USING ASD TO MITIGATE CO_2 METHANE AND BENZENE

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ABSTRACT

Over the last few years, WPB Enterprises has been contracted to reduce CO_2 in a number of residential buildings, methane in a commercial strip mall and benzene in a school building. Each of these has been successful mitigated. This paper will discuss the approaches taken with each of these gases and the results of the mitigations.

INTRODUCTION

In general the same techniques as those used with radon re-mediation can be used to control other gas entry. There are cases however where special considerations need to be taken into account because of the dangers that other gases may cause or because of the excessive air flow that may be coming out of the soil. In these cases it is important that consultants with the needed expertise or the proper government officials be included in the initial system design and final installation.

GASOLINE SPILLS

In 1989, WPB was hired by NJ State Police to mitigate excessive gasoline fumes in a police barracks that was due to a leaking underground gasoline tank. WPB at that time had not installed an explosion proof fan. A compliance investigator for the NJ State Department of Environmental Protection was consulted over concerns about the regulations for venting gasoline fumes. The building was a simple ranch style structure that had an unfinished basement. A sub-slab pressurization system was chosen in order to avoid the hazard of venting gasoline fumes into the atmosphere and the associated risk with explosion. The system included two pressure pits along the foundation wall where the highest concentrations of fumes had been measured. Two additional pressure pits with dampers in the pipe to reduce their flow were installed along the opposite foundation wall to ensure complete sub-slab pressurization. The basement was ventilated with window fans before any electrical tools were used. Each pit was constructed by boring a five inch hole through the slab and excavating two to four gallons of sub-slab material. A single 90 watt radon fan was mounted outside in a position to blow air down into the suction pits using four inch pvc piping. All cracks in the slab were carefully sealed. Test holes indicated that good sub-slab pressure was achieved. The fan was installed at grade. A chimney cap installed on the inlet of the fan had filter fabric secured around the opening into the fan to prevent any accumulation of debris in the pressure pits. The system included a u-tube monometer to indicate fan performance. Measurements made after the installation indicated no measurable traces of gasoline fumes.

CARBON DIOXIDE (CO_2)

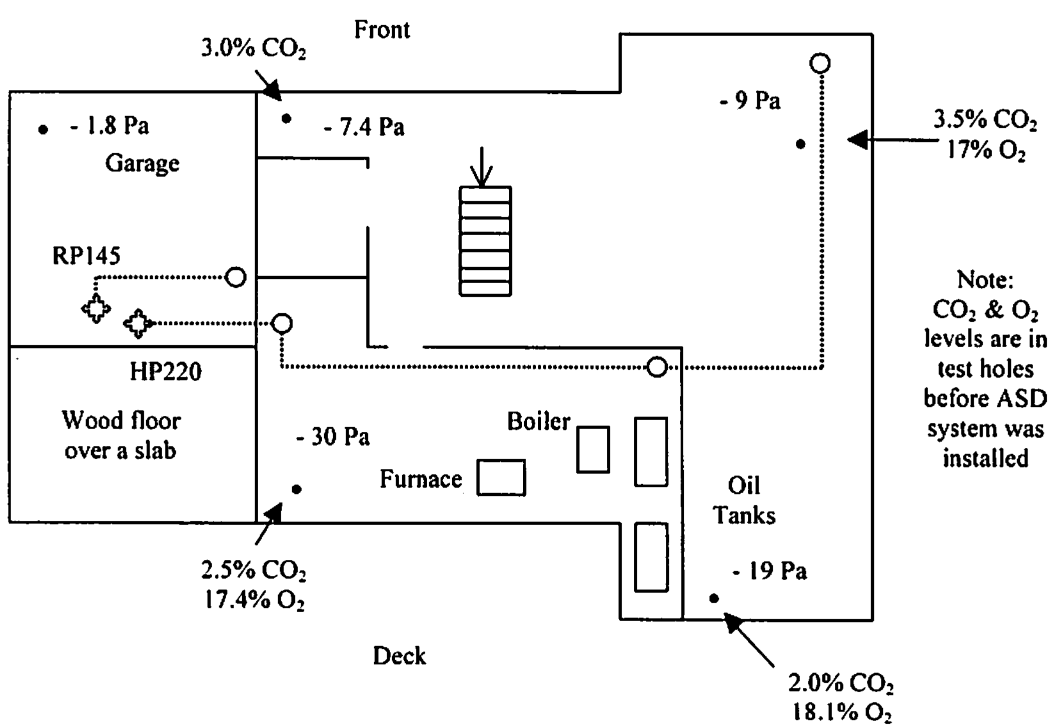
Carbon dioxide is produced by combustion and oxidation of materials containing carbon such as coal, oil and organic material. CO_2 levels in the air are typically in the 300 to 400 ppm range. Inside a densely occupied room, such as a classroom, the levels can rise to 1000 ppm or higher. Levels above 1000 ppm (0.1%) can lead to sleepiness. Navy sub-marine personnel can sometimes become adjusted over a period of time to working in concentrations as high as 10,000 ppm (1.0%). 1000 ppm is equivalent to 0.1% of the air. CO_2 is, however, 1.5 times more dense than air, so elevated concentrations are more likely at the slab level. Even if windows are open there can still be significant amounts of CO_2 near the slab. If levels of CO_2 get above 2%, the furnace and water heater will not operate due to lack of oxygen. Oxygen (O_2) in the air is typically around 21%. If levels of CO_2 rise above 2 to 3 %, the reduction in oxygen poses a significant risk of losing consciousness and even death.

RESIDENTIAL HOUSE IN CONSHOHOCKEN, PA

In the fall of 1999 a mother was down in the basement of her home in Conshohoken when her daughter passed out while playing on the basement floor. She was able to carry her daughter outside where the daughter quickly recovered. When the local fireman arrived, one of the fireman passed out in the basement. The home was a two story detached house built in a new development of similar homes. The home was only four years old. CO_2 and O_2 were measured in the open sump of this house and the next door neighbor's basement sump for two months before the ASD system was installed. During this period the CO_2 levels ranged from normal levels up to 80,000 to over 100,000 ppm (10%). The corresponding O_2 levels ranged from normal 21% to as little as 5%. There were periods were the O_2 levels in the sump were below 10% for two or three days. There was no known landfill or unusual soil conditions under either house. In November of 1999, WPB was asked to install a typical radon ASD system in the residence. The ASD system consisted of a single suction point that was vented with four inch pvc to a fan installed outside. The exhaust was vent above the roof eave. The sump pump was sealed. The perimeter of the basement had an open canal drain that was sealed with backer rod and urethane caulking. A 50 watt, RP145 radon fan was used. The final u-tube reading was 7/8" static inches of water. The pressure under the slab at the farthest distance from the suction point was negative 48 pascals. Continuous CO_2 measurements were made during the ASD installation to ensure safe conditions existed. The CO_2 and O_2 levels returned to normal after the fan was activated. The levels were monitored for three weeks after the ASD system was installed with no significant increases in CO_2. The CO_2 levels in the adjoining neighbors house also returned to normal levels even though the system was only installed in the first house.

RESIDENTIAL HOUSE IN POTTSVILLE, PA

In December of 1999, WPB was contacted by the United States Department of the Interior, Office of Surface Mining, Reclamation and Enforcement about a house in Pottsville, PA that had elevated radon and CO_2. The house was a 2500 square foot raised ranch that was only one year old. The radon levels were around 200 pCi/l. in the basement and 56 pCi/l on the first floor. The builder had installed a loop of perforated piping around the inside of the foundation footer in the gravel bed below the slab. The owner was initially complaining that the oil furnace would not function properly. The house is located in an area that contains old underground coal mines. The initial visit by the Office of Surface Mining found levels as high as 4% CO_2 near the floor of the basement with a dangerous level of only 17.1% O_2. A butane lighter could not produce a flame as it approached the floor. CO_2 levels of 2% were found on the first floor and 1.5% on the second floor, even though the heating system was hot water baseboard. The house was ventilated until the oxygen levels returned to 20.8%. Within three days the levels in the basement had deteriorated to 17.7% oxygen. Office of Surface Mining maps indicated mining occurred just to the north and south of the home. It was unknown if bootleg mining (non-recorded mining) had occurred beneath the home.



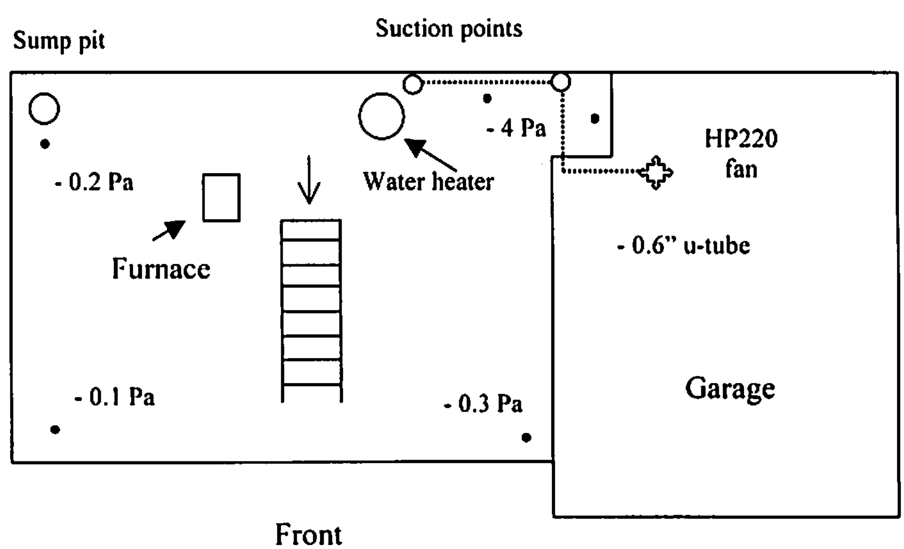
Probe holes were drilled around the outside of the house to locate any bootleg mines. Layers of coal were approximately thirty feet below grade. No mine tunnels were found. When the drilling rig completed a test hole about twenty feet from the house closest to the corner with the highest CO_2 level (3.5%), hot air stated rising out of the shaft. The snow around the hole soon melted. The shaft was still fuming hot air a month later. Samples of the air were sent to a laboratory for analysis. The lab reported that the CO_2 originated from newer wood than would have been coming from old mining timbers. It is suspected that there may have been large amounts of trees and brush buried at this location. The CO_2 in the basement may or may not have been coming from this source.

It was assumed that the CO_2 being produced came from decaying mining timbers or other organic material that may have been buried at the site.

Initially just an HP220 radon fan was installed. The CO_2 levels disappeared and the O_2 levels returned to normal on all floors. The radon levels, however, were still above the guideline at about 15 pCi/l. A second fan was installed and routed to a suction pipe in the garage floor. The second fan was an RP145. Both fans were installed in the garage attic and exhausted out the roof. All piping was four inch sewer and drain pvc. The "Pa" readings on the accompanying drawing are the final pressure readings in pascals at the test holes with both ASD fans operating. The HP220 basement system had a u-tube reading of 0.5 inches of water column and an airflow of 162 cfm. The final radon readings taken at the end of February 2000 were 0.8 and 0.3 pCi/l.

RESIDENTIAL HOUSE IN DURYEA, PA

In Fall of 1999, a house in Pottsville, PA had trouble keeping the gas furnace and water heater going. The house was a new, two story, 1800 square foot, home with a full basement. The foundation walls were constructed of block. An investigation by the Office of Surface Mining found 2.5% CO_2 and only 16.7% of O_2 near the basement floor. Mining maps revealed an abandoned coal mine existed about 67 feet below the home.



The Office of Surface mining hired another contractor to seal the perimeter canal drain with non-shrink grout and all cracks with a special sealant. Subsequent measurements revealed that the CO_2 levels had decreased but were still present.

WPB was hired in March of 2000 to install an ASD system. The system used an HP220 fan with two suction points to maximize airflow. The final u-tube reading was 6/8 of an inch water column. This indicates airflow of about 160 cfm. No CO_2 was present after the ASD system was activated. Sub-slab pressures away from the suction holes were weak (- 0.2 Pa) due to excessive airflow coming from the soil.

RESIDENTIAL HOUSE IN PITTSTON, PA

In September of 2000 WPB installed an ASD system in a 100 year old house in Pittston, PA for the Office of Surface Mining. This house was a narrow, 100 year old, home with two dirt crawl spaces. The gas appliances had been mal-functioning. The initial investigation found between 19% and 20.8% O_2 in the basement. In August, the site was visited again by the Office of Surface Mining and even though the basement windows were opened, the levels of O_2 near the basement floor were now at 15.7%. A coal mine existed about 35 feet below the home. A single RP145 fan was used with crawl space membranes and three basement slab suctions. The final u-tube reading was 5/8 of an inch of water column. The weakest vacuum measurement under the slab was - 0.8 pascals. No CO_2 was present after the ASD system was activated.

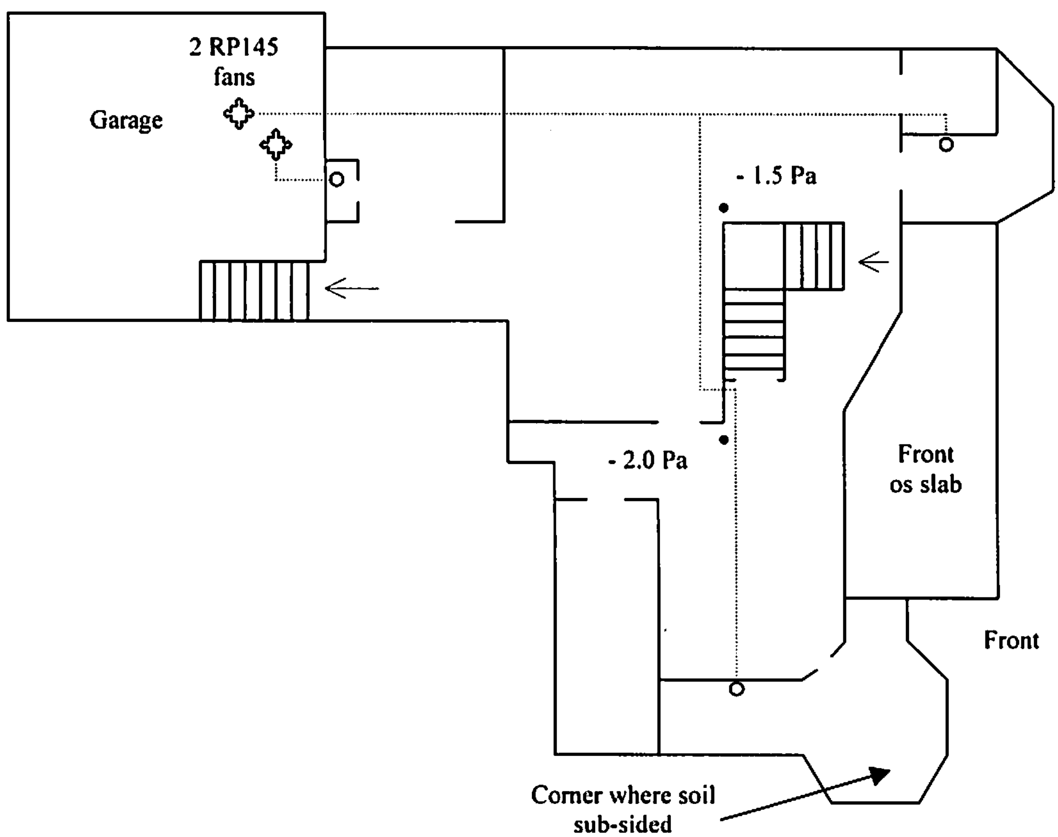
RESIDENTIAL HOUSE IN OLD FORGE, PA

The house in Old Forge, PA was built in 1995. It is a two story 2500 square foot home with a finished basement. During the installation of the foundation, a corner of the excavation collapsed into an old mine tunnel. The Office of Surface Mining had the opening filled with concrete. In the following years the owners had problems with failure of gas pilot lights. In October of 2002 the owners reported the problem had worsened. An investigation by the Office of Surface Mining found CO_2 levels ranging from 1.5 to 1.9% and O_2 levels ranging from 18 to 19.6%. The owners were also complaining that the moisture levels in the basement were excessive.

A perforated piping system had been installed below the basement slab with a stub up, out of the slab, near the garage side of the basement. WPB was hired by the Office of Surface Mining to install an ASD system in January of 2003 that was to be connected to the stub up, in the slab and vented through the garage. A test hole was drilled in the center of the slab. The pressure under the slab was 5.0 pascals positive. When the HVAC fan came on, the pressure increased to 8.0 pascals positive under the slab. The HVAC was creating an additional 3.0 pascals of negative pressure. The return duct work in the basement could not be inspected for leaks because the basement was finished. A test fan was connected to the stubbed up pipe and this reduced the pressure under the slab by 1.5 pascals. The owner was very concerned about aesthetics and fan noise, so a single

RP145 fan was installed in the garage attic and the exhaust was routed through the garage roof. The u-tube reading was 6/8 of an inch water column. This indicates there is some resistance induced by the builder installed piping system. Even with the radon fan running, there was still a positive pressure under the center of the slab of 7.0 pascals when the HVAC air handler was running. Radon measurements made after the single fan installation averaged 40.3 pCi/l in the basement.

In May of 2003 a second RP145 fan was installed in the garage attic and vented through the roof. This time, two new suction points were installed. The piping to the suction holes was difficult because of the finished basement. The u-tube installed in the garage on this second fan system also read 6/8 of an inch of water column. This restriction was due to the long piping run to the two suction holes. An outside mounted fan system would have provided better system performance but the owner did not want the fans visible on the outside. This time with two fans running, the pressure under the slab in the center reversed to a negative 1.5 pascals. Some of this performance gain was due to the warmer conditions of May. The initial radon measurements with two fans running averaged 4.7 pCi/l. A second duplicate radon test done in June averaged 1.5 pCi/l.



COMMERCIAL STRIP MALL IN WILKES BARRE, PA

WPB was contacted in the Fall of 2002 to help mitigate a small strip mall in Wilkes Barre, PA that had methane entering the building. The strip mall had been built over an old garbage dump. Methane is a colorless, orderless gas. It is produced by anaerobic bacterial decomposition of plant and animal matter. Methane itself has no odor but other decomposing elements can be a signal that it exists in the air. At room temperature, methane is less dense than air (It floats upward). Methane is combustible and mixtures of about 5 to 15 percent in the air are explosive (50,000 to 150,000 ppm). Methane is not toxic when inhaled, but it can produce headaches, dizziness or even suffocation by reducing the concentration of oxygen inhaled.

The employees in one of the stores had notified the police in 1996 when they detected strong odors in the building. The Police then notified a local PA, DEP office. Since that time the building has been investigated several times by PA DEP for recurring odors. In 1996, the DEP measured methane levels that were as high as 80% LEL in the mattress stores. The LEL is the lower explosion limit. Methane has an LEL of about 5.5% or 55,000 ppm. In 1997, two different stores in the same strip mall also had instances of a sicken gas smell. One of the stores had a methane measurement that reached 25% LEL. Then in 2002, the pool table store again reported a foul, sewer like, odor. Methane measurements near the floor of its bathroom were at 100% LEL.

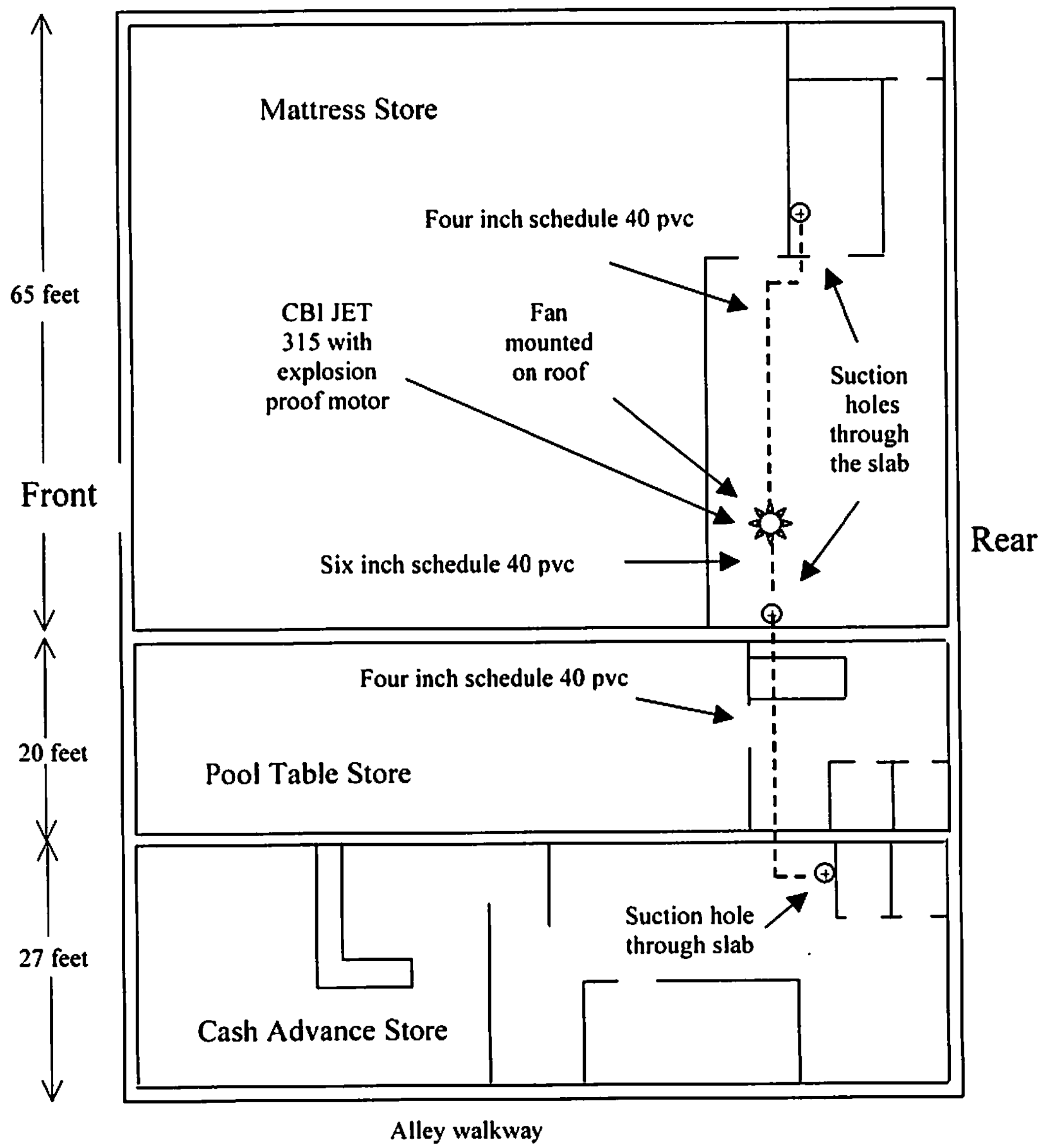
In the Fall of 2002, WPB made diagnostic measurements at the strip mall. A communication test was done by pressurizing the floor with a shop vacuum. A shop vacuum can become an explosive device if suction is applied to soil gas with methane in the 5 to 15% range. The communication test indicated that a single suction hole in the mattress store could produce a 2 to 6 pascal pressure reversal under the rear part of the store where the odors had been detected. There was only a slight pressure change from the mattress store to the cash store.

A three hole suction system was designed using an explosion proof fan installed on the flat roof. A CBI Jet 315 upblast exhaust blower with a 1/3 hp explosion proof motor was choosen for the fan. The local fire marshal was contacted to get approval for the fire-stop collars to be used as the vent pipe penetrated the firewalls between the stores. See the accompanying drawings.

In order to minimize the risk to store occupants and to the system installers, WPB installed the ASD piping and the roof mounted fan first. A new curb base was built on the roof and the CBI jet 315 fan installed. The electricians wired the fan the same day. The roofers flashed the roof the following week. After the roofers had completed the flashing, WPB used a wet diamond bit core drill to make all the suction holes through the slab. An environmental company was hired to make methane measurements during this phase of the work. There was 5000 ppm of methane in the pool table store back bathroom the day the final phase was completed (10% LEL). The main stores had very low levels of measurable methane in the air (0 to 500 ppm). The suction holes, after they were initially cut through the slab, had from 1400 to 2600 ppm of methane in the holes.

The ASD system, which was already running, was connected to each suction hole as soon as the holes were excavated out. This minimized the time the suction holes were left open to the store interiors.

The final system performance indicated a flow rate of 570 cfm. The far cash store u-tube read 9/8 of an inch of water column. The exhaust on the roof had 2200 ppm of methane in the exhaust (4 % LEL).



ELEMENTARY SCHOOL IN CENTRAL, PA

A two story elementary school in central PA was built in 1980 on top of an old coal gasification plant. There were a number of tar pits that were under the school that were never removed. Although measurements of benzene were never made in the school, the original owners of the coal gasification plants wanted to ensure that there would never be any chance of Benzene getting into the building. Low levels of benzene were, however, found under the school and under the parking lot outside the school.

Benzene is a clear, colorless, aromatic, highly flammable liquid. EPA has found short term exposure to benzene causes temporary nervous system disorders, immune system depression and anemia. Lifetime exposure to drinking water above the MCL (5 parts per billion) can cause cancer. Benzene released in the soil will evaporate quickly or leach to the groundwater. Some soil microbes can break benzene down.

WPB was initially hired to determine how much air would be required to pressurize the building. The building is about 40,000 square feet and has a single story multi-purpose room with twenty foot high ceilings. A triple blower door was used to pressurize the multi-purpose room first and then pressurize the main two story building. The building had numerous passive relief dampers on the roof that allowed a lot of leakage and stack effect to take place. The building was running about 2 pascals negative when the outside temperature was 50 to 60 degrees. Stack effect happens because a building acts like a chimney with heated air escaping at the top, and cooler air being drawn in at the bottom.

The following formulae for stack effect is from:

ASHRAE Fundamentals, 1993, section 23.4

P=C*D*G*(Hm-Hnpl)*(Ti-To)/To

The following are typical stack effect pressures at the elementary school using the above ASHRAE formula

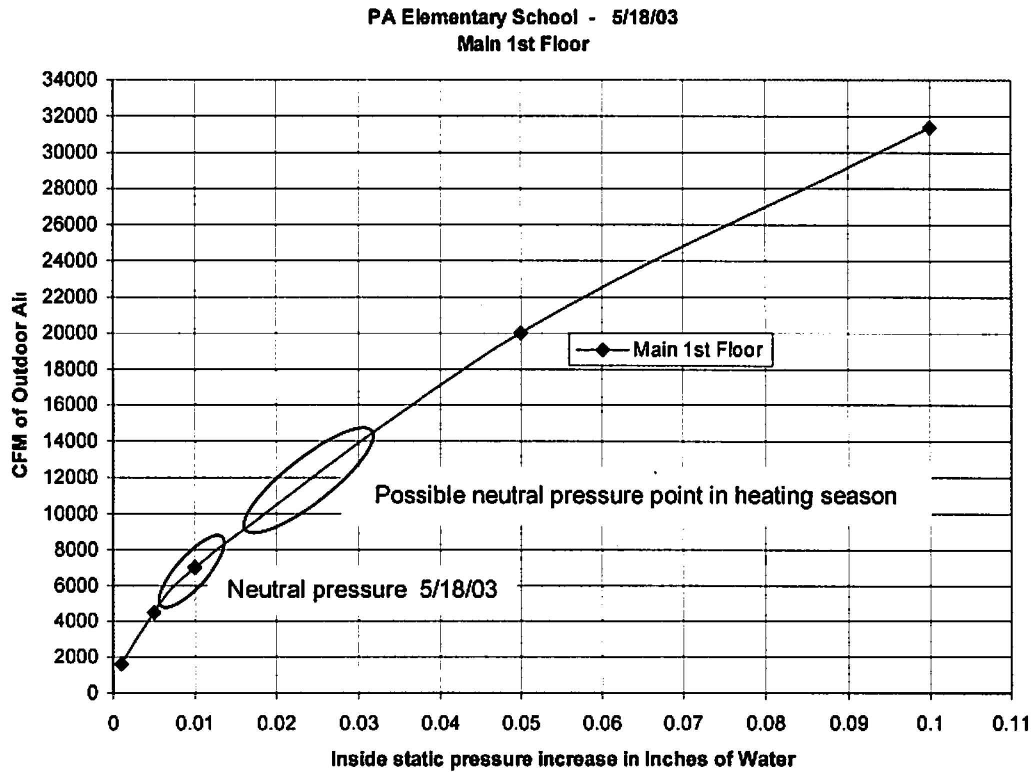
Where:

C =	unit conversion factor	0.00598
D =	air density	0.075 lb/ft3
G =	gravitational constant	32.2
Hm =	measurement height	30 ft
Hnpl =	neutral pres level	15 ft
Ti =	inside temperature	528 R
To =	outside temperature	?
P =	stack pressure	⟶

Calculated stack induced pressures

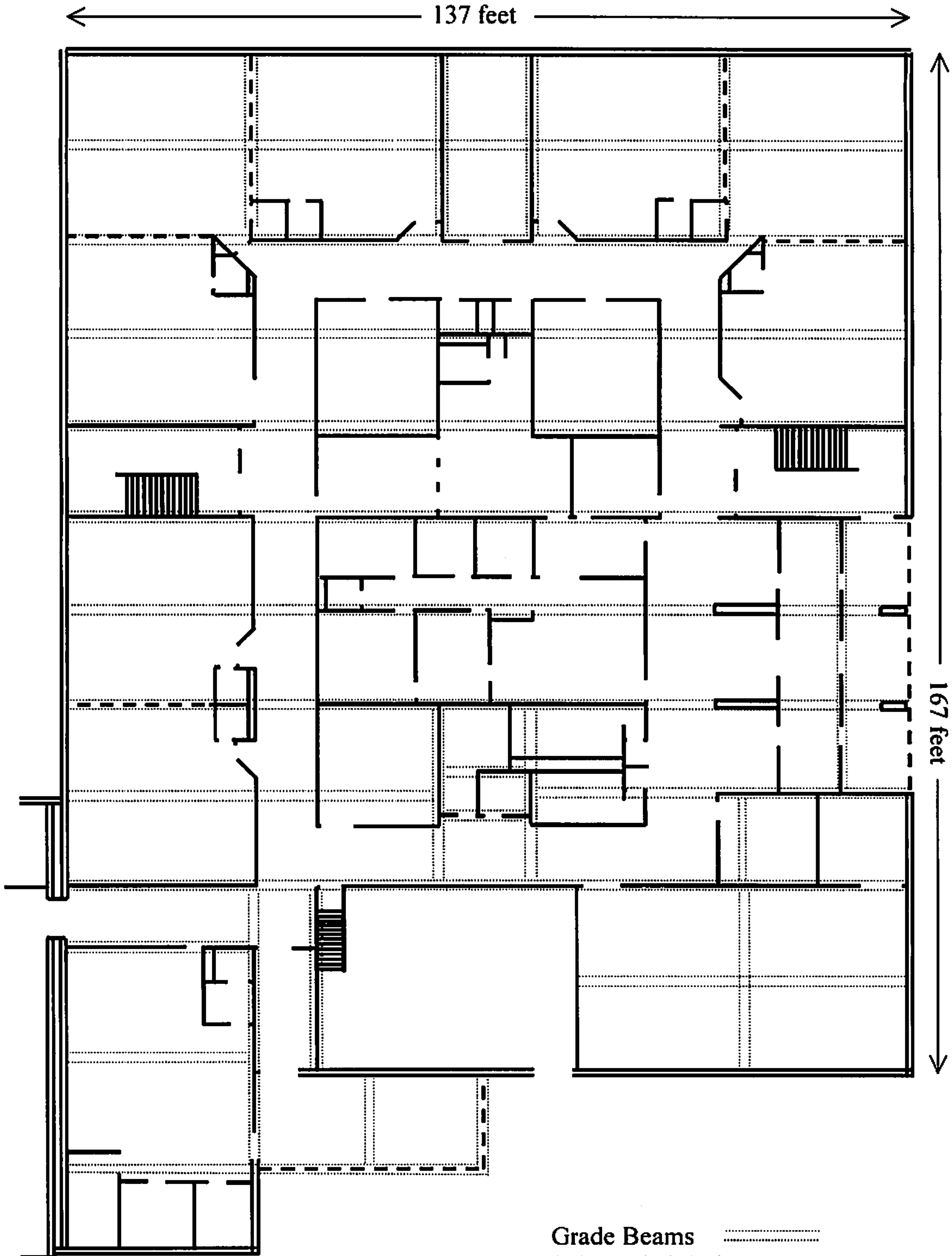
Outside Temp (F)	Stack Pres (in wc)
68	+ 0.000
50	- 0.008
32	- 0.016
0	- 0.032
-10	- 0.038
-20	- 0.043
100	+ 0.012

The blower doors indicated that it would require over 10,000 cfm of outdoor air to pressurize the main section of the building in the winter. The graph below indicates the amount of air needed to create pressure in the main portion of the building. The multi-purpose room would require an additional 4000 cfm of outdoor air in the winter.



The Elementary School was constructed with a series of columns that support a network of grade beams. These grade beams are from 20 inches to 66 inches tall. The perimeter beams are mostly 42 inches high and 16 inches wide. The interior grade beams are mostly 36 inches tall. The beams are typically 16 or 20 inches wide with re-enforcing steel bars. Eight inch thick concrete plank flooring, with steel re-enforcing in the concrete ribs, was laid across this network of grade beams. A two inch cement coating was poured in place over the concrete planking. See the accompanying drawings.

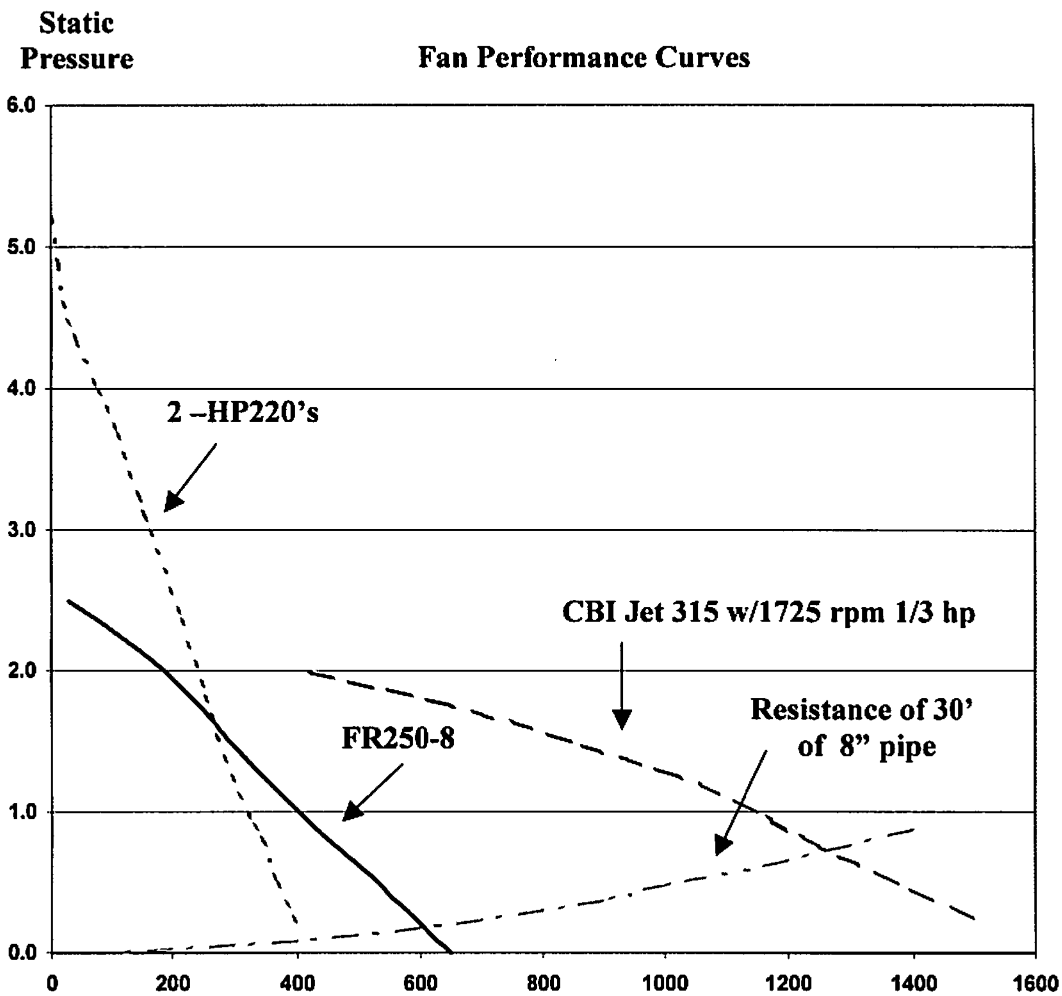
It was initially unclear whether there was any communication between the grade beams. The construction of the school in 1980 included three eight inch stack pipes that were routed from the space between the grade beams to the roof. The main building had two eight inch stacks. The multi-purpose room had one eight inch stack. A curb based roof fan was installed on one of the main building eight inch stacks. WPB removed this fan and installed a CBI 315 jet fan in its place. The two remaining eight inch pipes had FR250-8 fans installed. The final sub-slab negative pressures are depicted in the final floor plan drawing below. These sub-slab pressures should be able to overcome the stack effect pressures down to 10 to 15 degrees of outside temperatures.



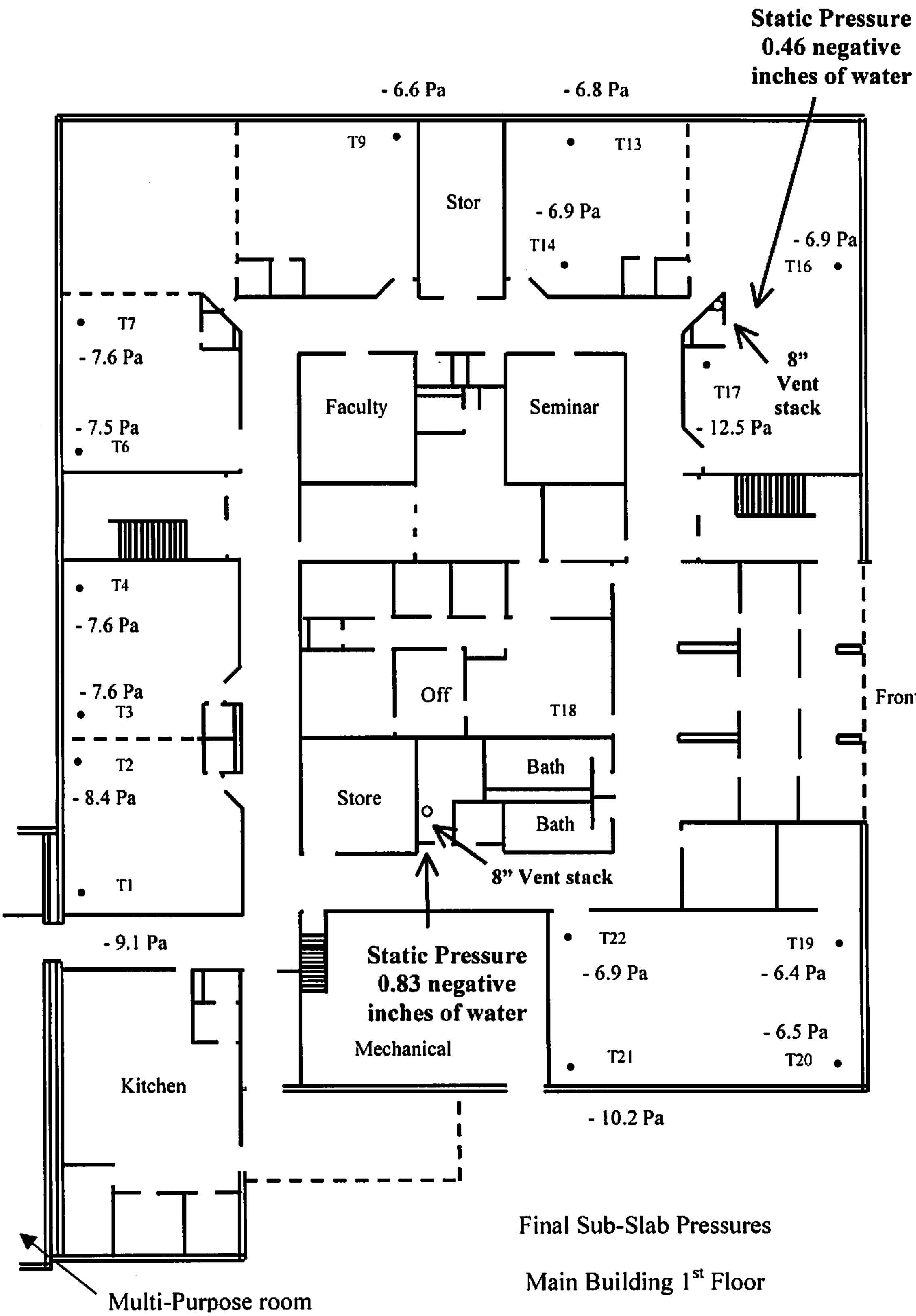
Grade Beams

avg grade beam height is 36"

perimeter grade beams are 42"



Static
Pressure
Fan Performance Curves
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
200
400
600
800
1000
1200
1400
1600
2 –HP220's
CBI Jet 315 w/1725 rpm 1/3 hp
Resistance of 30' of 8" pipe
FR250-8



Final Sub-Slab Pressures

Main Building 1st Floor

SUMMARY

Designing radon mitigation systems for buildings with soil gas other than radon uses the same basic principles as a radon system. During all of the work done for the Office of Surface mining and during the methane installation, measurements were being made to ensure the safety of the workers installing the system. In the case of methane, specialized explosion proof fans need to be used. The systems also needed to be sized to handle the amount of airflow required to obtain a pressure reversal under the slab. The following graph illustrates the maximum airflow obtained with different piping systems. Note that a 17 watt RP140 fan can move more air through 100 feet of 4" pvc pipe than a 120 watt HP220 fan can move through a 3" pipe. If these systems are installed on a commercial building, a mitigator must have a thorough knowledge of the buildings HVAC components, operation and influence. A mitigator must also be able to size the radon piping to minimize pressure drop so that an appropriate fan can be used.

Maximum Fan CFM capacity with different open Pipe