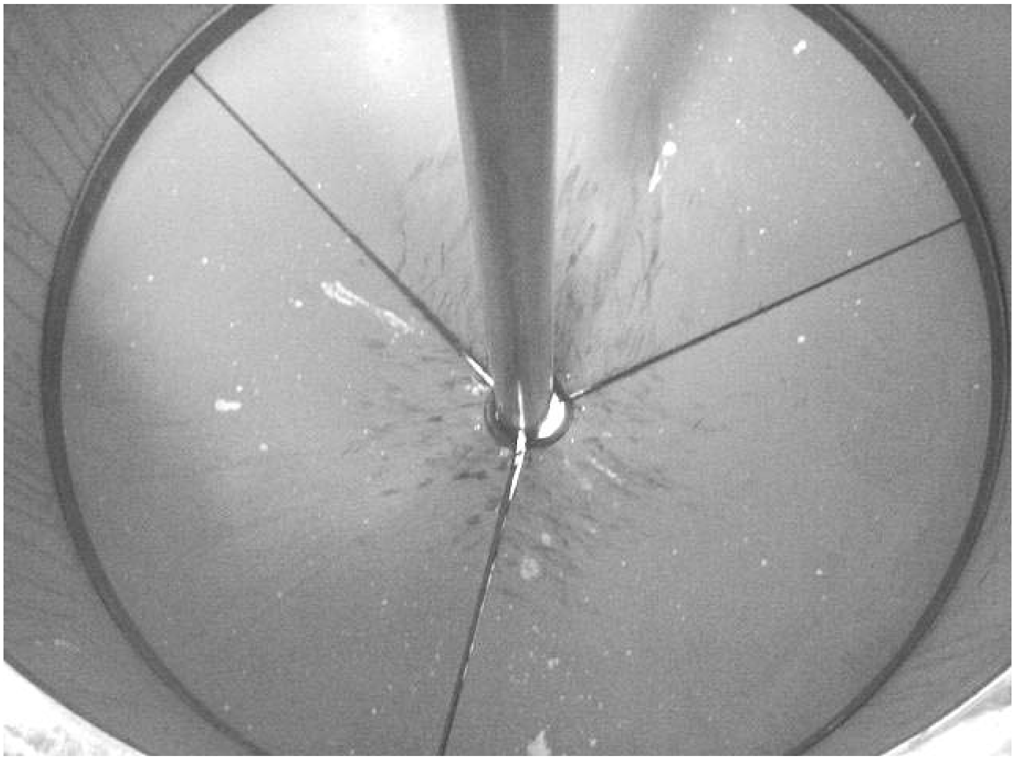


Approximate one-inch Gap beneath Watch Desk Door to Engine Bay

Picture 5

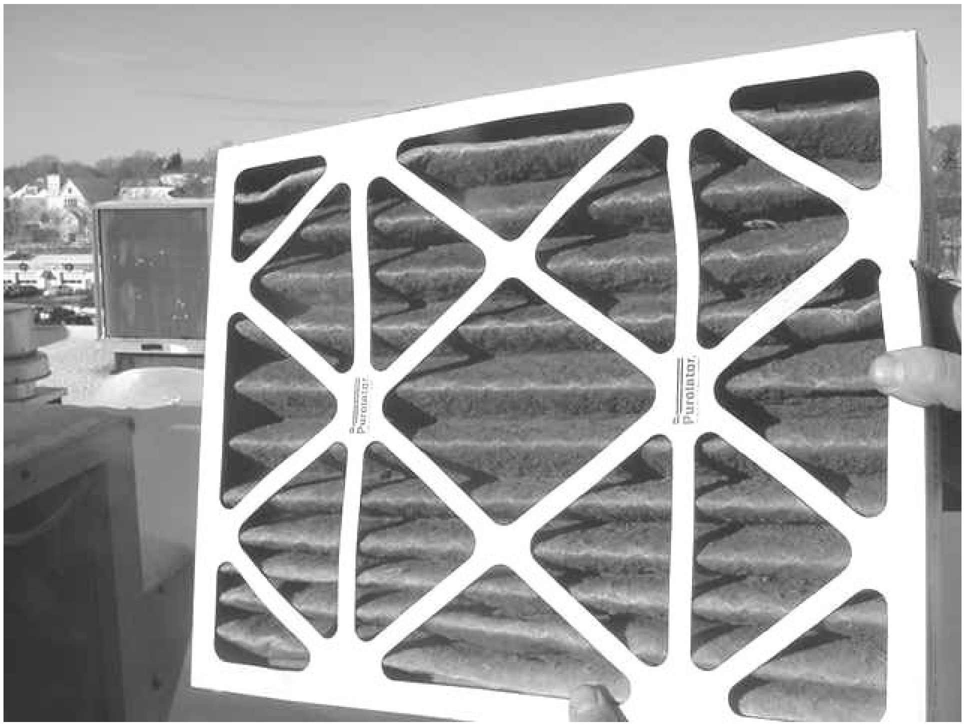
Space Beneath Stairway Door to Engine Bay

Picture 6

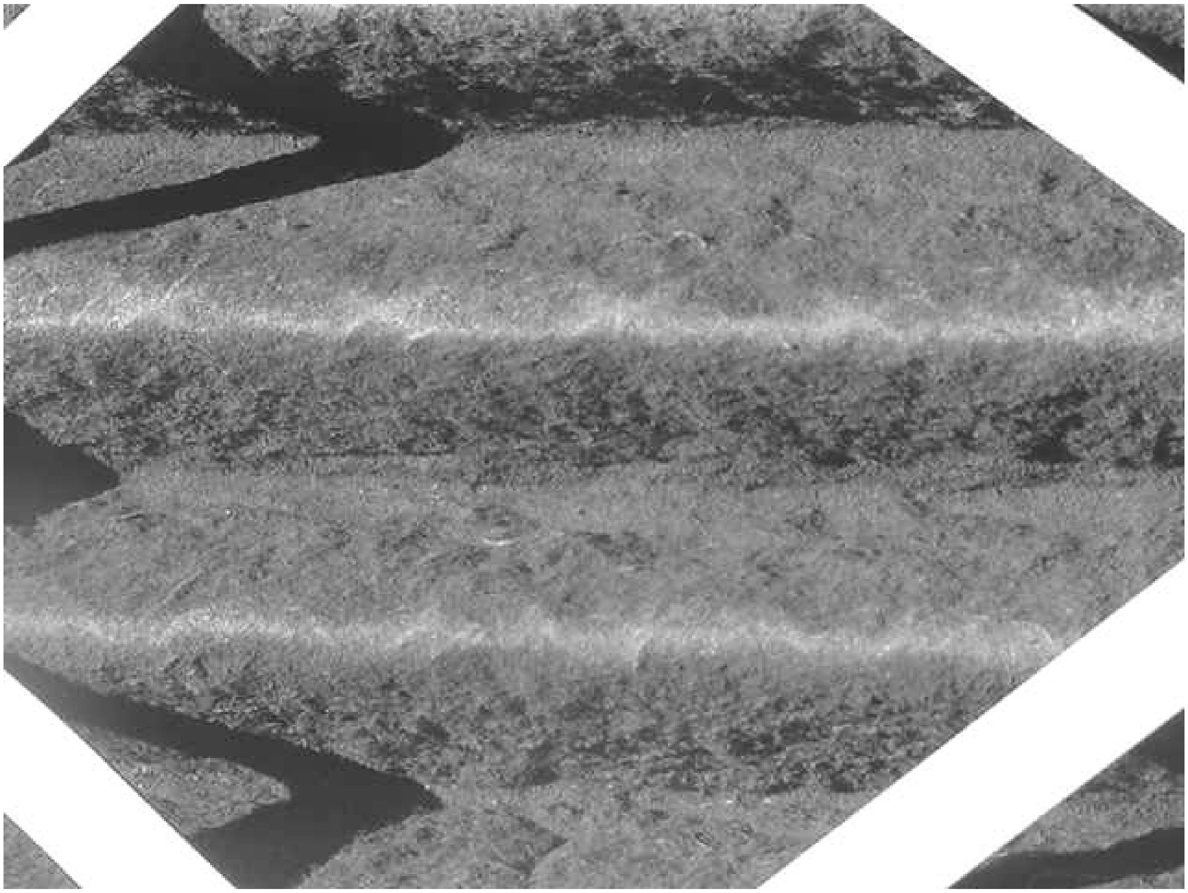


Spaces around Fire Pole Dampers Taken from Second Floor

Picture 7

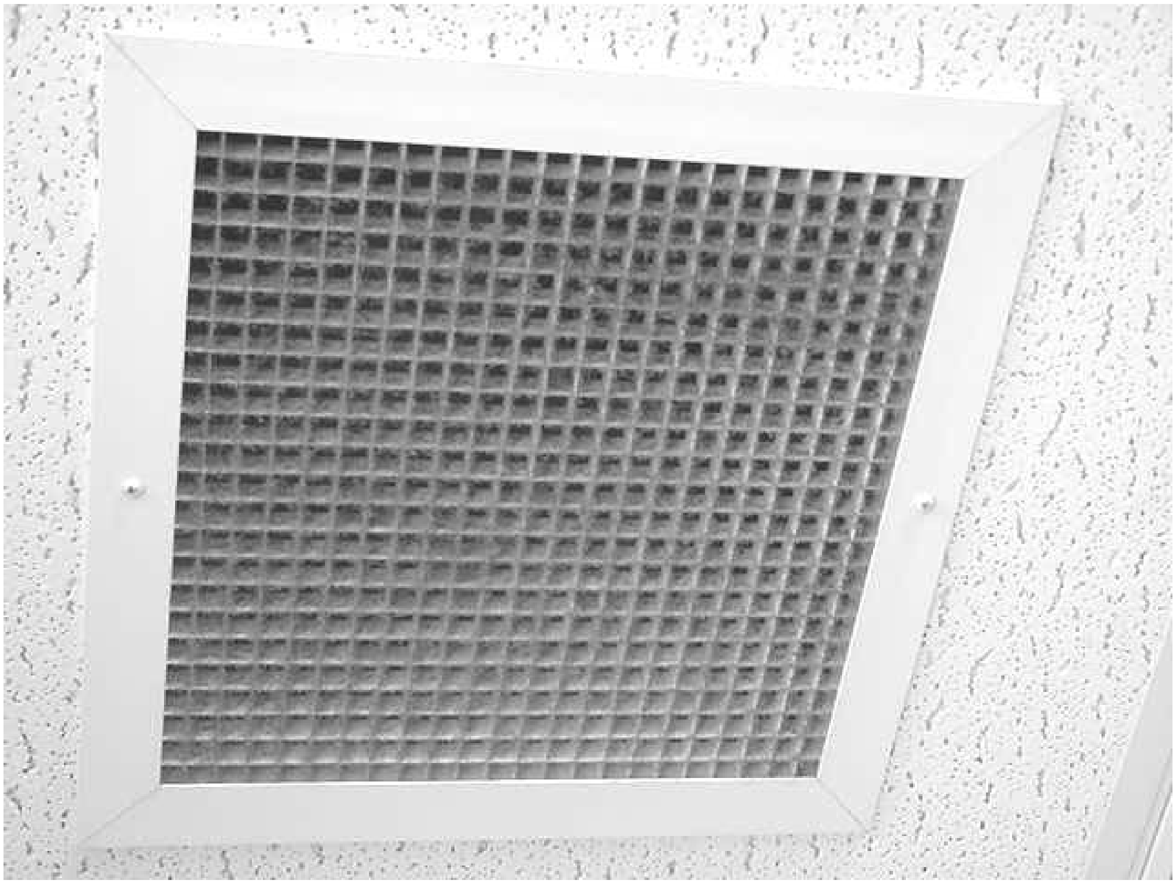


Picture 8



Close-up of Filter in Preceding Picture

Picture 9



Dirt/Dust Build-up on Return Vent

TABLE 1

Indoor Air Test Results – Natick Fire Department - Natick, MA – December 26, 2002

Location	Carbon Dioxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	368	37	33					Cold brisk wind 10-15 mph Moderate to heavy traffic
Watch Desk	799	63	41	5	Y	Y	Y	1-inch space beneath door
Front Stair Tower	575	66	32					1 space heater Door undercut Stairwell
Engine Bay	515	71	30	5	Y	Y	Y	5 Garage doors
Rear Entrance Hallway	404	71	25					
Class Room								Space heater Door undercut
Hallway between Classroom & Training Dept. Off.								7 CT
2nd Floor Hallway	553	69	24					
Library	506	70	25	0	Y	Y	Y	
Billiard Room	542	70	23	0	Y	Y	Y	5 CT

*** 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 – Natick Fire Department - Natick, MA – December 26, 2002

Location	Carbon Dioxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
TV Room	515	70	23	0	Y	Y	Y	
Gym	550	69	23	0	Y	Yes	Yes	2 dislodged ceiling tiles
Kitchen	686	70	25	5	Y	Y	Y	Gas stove Ducted outside
West Wing	794	71	22	0	Y	Y	Y	Window open

*** ppm = parts per million parts of air**
CT = water-damaged ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
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Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%