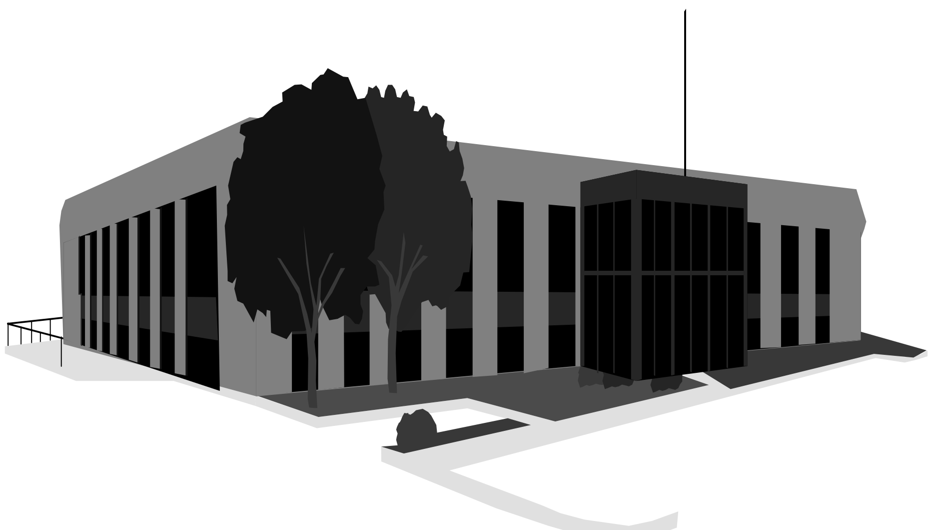
INDOOR AIR QUALITY ASSESSMENT

Reading Fire Department
757 Main Street Firehouse
Reading, Massachusetts



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Background/Introduction

At the request of Jane Fiore of the Reading Health Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at Reading Fire Station (the firehouse), 757 Main Street, Reading, Massachusetts. On February 15, 2001, a visit was made to this office by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA to conduct an indoor air quality assessment. Reports of fire department personnel experiencing respiratory symptoms and nose bleeds after sleeping in the bunkhouse prompted the request for this assessment.

The firehouse is a two-story red brick building constructed in 1989. The firehouse second floor has offices, a meeting room, bunkhouse, lounge and kitchen. The first floor contains three engine bays and reception office. The ground floor contains an indoor parking garage and storerooms. A stairwell connects the ground floor to the second and first floors on the north wall of the building. A stairwell and elevator shaft connect the first floor reception office to the second floor. The front of the building has three garage doors that enclose the engine bays. The second floor bunkhouse area has fire poles at each end of its hallway. Each fire pole is sealed from the bunkhouse hall by doors (see Picture 1). Two fire poles connecting the second floor to the engine bays exist. Windows are openable and are used by firefighters to create ventilation in bunkhouse rooms.

Methods

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

Results

These offices have 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 carbon dioxide levels were below 800 parts per million of air (ppm) in all areas sampled, indicating adequate air exchange. The second floor has a mechanical ventilation system installed above the suspended ceiling on the second floor. Fresh air is delivered to the ceiling-mounted air handling unit (AHU) by a passive rooftop vent by ductwork. The AHU delivers air to second floor rooms by ceiling mounted fresh air diffusers via ductwork. The AHU was operating during the assessment.

The second floor general mechanical ventilation system does not provide exhaust ventilation. Return air exhaust ventilation is provided by infiltration of air into an open plenum above the ceiling, which returns air to the AHU. This system has no ductwork, but uses the entire ceiling space to draw air back to the AHU. Air is drawn into the ceiling plenum through plastic grates. Some bunkrooms do not have plastic grates, which prevents air in these rooms from returning to the AHU. Originally, this ventilation system did not have a fresh air supply. A passive vent was retrofitted to the roof and connected to the original AHU. Prior to this installation, the ventilation system would only recirculate air on the second floor. The ventilation system does 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 vehicle exhaust ventilation system was installed in the engine bays to remove carbon monoxide and other products of combustion. These wall-mounted fans were originally designed to draw pollutants from the engine bays and eject them from the building at the same level as the engine bays (see Figure 1 and Picture 2). This design reportedly resulted in vehicle exhaust entering bunkhouse rooms when windows were open. These type of exhaust systems are customarily connected to a chimney system that terminates above the roof (see Picture 3 for examples at another firehouse). In an effort to prevent vehicle exhaust penetration, fire department officials reported that the exhaust fans were *intentionally reversed* to inject outside air *into* the engine bays (see Figure 2). This reconfiguration can result in the forcing of engine bay pollutants into the second floor.

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 fire houses 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 72^{o} F to 74^{o} F in the second floor areas, which were within 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 the building was below the BEHA recommended comfort range of 40 to 60 percent in all areas sampled the day of the assessment. Relative humidity measurements ranged from 21 to 23 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

The training room had water-damaged ceiling tiles that can indicate water leaks from either the roof or condensation from the ventilation system. Ceiling tiles can serve as growth media for mold, especially if wetted repeatedly. These materials should be replaced after a water leak is discovered.

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:

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

Of particular importance is vehicle exhaust. The firehouse is equipped with a mechanical exhaust system to remove exhaust from the engine bays during vehicle idling. Each fire engine is connected to the mechanical ventilation exhaust system by using a flexible hose (see Picture 4). As the mechanical exhaust vent system operates, vehicle exhaust is drawn to a fan motor. In addition, fans are installed at floor level to provide exhaust ventilation for the engine bays (see Picture 5). This floor exhaust ventilation system was reportedly altered to attempt to prevent fire apparatus exhaust from penetrating into the second floor. Vehicle exhaust is ejected into the interior of the firehouse as fire apparatus leave and return to the engine bays. Once vehicle exhaust enters the interior of the firehouse, a number of pathways exist for vehicle exhaust and other pollutants to move from the engine bays into the dispatch office and second floor.

1. The doors between the engine bays and reception office have spaces in the doorframe when closed.
2. Enhancing the draw of air through the reception office from the engine bays as well as from the ground floor parking garage is the operation of the building's elevator. An elevator traveling up and down in its shaft acts like a piston, which can draw air and accompanying pollutants into the elevator shaft.
3. The elevator is also connected to the indoor parking garage below the engine bays. As with the reception office, pollutants from the parking garage can be drawn into the elevator shaft and distributed to other floors of the firehouse.
4. The doors on all floors in the north stairwell also have spaces around the doorframe.
5. The door that seals the fire pole has spaces in the doorframe when closed. Heavy deposition of dust and soot were noted along the inside surface of the lounge fire pole door (see Picture 6).
6. The ceiling of the engine bays is penetrated by holes for utilities (see Picture 7). These holes are not sealed.

Each of these conditions present pathways for air to move from the engine bays to the reception office and 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, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
6. Drafts or airflow created by the stack effect can draw particulates into the air stream.
7. The operation of the mechanical ventilation systems on the second floor (both the AHU and restroom/shower exhausts) can create negative air pressure, which can draw air and pollutants from the engine bays.
8. The top of each fire pole chamber is sealed within a suspended ceiling tile system. Suspended ceilings are not airtight and can allow pollutants from the engine bays to enter the ceiling plenum. Separating the plenum of the fire pole shaft from the AHU is an interior wall. If any seams or penetrations exist in this interior wall, pollutants in the fire pole ceiling plenum can penetrate into the AHU ceiling plenum.

Each of these concepts has an influence on the movement of odors to the second floor and reception office. As motor vehicles operate indoors, the production of 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, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, sealing of pollutant pathways to the second floor should be considered.

In order to overcome the creation of airflow through the mentioned pathways, two methods could be employed. The Massachusetts Building Code requires a minimum ventilation rate of 1.5 cubic feet per minute (cfm) per square feet of floor space of fresh outside air (SBBRS, 1997; BOCA, 1993) in garages. 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.

The AHU filter was examined. Attempts were made to remove this filter. The configuration of the pipes connected to the AHU required that the frame of the filter be bent into place (see Picture 8). Bending destroys the integrity of the frame, which can allow for particles to by-pass the filter and be distributed by the ventilation system. AHUs are equipped with filters that strain particulates from airflow. In addition, the openings in gypsum wallboard of bunkhouse rooms are not sealed, exposing fiberglass insulation. Particulate in the wall cavities can be drawn into the AHU and distributed by the ventilation system throughout the second floor. 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 heat pump by increased resistance. Prior to any increase of filtration, each AHU should be evaluated by a ventilation engineer to ascertain whether it can maintain function with more efficient filters.

Fire department officials also report that kitchen odors are detectable in the second floor during cooking. The kitchen stove has a ventilation hood installed over the burner, but this equipment is not ducted outdoors. Enhancing the distribution of kitchen odors is the use of the ceiling plenum to return air to the AHU and the close proximity of the AHU to the kitchen. Air from bunkrooms enters the ceiling plenum through holes cut into the gypsum wallboard that forms interior walls (see Picture 9). Several holes and pipes penetrating the gypsum wall board of the kitchen open into the ceiling plenum near the AHU, which can serve as pathways for cooking odors (see Picture 10).

A sewer vent pipe was noted on the rooftop in close proximity to the fresh air intake for a rooftop AHU (see Picture 11). Depending on wind conditions it is possible for sewer gas to enter the AHU and be distributed to occupied areas of the building by the ventilation system. Sewer gas can be a source of odor and be an irritant to the eyes, nose and throat.

Conclusions/Recommendations

Health and building complaints are consistent with conditions found in the building at the time of the assessment. In order to improve indoor air quality the following recommendations are made:

1. Consideration should be given to installing an exhaust vent stack for the engine bay exhaust system that extends over the height of the roof as depicted in Picture 3. Please note that the Massachusetts Building Code states that vents of pollutants must be either ten feet from or two feet above the fresh air intake of the ventilation system (SBBRS, 1997; BOCA, 1993). Once this ductwork is installed, the motors of the vehicle exhaust ventilation system should be reversed to their original design.
2. Reconfigure the pipes connected to the AHU to allow the unhindered replacement of the filter. Consider increasing the efficiency of the AHU filter to remove particles from the air stream.
3. Seal utility holes in the walls and ceiling of the engine bays.
4. Render the top of the fire pole shaft airtight by installing a gypsum wallboard ceiling that has all seams sealed with gypsum wallboard sealant.
5. Install weather stripping along the doorframe and a door sweep on both second floor fire pole shaft access doors.
6. Install weather stripping along the doorframe and a door sweep on the underside of all doors that access the engine bays.

7. Consider operating the mechanical exhaust system in the ground floor parking lot on a timer, to operate at peak use times instead of at a set carbon monoxide level to prevent odors from being drawn into the elevator shaft.

8. Make openings in gypsum wallboard for bunkrooms that do not have plastic grills in their ceilings. Cap the openings to the interior wall cavities with aluminum sheeting or another appropriate barrier (See Figure 3). Apply a sealant compound along the edges of the barrier material. Once completed, replace the ceiling tile closest to the hallway door with a plastic grate to create a return vent for the bunkroom.

9. Cap existing return vent plenum openings to the interior wall cavities with aluminum sheeting or another appropriate barrier. Apply a sealant compound along the edges of the barrier material.

10. Identify the source of moisture wetting ceiling tiles in the training room and repair. Once repaired, replace ceiling tiles.

11. Extend the height of the sewer vents on the roof to prevent odor entrainment by the AHU fresh air intake.

12. Examine the feasibility of ducting the kitchen stove hood outdoors.

13. 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

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

MEHRC. 1997. Indoor Air Quality for HVAC Operators & Contractors Workbook. MidAtlantic Environmental Hygiene Resource Center, Philadelphia, PA.

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.

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Figure 1 **Original Design Expels Engine Exhaust out Rear Wall, Which Then Infiltrates into Bunk House Rooms through Open Windows**

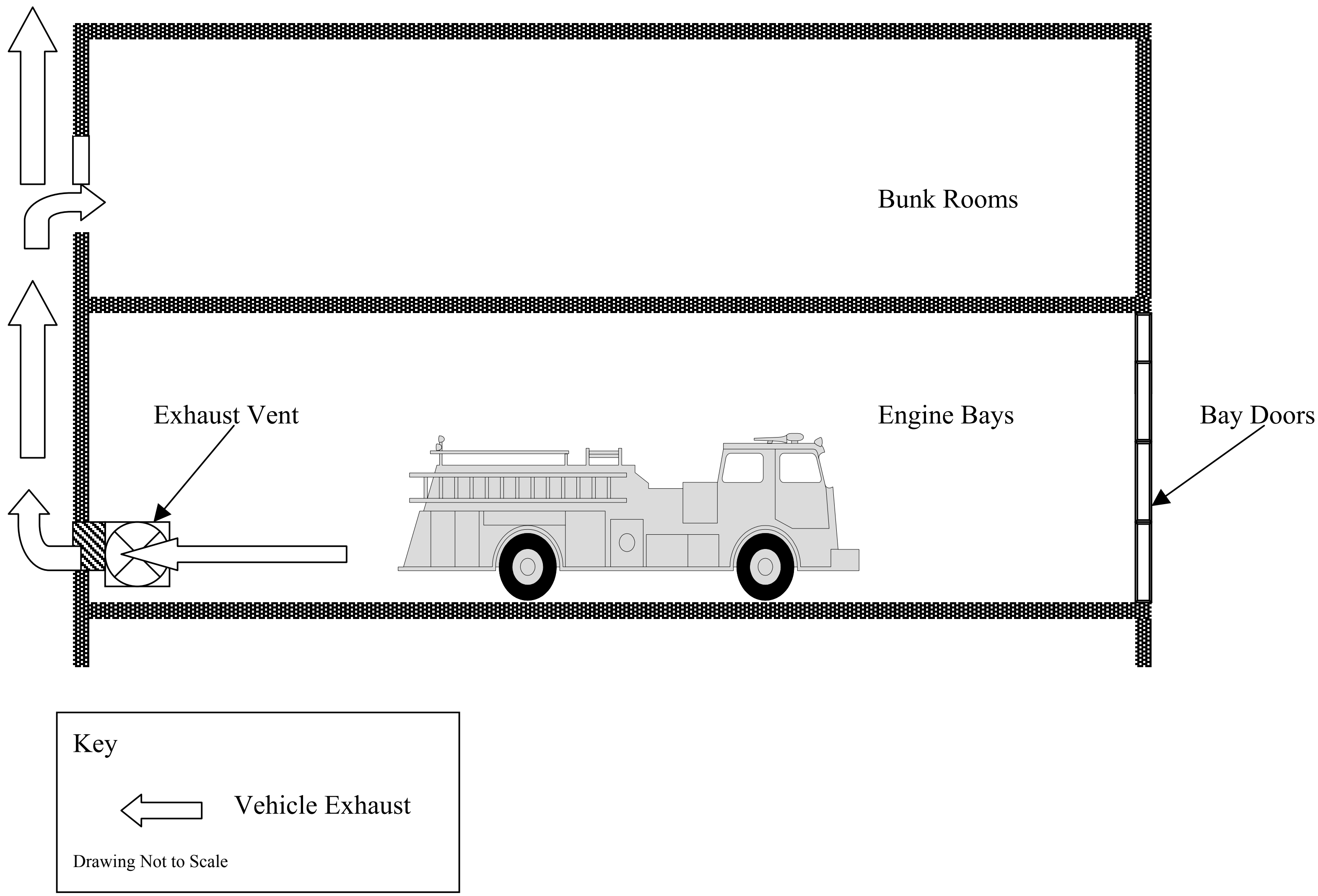


Figure 2 **Altered Design Forces Air and Particles into Engine Bays and Pollutants through Holes in Ceilings and Spaces around Door Frames**

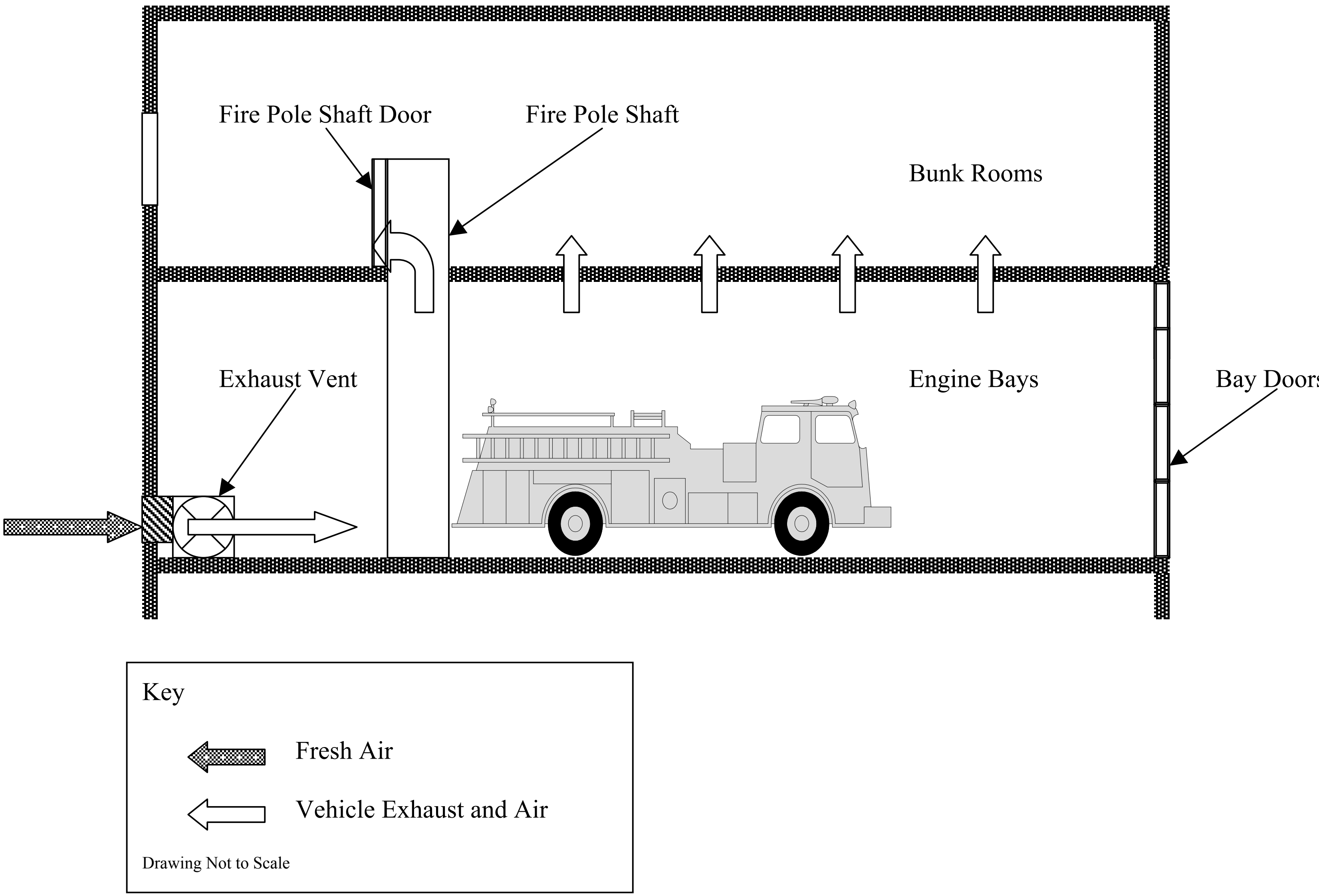
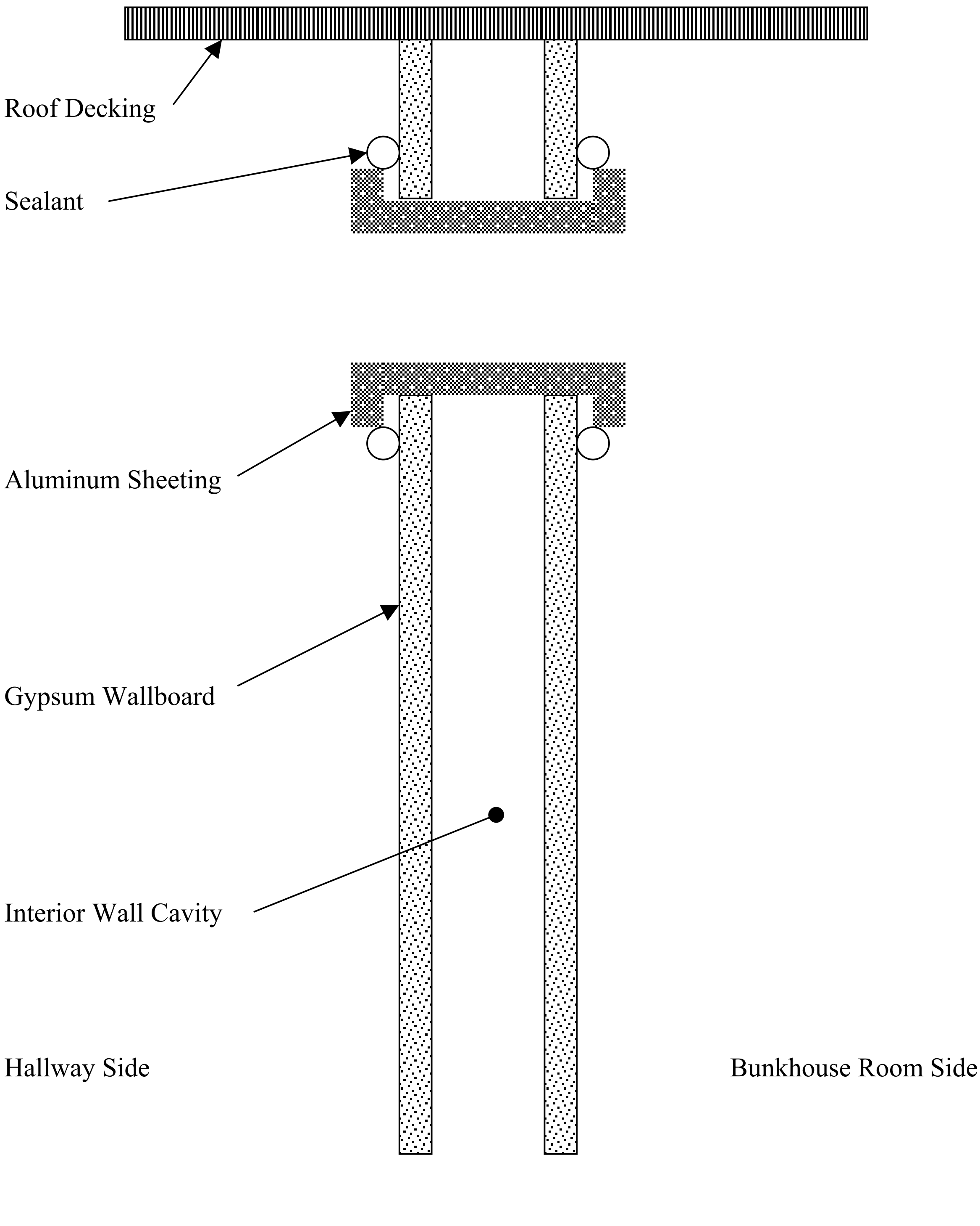


Figure 3 **Sealing of Gypsum Wallboard Holes from Bunkhouse Rooms to Hallway Ceiling Plenum**

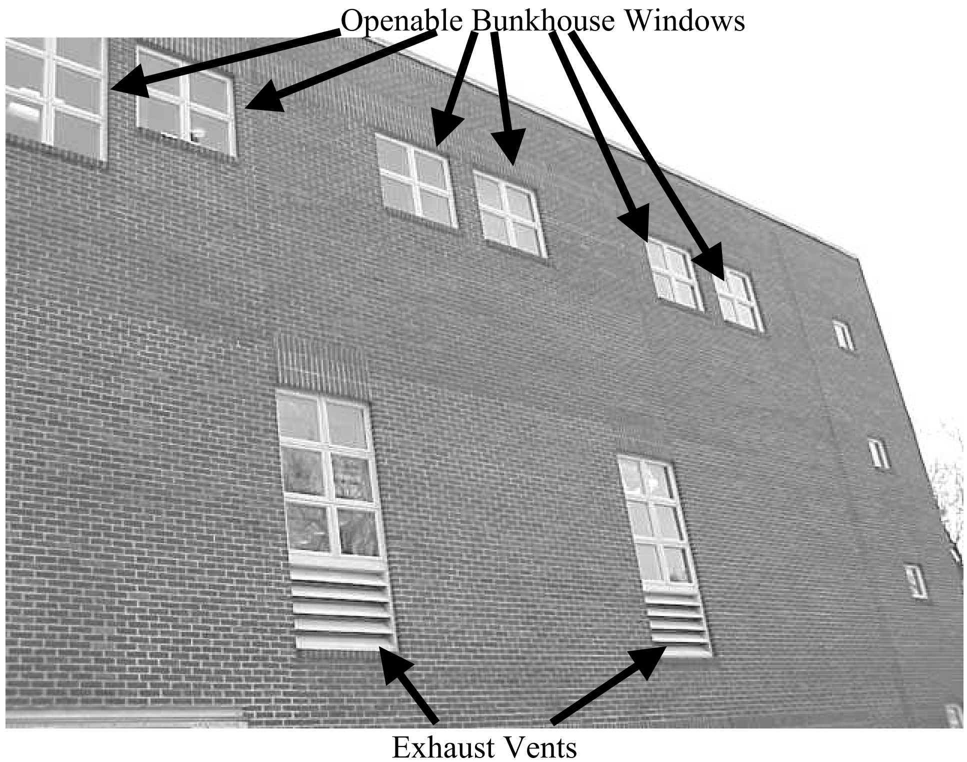


Drawing Not to Scale

Picture 1

Fire Pole Hallway Door

Picture 2



Exhaust vents for Engine bays at First floor Level, Note Bunkhouse Windows above Exhaust vents

Picture 3

Exhaust Vent Stack

Vehicle Exhaust Vent (40 West Central Street Firehouse, Franklin, MA), Note the Position and Height of Vent away from Windows at rear of Building

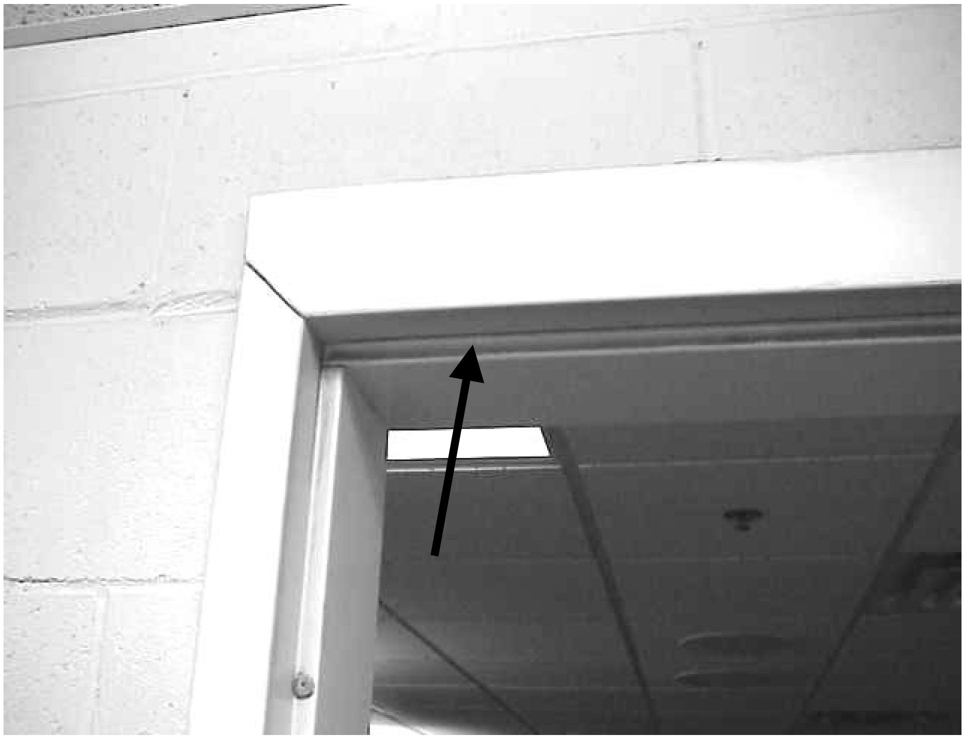
Picture 4

Tail Pipe Exhaust Vent System

Picture 5

Floor Exhaust Fan in Engine Bays

Picture 6



Dust and Soot Deposition on inside Surface of Fire Pole Door Frame

Picture 7

Utility Hole in Engine Bay Ceiling Decking

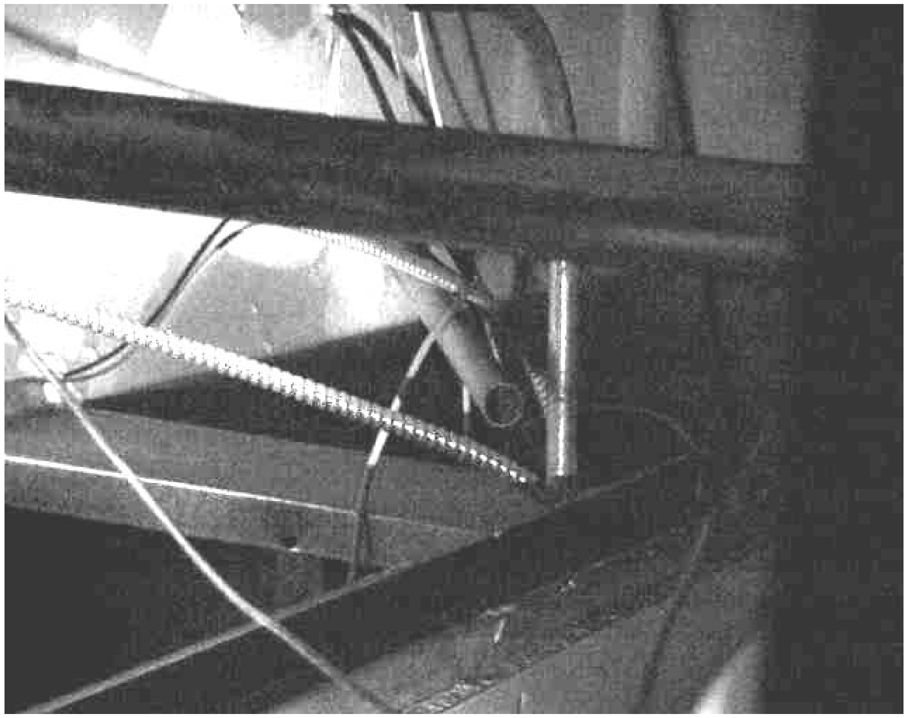
Picture 8

Filter Access Panel behind AHU Pipes

Picture 9

Holes Cut Into the Gypsum Wallboard to Create Pathway from Bunkroom Ceiling Plenum into The Hallway Ceiling Plenum, Note Exposed Fiberglass Insulation

Picture 10



Open Pipe Penetrating Kitchen Gypsum Wallboard into the Hallway Ceiling Plenum

Picture 11

Fresh air Intake **Sewer Vent Pipe**

Fresh Air Intake in Close Proximity to Sewer Vent Pipe

TABLE 1

Indoor Air Test Results – Reading Fire Department, Reading, 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 Desk	566	0	73	23	0	No	Yes	Yes	
Assistant Chief	603	0	74	23	0	Yes	Yes	No	Door open
Copier Room	547	0	74	21	0	Yes	Yes	Yes	Photocopier, door open
EMS	584	0	74	21	0	Yes	Yes	Yes	Door open
Training Room	550	0	72	21	0	Yes	Yes	Yes	2 water damaged CT, door open
Men's Restroom/Shower							No	Yes	
Captain's Room	721	0	73	23	1	Yes	Yes	No	Door open
Room 1	623	0	72	22	0	Yes	Yes	Yes	Door open
Room 2	625	0	72	22	0	Yes	Yes	Yes	Door open
Room 3	571		72	21	0	Yes	Yes	Yes	Door open
Room 4	608		72	21	0	Yes	Yes	No	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 – Reading Fire Department, Reading, MA – February 15, 2001

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Intake	Exhaust	
Kitchen	650	0	73	23	0	Yes	Yes	No	Kitchen hood-no exhaust
Lounge	595		73	21	1	Yes	Yes		Exhaust in hallway, fire pole door
Garage	467		65	22	1	Yes	Yes	No	Reverse positive pressure
Front Desk	518		66	23	0	Yes	No	No	

*** ppm = parts per million parts of air**
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