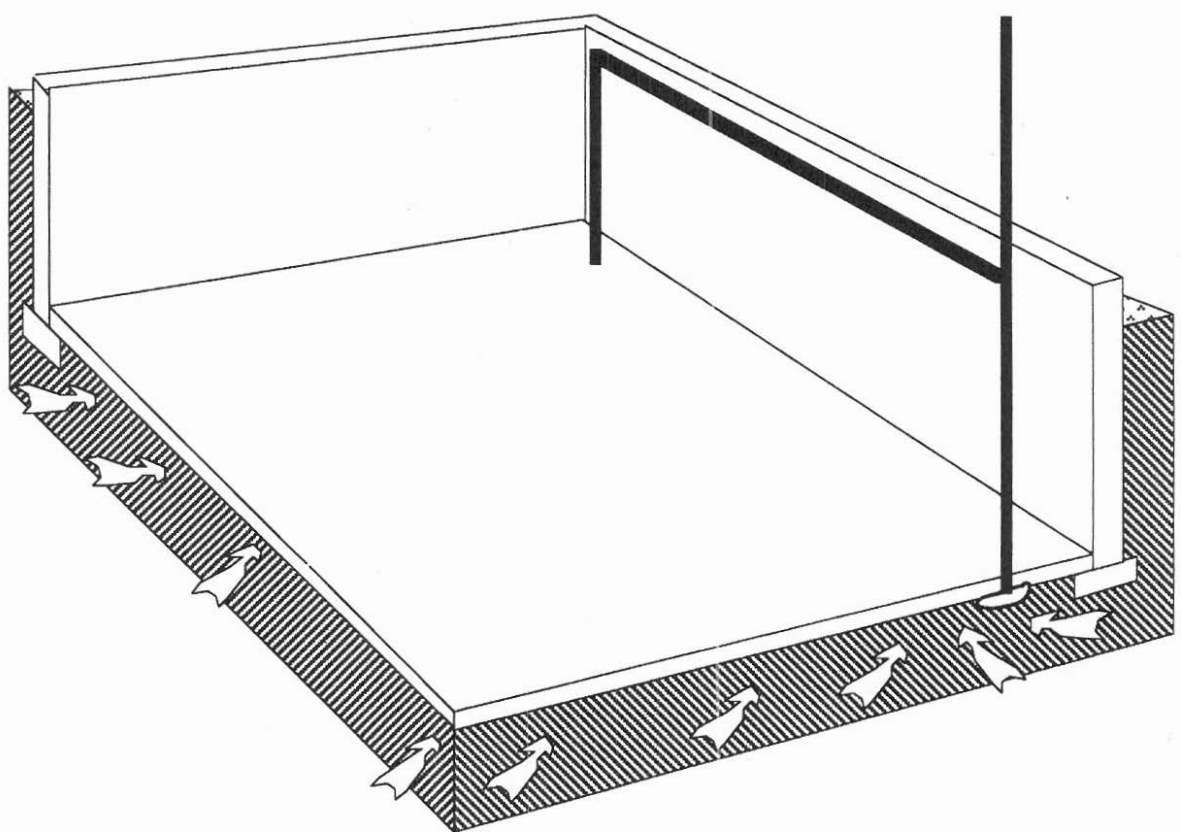
MAKING YOUR MITIGATION SYSTEM MORE EFFECTIVE

A TECHNICAL GUIDANCE MANUAL



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PURPOSE

The effort to reduce indoor radon concentrations in homes has been an on-going learning process for the past decade. Research, funded by agencies such as NJDEPE and EPA as well as innovative work by the private sector, has increased the knowledge of radon-reduction technology. Standardized mitigation techniques are being offered by many professional radon mitigators across the country.

This manual is an effort to provide mitigation contractors with information to improve the effectiveness of their mitigation systems. It is intended to help mitigators identify potential problems in an installed mitigation system. It is not a pre-mitigation diagnostics guide.

The manual has been designed as a training aid, to be used by those offering continuing education workshops, as well as a stand-alone technical guidance manual. It contains how-to information on measurements required or recommended by the current EPA Radon Mitigation Standards (EPA 402-R-93-078 and April 1, 1994 Errata Sheet). Employment of the techniques described in this manual will ensure that the mitigation system achieves a maximum radon and subsequent health risk reductions on the first effort. This means fewer callbacks for the mitigator and potentially lower costs to the consumer.

INTRODUCTION

The New Jersey Department of Environmental Protection and Energy (NJDEPE) recently completed a two-year investigation of radon mitigation systems that had been installed in New Jersey homes. The study was to determine if the mitigation systems had common design or installation mistakes or details that lessened their effectiveness, and also to determine if the age of the systems lessened their effectiveness.

The investigation of each system began with a visit to the house. A total of 100 mitigation systems were investigated. The mitigation systems were installed from 1986 through 1991. The majority employed active soil depressurization (ASD) techniques. The ASD systems included subslab depressurization (SSD) and combination subslab and block wall depressurization (SSD/BWD) installations. Other types of mitigation systems investigated included heat recovery ventilators (HRVs), sealing of radon entry points, crawlspace depressurization (CSD), and baseboard depressurization (BBD). Each mitigation system was tested to determine if it complied with its conceptual operating characteristics. For example, was the ASD system actually depressurizing the area that it was intended to, and if not, why not? Pressure field extension (PFE), as well as system static pressure and airflow measurements were made to provide that information. To determine if the systems were operating effectively, four quarterly measurements, using electret ionization chambers (EIC) were made at each home. One measurement was made in the lowest livable area, one on the next level, and one outside.

In addition to investigating the mitigation systems, corrective actions were applied to 15 systems. This was done as a check to make sure that what was thought to be lessening the effectiveness of the system actually was the problem.

PROJECT OBJECTIVES

ASSESS THE EFFECTIVENESS OF RADON CONTROL TECHNIQUES BY MITIGATION SYSTEM TYPE.

DISCOVER COMMONLY MADE AND EASILY CORRECTED MITIGATION SYSTEM MISTAKES

PROVIDE MITIGATORS WITH GUIDELINES AND TECHNIQUES TO IMPROVE THEIR SYSTEMS

PROJECT DESIGN

INVESTIGATE MITIGATION SYSTEMS IN 100 NEW JERSEY HOMES.

PERFORM SYSTEM DIAGNOSTICS TO DETERMINE HOW THE SYSTEMS ARE OPERATING.

PERFORM QUARTERLY RADON MEASUREMENTS TO OBTAIN ANNUAL AVERAGE RADON CONCENTRATIONS. USE THE RESULTS TO DETERMINE IF THE MITIGATION SYSTEM WAS A SUCCESS OR A FAILURE.

DEVELOP THEORIES ABOUT WHY THE FAILED SYSTEMS FAILED.

APPLY CORRECTIVE ACTIONS TO 15 MITIGATION SYSTEMS TO DETERMINE IF THE FAILURE THEORY WAS CORRECT.

RESULTS/CONCLUSIONS

A mitigation effort was considered to be either a success or a failure in accordance with New Jersey post-mitigation radon mitigation system success/fail protocols. A total of 87 homeowners completed four quarterly measurements at their homes. The measurements disclosed that 24 homes had mitigation efforts that were failures. Eight SSD systems failed. Four of these systems were installed by contractors, and four installed by homeowners. Two combination sub-slab and block wall depressurization systems failed. Both failed systems were installed by contractors. Six homes where sealing radon entry points was the mitigation approach had radon concentrations greater than 4 pCi/L. All six of those were homeowner efforts. Heat recovery ventilators failed to successfully reduce radon levels to less than 4 pCi/L in seven of the eight homes where they were installed. Two of the failed HRVs were installed by contractors and the other five by homeowners. The HRV failures were primarily due to improper installation and maintenance, and not to a theoretical limitation. The HRVs most likely would have worked if they were installed, maintained, and operated correctly. One crawlspacece depressurization system, installed by the homeowner, failed. Figure 1 presents a summary of successful and failed mitigation systems, by system type. Figure 1 includes all systems installed by all categories of installers.

We will devote the bulk of our efforts in this document towards making ASD systems more efficient because those type systems are the most common that mitigators install. We will spend a little time discussing heat recovery ventilators. We will not discuss sealing at all because we could not identify any error that made the sealing only jobs fail. Due to the small sample, no problems could be clearly identified in the other type systems, and therefore, those systems will not be discussed.

NEW JERSEY POST-MITIGATION RADON MITIGATION SYSTEM SUCCESS/FAILURE PROTOCOLS

AT A MINIMUM, CONDUCT A SHORT-TERM TEST IN THE LOWEST LIVABLE AREA OF THE HOME.

IF THE SHORT-TERM RESULT IS LESS THAN OR EQUAL TO 4 pCi/L, THE MITIGATION SYSTEM IS A SUCCESS.

IF THE SHORT-TERM RESULT IS GREATER THAN 4 pCi/L, THEN CONDUCT A LONG-TERM TEST IN THE LOWEST LIVING AREA OF THE HOUSE:

if the long-term result is less than or equal to 4 pCi/L, the mitigation system is a success,

if the long-term result is greater than 4 pCi/L, the mitigation system is a failure.

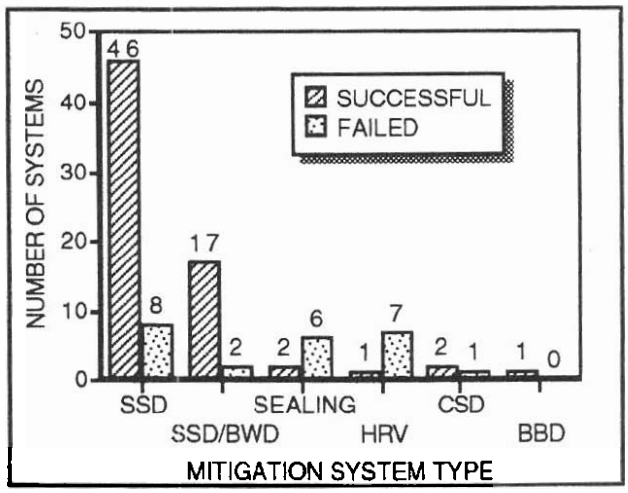

Figure 1. Summary of successful and failed mitigation systems, by system type. Figure includes contractor and homeowner installed systems.

ACTIVE SOIL DEPRESSURIZATION SYSTEM DEFICIENCIES

The conceptual theory of operation of an ASD system is that the system creates an air pressure beneath the floor slab (or within a hollow core block wall) that is lower than the air pressure in the home. In this way, air moves from the home into the surrounding soil, rather than from the soil into the home, and radon levels in the home are reduced. To determine the existence and frequency of ASD system deficiencies, measurements were made to answer the following questions:

- does the sub-slab depressurization system develop an adequate pressure field beneath the slab;
- does the sub-slab block wall depressurization system develop an adequate pressure field beneath the slab and within the block walls, and;
- does the mitigation system treat all ground contact areas?

The questions about the pressure field extension (PFE) are performance related and answered by making pressure difference measurements. However, the definition of an adequate pressure field may be arguable. For this study, an adequate pressure field was defined as a negative pressure, of any strength, that extended across the floor slab, or in the case of block walls, throughout each wall where a suction point was located. Untreated areas were defined as a ground contact area that the ASD system was not designed to treat. For example, consider a house with a combination basement and crawlspace foundation. The ASD system has suction points in the basement but none in the crawlspace. The crawlspace would be defined as an untreated area.

Figure 2 presents a summary of the deficiencies found in failed and successful sub-slab depressurization (SSD) systems. A total of 54 SSD systems were investigated. Of the eight systems that failed, every one either did not develop an adequate pressure field, failed to treat a ground

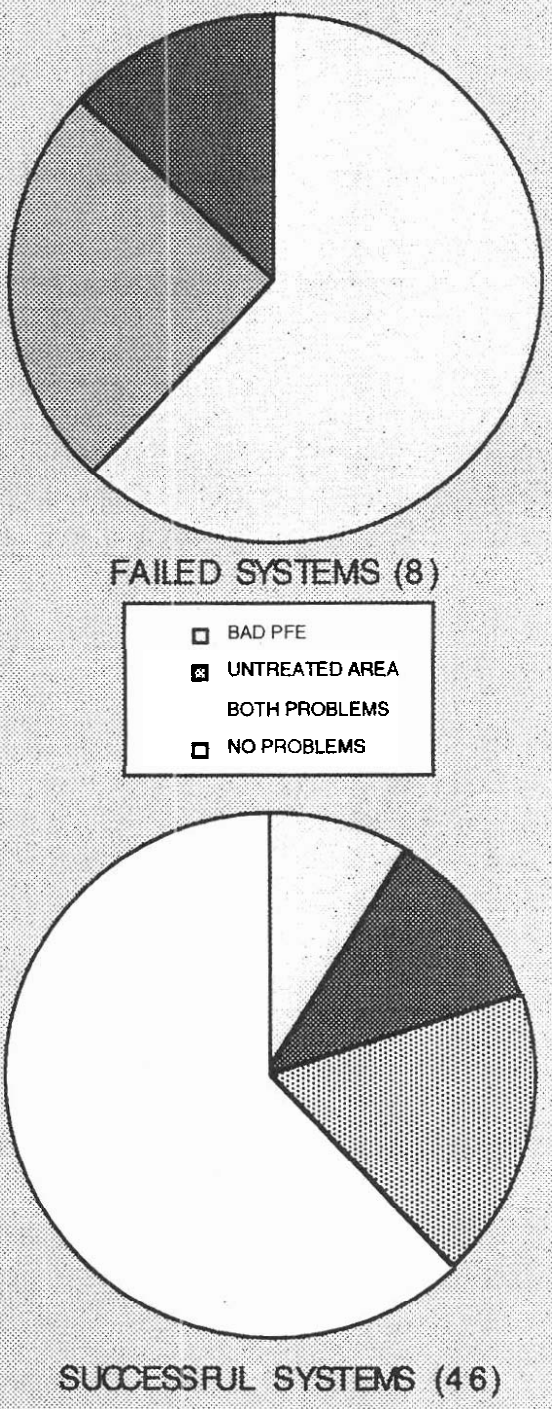

Figure 2. Sub-slab depressurization system deficiencies.

contact area, or both. The most prevalent deficiency was the lack of an adequate pressure field. Five (62%) of the houses where the sub-slab depressurization system was a failure had an inadequate pressure field. Two (25%) of the homes with a failed sub-slab system had untreated areas. One (13%) of the homes had both deficiencies.

Forty-six of the SSD systems were successful. Seventeen (38%) of the successful systems did not develop an adequate pressure field, had untreated ground contact areas, or both. Four (9%) of the successful systems did not develop an adequate pressure field. Eight (18%) of the systems failed to treat a ground contact area. Five (11%) of the systems had both deficiencies. Twenty-nine (63%) of the systems had no deficiency.

A total of 19 homes had combination SSD/BWD systems installed. Of those 19 systems, two failed to maintain radon concentrations below the 4 pCi/L level. The two failed systems both developed an adequate pressure field beneath the slab and within the block walls. One failed system did not treat a crawlspace, and the other was installed with the exhaust close to an outside entrance to the basement. Additional measurements indicated that exhaust entering the basement through the exterior door was the cause of the elevated radon levels.

Analysis of data collected revealed that ten (59%) of the successful SSD/BWD systems were developing adequate sub-slab and wall pressures, and were treating all ground contact areas. Three (18%) of the successful systems failed to develop an adequate sub-slab pressure field. One (6%) failed to develop an adequate wall pressure. Two (12%) failed to treat a ground contact area. A single SSD/BWD system had two problems.

In short, the deficiencies found in the ASD systems can be identified as either a failure to treat a ground contact area, or the lack of an adequate pressure field. The next step was to determine what factors caused those deficiencies.

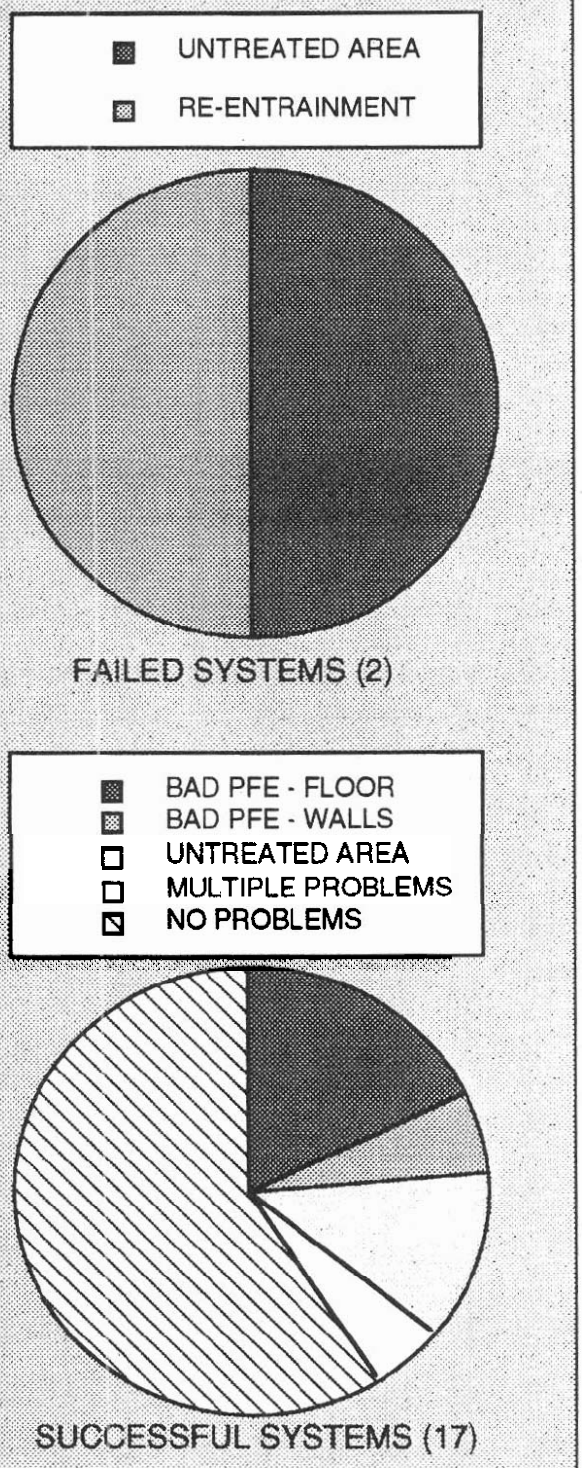

Figure 3. Failed and successful SSD/BWD depressurization systems.

CAUSES OF ASD SYSTEM DEFICIENCIES

The factors which caused ground contact areas to go untreated are hard to positively identify. The mitigation contractors were not interviewed as part of this project. We could not determine why, for example, the ASD system in one house treated a 200 square foot basement but left an adjoining 1000 square foot crawlspace untreated. The following discussion on untreated areas is purely hypothetical, based on our, and other mitigators experiences, and not from data collected during this project.

One of the reasons ground contact areas go untreated is based on economics. The homeowner often (some mitigators we have talked to say always) selects the lowest priced proposal. In our example above, treating the crawlspace would obviously increase the cost of the mitigation system. The homeowner may not be aware, or fails to understand, that one bid involves treating more than one area, and therefore is more costly. A mitigator who insists on treating all ground contact areas may not survive in the intensely competitive market. A second reason areas go untreated is that houses with more than one foundation type may require extensive or time consuming pre-mitigation diagnostics. The residential mitigation market does not support the pre-mitigation diagnostic methods it would take to determine if an area does require treatment. In some cases, it is more economical to rely on post-mitigation diagnostics and radon measurements to determine if an area requires treatment.

There are simple precautions mitigators can take to ensure that the design and installation of the system is not adversely affecting the pressure field strength and extension. This involves making simple pressure and airflow measurements in the system after it is installed. These measurements, made during the project, identified three common causes of inadequate pressure field extension. These causes were; restrictions that resist airflow through the system, improper balancing of multiple-point systems, and an inadequate number of suction points. Methods for making the measurements, as well as design details which contribute to the deficiencies are described in the student activities.

ASD SYSTEM DEFICIENCIES

INADEQUATE PRESSURE FIELD EXTENSION (PFE)

UNTREATED GROUND CONTACT AREAS

CAUSES OF THE ASD SYSTEM DEFICIENCIES

RESTRICTIONS TO AIRFLOW THROUGH THE SYSTEM

IMPROPER BALANCING OF AIRFLOW IN MULTIPLE SUCTION POINT SYSTEMS

INADEQUATE NUMBER OF SUCTION POINTS

STUDENT NOTES

RESISTANCE TO AIRFLOW

An ASD system moves air through five elements:

- the soil surrounding the foundation;
- the leaks in the foundation;
- the sub-slab material;
- the pipe below the fan (lower pipe), and;
- the pipe above the fan (upper pipe).

All five elements create a resistance to airflow that can result in a weaker and less extensive pressure field. Each element is illustrated on Figure 4.

Pressure field extension and strength are at their best when the foundation and surrounding soils are tight, and air flows easily through the pipe system and the sub-slab material. To get the best PFE for a given house, airflow resistance in the pipe and sub-slab material must be minimized, and resistance of the foundation and surrounding soil must be maximized.

Mitigators have no control over the soil surrounding the foundation. Mitigators can affect the tightness of the foundation by sealing airleaks in the foundation. In addition, the sub-slab resistance can be lessened by digging a suction pit and adding more suction points. These details are rather well-known to mitigators. However, the results of the investigation revealed that details used to lessen the resistance created by the lower and upper pipe are either not understood, or often overlooked. This section will focus on those details.

To further illustrate the resistance elements, we will describe one of the ASD systems investigated during the project. The system layout is illustrated on Figure 5. The system was a two-point ASD system with the fan located in the basement. Visualize the path that the exhausted air takes on its journey. The air moves through the soil, into and through the pipe system below the fan. It travels through the fan into the pipe system above the fan, and finally, is exhausted outdoors. As it

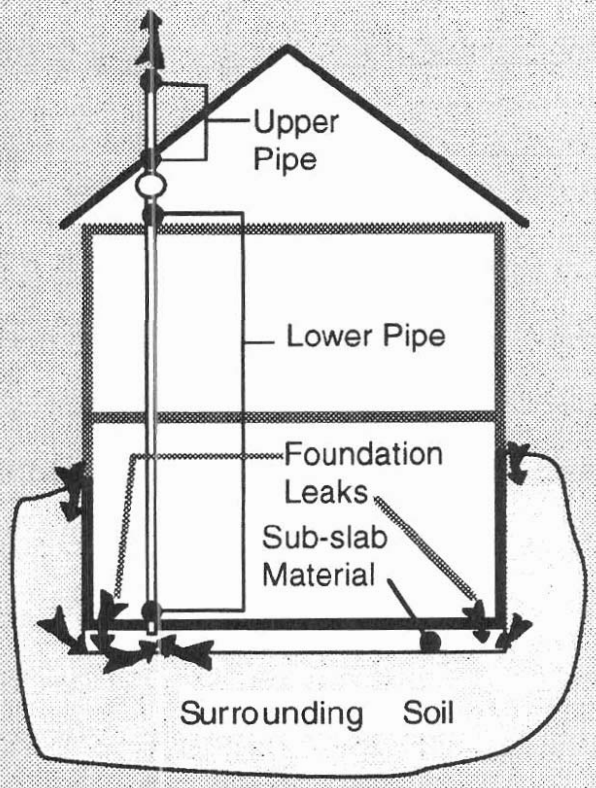

Figure 4. Five elements that create a resistance to airflow in ASD systems.

moves through the system, its movement is hampered by the five resistance elements that we have just discussed. The soil-foundation resistance in our example system is -0.332 inches WC. (We measure the resistance to airflow, also called static pressure loss, using a differential pressure indicator, therefore the units of measure are usually inches of water column or Pascals.) The resistance in the pipe system below the fan is -0.118 in. WC. The lower pipe system consists of about 40 feet of pipe, and has four changes of airflow direction. The upper pipe resistance is 0.530 in. WC. The pipe system above the fan includes approximately 30 feet of pipe, four changes in airflow direction, and a dryer vent cap as a terminator.

The resistance in the upper pipe system is quite high. In fact it is greater than the other elements combined, and in particular, is greater than the soil/foundation resistance. In other words, the fan is doing more work getting the air out of the upper pipe system than it is getting it out of the soil. Figure 5 illustrates the resistance through each element. Notice that in the preceding paragraph, the signs for the soil and lower pipe elements are negative and the sign for the upper pipe is positive. The graph however, has all of the elements as positive. The total resistance in the system is the sum of the absolute values of all three elements.

Now that we have identified the resistance elements that can affect the strength and extent of the pressure field, let's look at an example of their affect on a particular ASD system. One of the ASD systems investigated was a single-point sub-slab depressurization system with no suction pit dug at the suction point, and a raincap on the end that was made from a 4 in. diameter PVC pipe cap. The pipe cap had thirty-two 1/4 in. holes drilled through it. This gave the system a total of about 6.3 square inches of area to exhaust through. Compare this to an open-ended 4 in. diameter pipe with about 12.6 square inches of area to exhaust through. The cap effectively decreased the 4 inch pipe to 2 inches. Pressure field measurements at various distances from the suction point were made with the system in its original condition, and with the raincap removed and a suction pit installed.

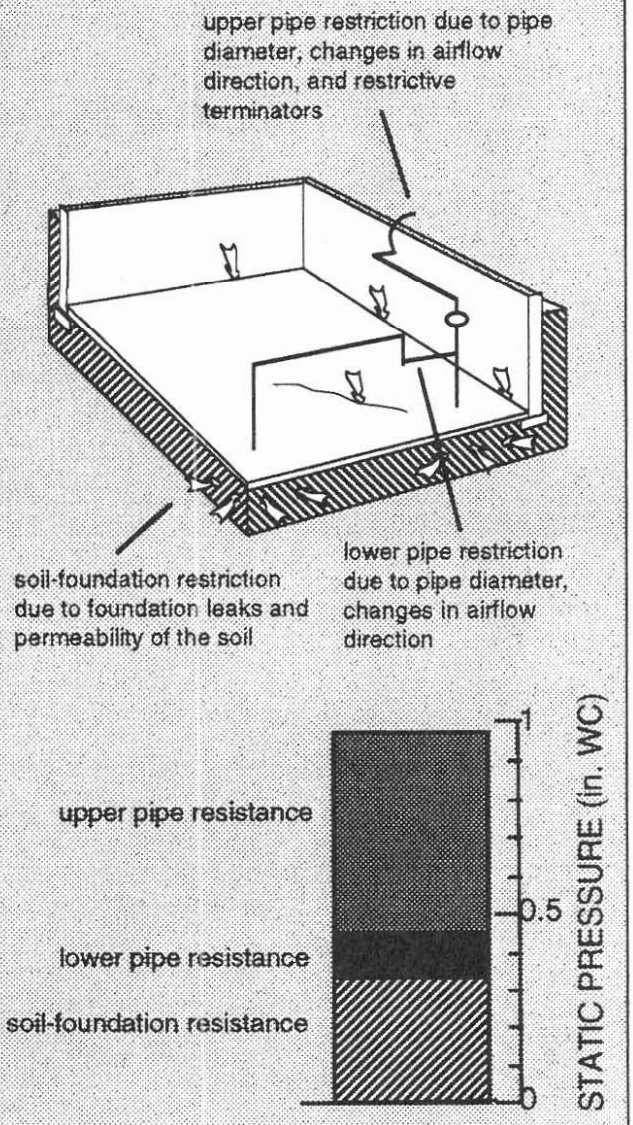

Figure 5. Example house ASD system layout and static pressure due to component restrictions.

The pressure beneath the slab was -0.078 in. WC one foot from the suction point, -0.068 in. WC three feet from the suction point, -0.048 in. WC six feet from the suction point, and -0.020 in. WC 17 feet from the suction point. This is a pretty strong pressure field to begin with, but let's see how removing the raincap and digging a suction pit changed the pressure field. After the corrections, the new sub-slab pressure differences were -0.484 in. WC at the one foot test point, -0.363 in. WC at the three foot point, -0.310 in. WC at the six foot test point, and -0.166 in. WC at the 17 ft. test point. Figure 6 illustrates the pressure differences in the original system, and after the raincap was removed.

You may wonder how many ASD systems were developing a weakened pressure field because of high restrictions to airflow. Figure 7 shows the results of the measurements made in 47 of the ASD systems that were investigated. Each bar represents the pressure loss, and therefore illustrates the magnitude of the resistance to airflow of each element. The lower portion of the bars include the restriction due to the soil-foundation elements and to the pipe below the fan. The upper portion of the bars includes the restriction due to the pipe above the fan. Although it is not apparent from Figure 6, most of the ASD systems had a very small resistance due to the pipe below the fan. This was mainly due to the fact that most of the systems had the fans in the basement, and therefore, had short lower pipe runs. The most frequent cause of the restriction was a raincap placed on the end of the pipe. Another cause of restriction was the use of smaller diameter pipe, particularly a 2x3 inch rain downspout, on the outside of the house.

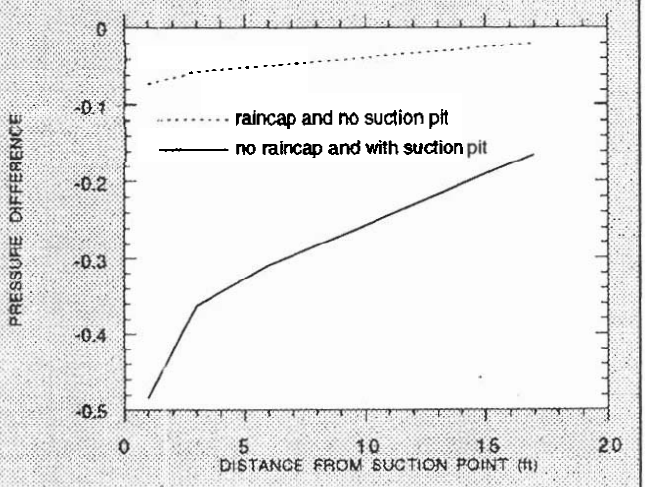

Figure 6. Sub-slab pressures versus distance from suction point before and after corrective actionns.

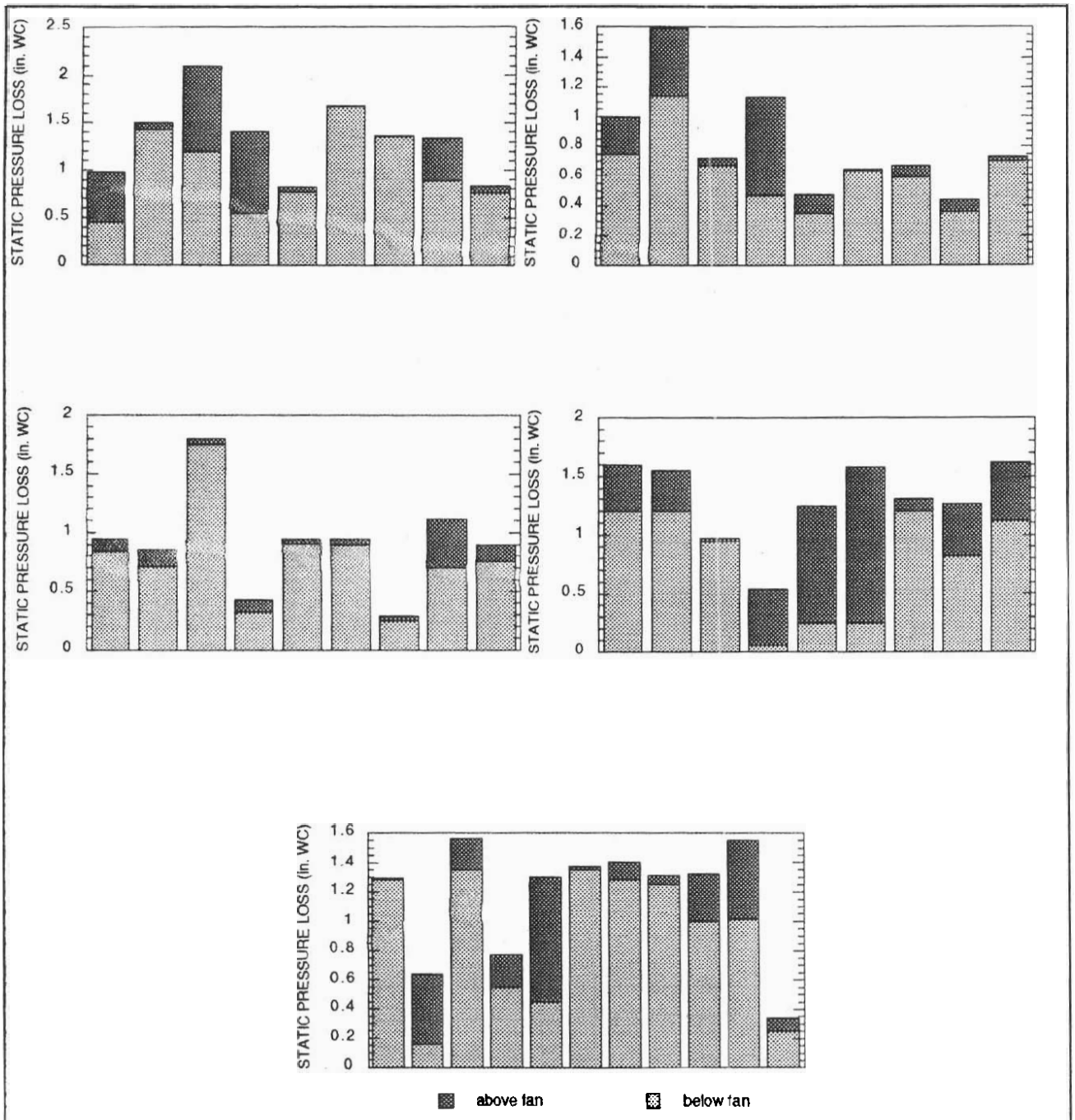

Figure 7. Results of system pressure measurements illustrating the resistance to airflow in ASD systems.

UNBALANCED AIRFLOW IN MULTIPLE-POINT SYSTEMS

It is very important to make airflow measurements in ASD systems that have more than one suction point. These systems may have to be tuned to ensure that all suction points are producing the desired pressure field. Airflow measurements made at each suction point will reveal if you need to adjust the dampers for a more evenly distributed pressure field. This is particularly important in combination sub-slab and block wall depressurization systems where the resistance to airflows in the two elements (the soil and the block walls) are usually quite different. It is normally much easier for the fan to draw air from within the block walls than it is to draw air from beneath the slab. If this is not planned for, then most, if not all, of the air that the fan can handle will come from the walls. This will result in no pressure field beneath the floor slab. It is not always possible to have equal pressure at each suction point, but it is possible to get some suction at each point.

A combination ASD/BWD system in a house investigated during the project serves as a good example of an unbalanced system. The system was installed with four slab and four wall suction points. There were no dampers installed in the system. Pressure field extension tests revealed that the system was developing a good pressure field within the block walls closest to the fan, but no pressure field within the other walls nor beneath the floor slab. Airflow measurements revealed that most of the air that the fan was moving was coming from the first two wall suction points. Airflows in the other two wall points, as well as the floor suction points, were too low to measure. Figure 8 illustrates the system.

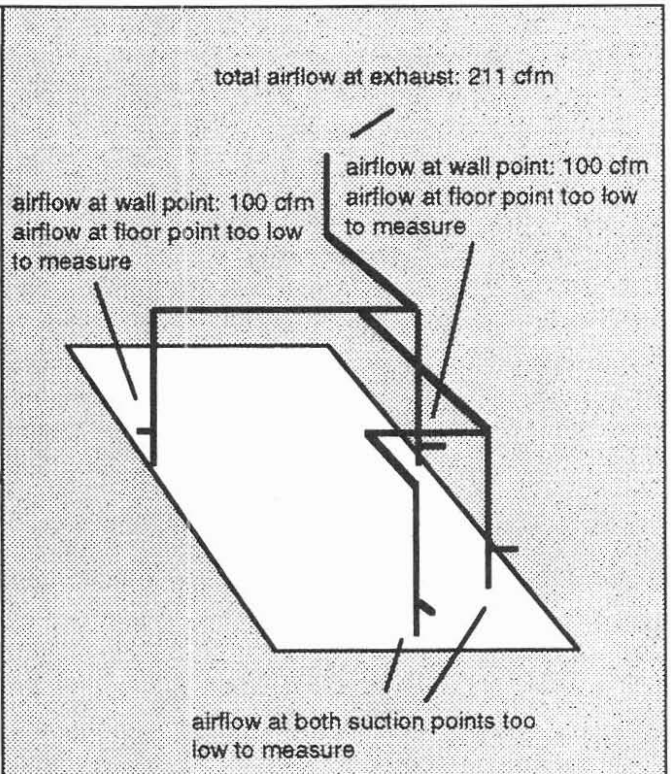

Figure 8. Layout of example combination ASD/BWD system.

INADEQUATE NUMBERS OF SUCTION POINTS

An inadequate number of suction points can cause two of the identified deficiencies; 1) inadequate pressure field development, and, 2) untreated ground contact areas.

An ASD system that fails to develop an extensive pressure field because of an inadequate number of suction points is fairly easy to identify.

The pressure and airflow measurements previously discussed will serve that purpose. If the pressure and airflow measurements indicate that the pipe below the fan and the pipe above the fan is not restricting airflow, then the only component left is the soil-foundation component. If this is the case, and the mitigator has installed a suction pit and sealed foundation penetrations, additional suction points may have to be installed to help extend the pressure field.

A FEW WORDS ON FIRE PROTECTION

One prevalent deficiency found in a large number of the ASD systems that does not impact the effectiveness of the system, but is of paramount importance, was the failure to protect firewall integrity. Model building codes such as the Council of American Building Officials (CABO) One and Two Family Building Code, and the Building Officials and Code Administrators (BOCA) National Building Code, require that attached garages be separated from the living areas by a fire-rated wall. Pipes that penetrate a fire-rated wall must be protected with an approved closure system. In the large majority of systems investigated, this was not done.

Two acceptable methods for ensuring firewall integrity are the installation of fire dampers or collars. The other method would be to box the pipe system in with an acceptable material such as sheet-rock. If this method is used, the mitigator should box in the pipe in the garage.

HEAT RECOVERY VENTILATORS

The theory of operation of a heat recovery ventilator (HRV) as concerned with radon mitigation, is that by introducing volumes of low-radon air, radon concentrations in the home will be diluted. There may be an additional benefit if the HRV can be used to pressurize, or at least, lower the negative pressure in the home.

A total of eight HRV systems were investigated during this project. Only two of the HRVs were used during the time of the investigation, and neither one of them was working correctly. The others were not used because they were broken, or because the homeowners objected to noise or com-

FIRE PROTECTION FOR ASD SYSTEMS

WHEN PIPING PENETRATES A FIRE-RATED WALL, SUCH AS THE WALL SEPARATING THE LIVING AREA AND AN ATTACHED GARAGE, FIRE PROTECTION MUST BE INSTALLED.

PROBLEMS FOUND WITH HEAT RECOVERY VENTILATORS

IMPROPER INSTALLATION

- INTAKES AND EXHAUSTS TOO CLOSE TOGETHER. THIS ALLOWS EXHAUSTED AIR TO BE DRAWN BACK INTO THE HOME.
- NO SUPPLY DIFFUSERS. THIS CREATES DRAFTS.
- LESS SUPPLY AIR THAN RETURN AIR. THIS CREATES A NEGATIVE PRESSURE.

POOR MAINTANENCE

- DIRTY FILTERS. THIS DECREASES THE AIRFLOW.
- WORN OR BROKEN BELTS.

fort. None of the systems that were looked at had properly designed supply and return openings. Supply diffusers should be used to mix the outdoor air and room air so that drafts are not created. If this is done, and drafts are still a problem, electric resistance heaters in the HRV ductwork, or an existing warm air furnace can be used to heat the mixed room and outdoor air to comfortable temperatures.

A further problem, also found during the investigations, were systems that depressurized the homes. To alleviate this problem, the system should be balanced after installation, so that HRV operation does not further depressurize the home. In cold climates, such as that found in New Jersey, the system should have no effect on the indoor/outdoor air pressure relationship, or, it should slightly pressurize the basement and depressurize the upper floor. Depressurizing the basement will increase the radon entry rate, which is not a desirable effect for a radon mitigation system. Pressurizing the upper portions of the home can increase the risk of moisture condensation in the walls and attic. This is also an undesirable effect.

A final problem identified was the poor placement of intakes and exhausts. Several of the systems had the intakes and exhausts within a few feet of each other. This could result in a short-circuit which would allow exhausted air to be drawn back into the house. In addition, one HRV system had the intake located within one foot of the natural gas meter vent pipe. The purpose of a vent pipe is to allow the natural gas to escape from the gas lines in the event that the gas supply pressure exceeds the gas regulator setting. According to one utility representative, this does not happen very often, but when it does, it may go unnoticed for quite some time. The utility representative revealed that their policy is to shut off gas supplies to any homes found with any opening in the building which is within 18 inches of the vent.

The two HRVs that were used, were not working well. One had dirty filters that were restricting airflow. The other system had a broken belt.

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It may be inferred that from this section that we do not recommend the use of HRVs for radon mitigation. This is not true. Heat recovery ventilators are a viable alternative to ASD systems in many homes. Sometimes they are the only system that can be used. We recommend that any mitigator who installs an HRV be completely familiar with all installation requirements. Installing an HRV is not just a matter of hanging it in the basement and connecting a length of ductwork.

SYSTEM AGE

The mitigation efforts that were investigated during the project, with the exception of the heat recovery ventilators, did not seem to suffer any durability problems. All fans used for ASD systems were switched off, and then back on to see if the starting capacitor had failed. No problem fans were found.

A few homes had foundation penetrations sealed with a latex or other type caulk which had hardened and cracked, but the majority of seal efforts were still in good shape.

As previously mentioned, the heat recovery ventilators did suffer durability problems. Many of the HRVs were not operating, and would not operate due to broken or worn belts. In addition, regular filter replacement, which is important for efficient operation, was obviuosly not taking place in any of the homes.

SUMMARY

This manual is the result of an investigation of radon mitigation systems that were installed in New Jersey homes between 1986 and 1991. The purpose of the investigations was to determine if there were any commomly made and easily corrected mistakes in the mitigation system design and installation. The final objective of the project was to transfer information to mitigators that would help them provide consumers with more effective radon mitigation systems.

The majority of the systems investigated were ASD systems of one sort or another. The investigation revealed that, for the most part, mitigators are doing a good job at reducing indoor radon levels for their clients. There were, however,

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a few deficiencies in the design or installation of the ASD systems that lessened their effectiveness. The deficiencies included poor pressure field extension, due mainly to restrictions in the pipe system, and untreated ground contact areas.

The causes of the restrictions in the pipe systems were mainly raincaps or other terminators that reduced the free vent area of the pipe, and the failure to dig suction pits at each suction point. (This is now mandatory for RCP contractors and therefore should not continue to be a problem.) Identification of these problems is relatively easy. Airflow and pressure measurements will alert the mitigator to possible problems. The cause of untreated areas could not be positively identified, but it is suspected that it is an economic consideration.

Mitigation systems other than ASD were also investigated. The sealing of radon entry points was tried in eight homes. Six of those efforts failed. Heat recovery ventilators were installed in eight homes, but only two of the HRVs were being used as a primary mitigation technique. The other HRVs had been replaced with ASD systems. This was mainly due to the improper installation or maintanence of the HRVs and not due to any theoretical limitation

RECOMMENDATIONS

Homeowners across the country rely on the professional radon mitigator to install radon-reduction systems that continuously maintain low indoor radon levels. Currently, the most widely used radon-reduction technique is an ASD system. The recently completed New Jersey mitigation system study found problems with several ASD systems. The problems caused the systems to fail to lower the indoor radon levels to less than 4 pCi/L. It is the judgement of the investigators that, if proper post-mitigation diagnostics were performed on those systems, the problems would have been identified, and the mitigation system made more effective.

U.S. Environmental Protection Agency Radon Mitigation Standards require contractors who participate in the Radon Contractor Prpficiency Program (RCP) to measure suctions or airflows in a depressurization system to assure

STUDENT NOTES

that the system is operating as designed. The Radon Mitigation Standards also recommend that mitigators make pressure field extension measurements. These measurements will serve to alert mitigators to possible system problems. Techniques for making the required and recommended measurements are presented in the following section.

STUDENT NOTES

ACTIVITIES

Post-mitigation system diagnostics are an important part of the mitigation effort. EPA Radon Mitigation Standards require suctions and airflows be measured within the pipe system. It is also recommended that mitigators perform a pressure field extension test. The following activities have been designed to teach mitigators how to make airflow and pressure measurements, to interpret the results, and to identify design or installation details that may contribute to poor pressure field extension.

AIRFLOW MEASUREMENTS

Airflow measurements can alert the mitigator to unbalanced conditions in multiple-point systems, and also warn the mitigator of fan sizing problems. Making the airflow measurements involves drilling a small hole in the system piping, making the measurements, and then sealing the hole. Care must be taken to ensure that the hole is sealed in a way that it will not open at some later date. A permanent seal can be obtained by cutting a small patch from a elbow, tee, or coupling and gluing the patch over the hole.

A pitot tube and micromanometer is used to make the airflow measurements. A small hole should be drilled through the pipe at least 8-1/2 pipe diameters above, and 1-1/2 pipe diameters below anything in the system that would create turbulent airflow. This includes the fan, elbows, tees, and bends in the pipe. This will help to ensure that the velocity profile is uniform. The pitot tube is inserted into the pipe, facing into the airstream. Make three measurements, one about 1 inch from the far wall of the pipe, one in the middle, and one about 1 inch from the near wall of the pipe. These locations are labelled A,B, and C on Figure 9. The display on the micromanometer will bounce around as you are taking the measurement. Be aware that the results at A,B, and C may not be the same as each other. Once you are confident that you have valid measurements at A,B, and C, average the three values. The average value is called the velocity pressure.

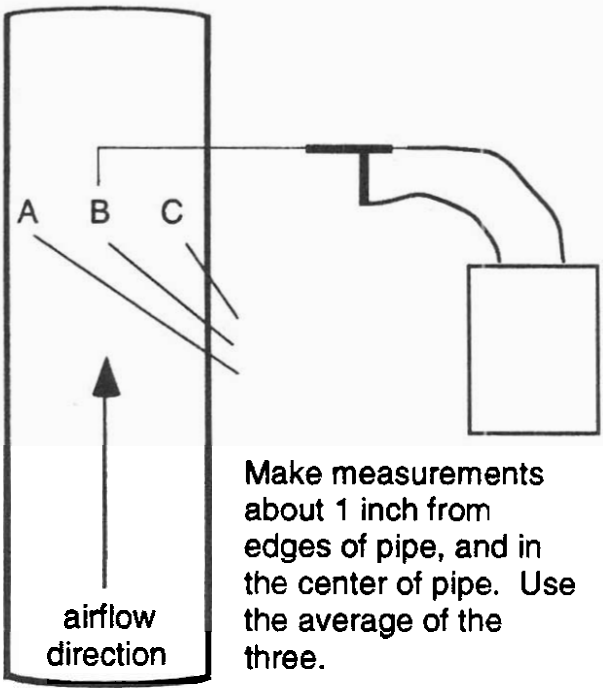


Figure 9. Locations for making velocity pressure measurements.

The velocity pressure is converted to an air velocity, using conversion techniques supplied by the manufacturer of the pitot tube. The resultant velocity, in feet per minute, can then be converted to an air volume using the following equation:

volume (cfm) = velocity (fpm) x area of pipe (sq. ft)

For our demonstrations we will be using a 4 inch diameter pipe. The area of the pipe is 0.087 square feet.

EXAMPLE
Velocity pressure at A: 0.085 in. WC
Velocity pressure at B: 0.095 in. WC
Velocity pressure at C: 0.090 in. WC
average velocity pressure: 0.090 in. WC

The average velocity pressure of 0.090 in. WC converts to an air velocity of 1200 fpm. Multiplying the velocity of 1200 fpm by the area of the 4 inch diameter pipe, 0.087 sq. ft., results in an airflow volume of 104 cfm.

Although this method is not as detailed as those published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and other professional societies, the accuracy obtained by using this method is sufficient for the purposes discussed here.

ACTIVITY 1. ADJUSTING DAMPERS IN MULTI-POINT ASD SYSTEMS

ASD systems with more than one suction point, particularly combination sub-slab and block wall depressurization systems, may need to be tuned to ensure than an adequate pressure field is being developed within the wall and beneath the floor slab.

For this demonstration, the mock-up illustrated on Figure 10 will be used. This mock-up simulates a combination sub-slab and block wall depressurization system. The section of pipe identified by test point FP1 represents the pipe leading to a sub-slab suction point. Pipe sections FP2 through FP5 represent the soil beneath a floor slab. The pipe sections identified by test points WP1 through WP4 represents the piping leading into the block wall. The pipe section identified by test point WP5 represents the inside of a block wall.

- The objective of this activity is to demonstrate the impact of un-balanced airflows in multi-point ASD systems. The student will make airflow measurements to determine the volume of air flowing through the pipe system leading to the block wall, and the volume of air flowing through the sub-slab soil. In addition, differential pressure measurements will be made at all test points.

The measurements will be made with the mock-up in the following configurations:

° system with damper fully open,

° system with damper adjusted.

All measurements should be made with the system in one configuration before moving on to the next configuration.

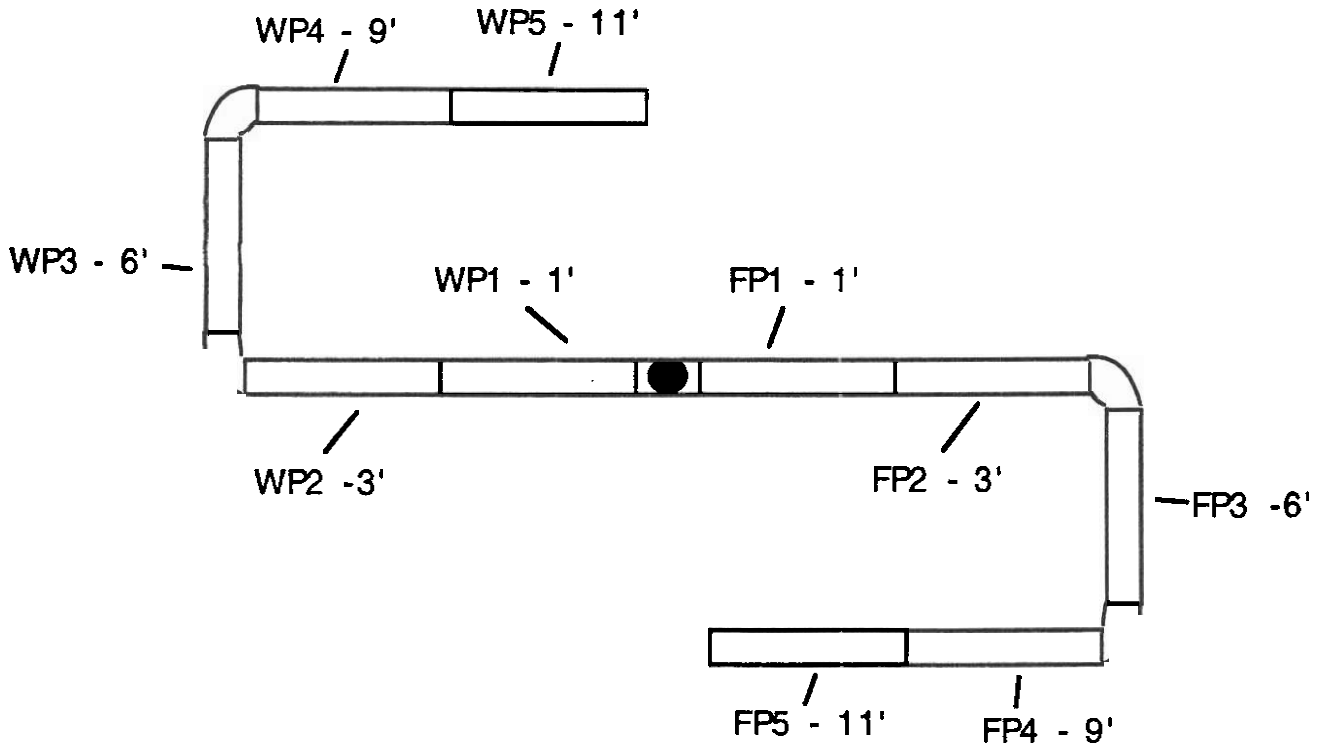


Figure 10. Demonstration unit for all activities.

SYSTEM WITH DAMPER FULLY OPEN

1. Measuring System Airflows

Connect the pitot tube to the micromanometer and insert the pitot tube at the hole labelled WP1. Make the same measurement at FP1. Make the measurements using the method previously described. Record the results in the spaces provided. The dampers should be completely open.

Note: As previously mentioned, airflow measurements should be made no closer than 8 1/2 pipe diameters from an obstruction. The test points WP1 and FP1 do not fulfill this requirement, however, to ease the transport of the demonstration units, a compromise was made between accuracy and transportability. Measurements made during the demonstration unit design revealed that, at the operating airflows found in the demonstration units, very little accuracy was lost.

Velocity pressure	WP1	A:_____		FP1	A:_____
		B:_____			B:_____
		C:_____			C:_____
Average pressure:		_____			_____

To convert the velocity pressure into air velocity, use the air velocity calculator that has been supplied. For this demonstration, assume a standard air density of 0.075 lbs. per cubic foot. Record the air velocity in the space provided:

Air velocity (fpm): WP1:_____ FP1:_____

To calculate the airflow, in cubic feet per minute, multiply the air velocity, in feet per minute, by the cross-sectional area of the pipe, in square feet. The cross sectional area of a 4 inch pipe is 0.087 sq. ft.

Airflow (cfm) WP1:_____ FP1:_____

2. Measuring the Pressure Differences

Using the micromanometer, measure the pressure difference at all test points in the mock-up. Record the results in the spaces provided.

WP1 - 1 foot	_____	FP1 - 1 foot	_____
WP2 - 3 foot	_____	FP2 - 3 foot	_____
WP3 - 6 foot	_____	FP3 - 6 foot	_____
WP4 - 9 foot	_____	FP4 - 9 foot	_____
WP5 - 11 foot	_____	FP5 - 11 foot	_____

SYSTEM AFTER ADJUSTING DAMPER

Adjust the damper in the wall piping to get the most evenly distributed pressure field in both sections. Record the results in the spaces provided.

1. Measuring System Airflows

Velocity pressure	WP1	A:_____	FP1	A:_____	
		B:_____		B:_____	
		C:_____		C:_____	
Average pressure:		_____		_____	

Air velocity (fpm): WP1:_____ FP1:_____

Airflow (cfm) WP1:_____ FP1:_____

2. Measuring the Pressure Differences

Using the micromanometer, measure the pressure difference at all test points in the mock-up. Record the results in the spaces provided.

WP1 - 1 foot	_____	FP1 - 1 foot	_____
WP2 - 3 foot	_____	FP2 - 3 foot	_____
WP3 - 6 foot	_____	FP3 - 6 foot	_____
WP4 - 9 foot	_____	FP4 - 9 foot	_____
WP5 - 11 foot	_____	FP5 - 11 foot	_____

What damper position makes the best pressure distribution? _____

2. Place the end cap on the end of the pipe section identified by WP5. Measure the pressure difference at WP5 and FP5. Record the results in the spaces provided.

WP5:_____ FP5:_____

What happened to the pressure differences, and why?

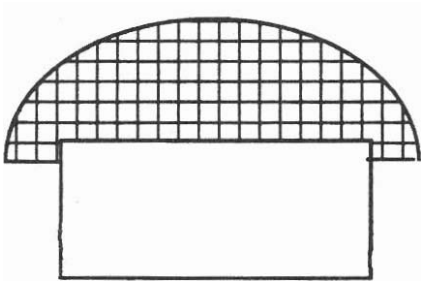
ACTIVITY 2. DEMONSTRATING RESTRICTIONS THAT IMPACT THE PRESSURE FIELD EXTENSION

For this demonstration, we will assume that you have installed an ASD system, and pressure field extension (PFE) measurements have indicated that the system is not developing an adequate pressure field. Your soil communications test revealed that the soil beneath the slab is fairly permeable to airflow, and you expected a much better pressure field. In accordance with EPA Radon Mitigation Standards, you have installed a suction pit at the suction point. You have also sealed the leaks in the foundation as well as you reasonably can.

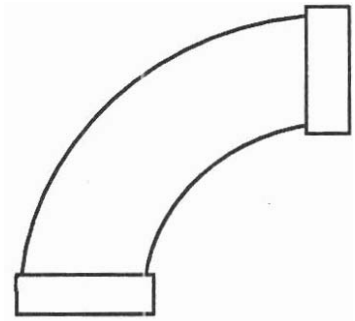
Research has shown that many ASD systems do not develop an adequate pressure field because of restrictive terminators that have been placed on the system. To demonstrate the effect that commonly used terminators have on the strength and extent of the pressure field, each group will make pressure difference measurements at all test points with the system in the following configurations:

- system with no terminator,
- system with terminator #1,
- system with terminator #2,
- system with terminator #3,
- system with terminator #4.

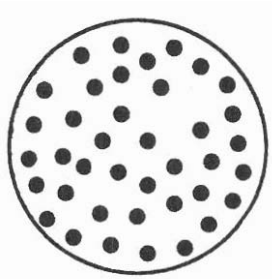
Make all measurements with the system in one configuration before changing terminators.



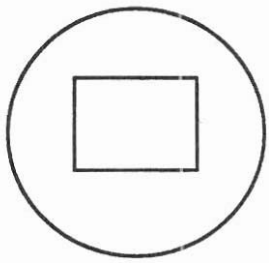
terminator #1



terminator #2



terminator #3



terminator #4

Figure 11. Terminators to be used for Activity #2.

SYSTEM WITH NO TERMINATOR

1. Measuring the pressure created by the terminators

Place an end cap on the wall pipe system. Make a pressure measurement at the points above and below the fan as illustrated on Figure 11. Record the results in the spaces provided.

Above fan pressure: _____
Below fan pressure: _____

2. Measuring the pressure field extension

Make a pressure measurement at each test point as illustrated on Figure 10. Record the pressure in the spaces provided.

FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

Make the pressure measurements with the system in each configuration and record the results in the spaces provided. When you have finished with all measurements, plot the pressure measured at test points FP1 through FP5 versus the distance, on the graph paper that has been provided.

SYSTEM WITH TERMINATOR #1

Above fan pressure: _____
Below fan pressure: _____

Pressure
FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

SYSTEM WITH TERMINATOR #2

Above fan pressure: _____
Below fan pressure: _____

Pressure
FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

SYSTEM WITH TERMINATOR #3

Above fan pressure: _____
Below fan pressure: _____

Pressure
FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

SYSTEM WITH TERMINATOR #4

Above fan pressure: _____
Below fan pressure: _____

Pressure
FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

ACTIVITY 3. DEMONSTRATING THE AFFECT OF THE SOIL-FOUNDATION COMPONENTS

For this demonstration, we measure the pressure difference at each test point with the system in the following configurations:

- system without terminator 3,
- system with terminator 3.

SYSTEM WITHOUT TERMINATOR

1. Measuring total system airflow

Connect the pitot tube to the micromanometer and insert the pitot tube in the hole labelled FP2. Make the measurements as previously described. Record the results in the spaces provided

Velocity pressure A:_____
B:_____
C:_____

Average pressure: _____

To convert the total airflow, in cubic feet per minute, multiply the air velocity, in feet per minute, by the cross -sectional area of the pipe, in square feet. The cross sectional area of a 4 inch pipe is 0.087 sq. ft.

Total system airflow: _____

2. Measuring the pressure field extension

Remove the pitot tube from the micrmanometer. Connect one side of the micrmanometer to each pressure port. Record the pressure in the spaces provided.

FP1 - 1 foot: _____
FP2 - 3 foot: _____
FP3 - 6 foot: _____
FP4 - 9 foot: _____
FP5 - 11 foot: _____

SYSTEM WITH TERMINATOR

Install terminator 3 on the end of the slab pipe system and make the airflow and pressure measurements. Record in the spaces provided.

1. Velocity pressure A: _____
B: _____
C;_____

Average pressure: _____
Air velocity (fpm): _____
Total system airflow: _____

Air velocity (fpm): _____

Total system airflow:_____

2. Measuring the pressure field extension

Remove the pitot tube from themicromanometer. Connect one side of the micromanometer to each pressure port. Record the pressure in the spaces provided.

FP1 - 1 foot: _____

FP2 - 3 foot: _____

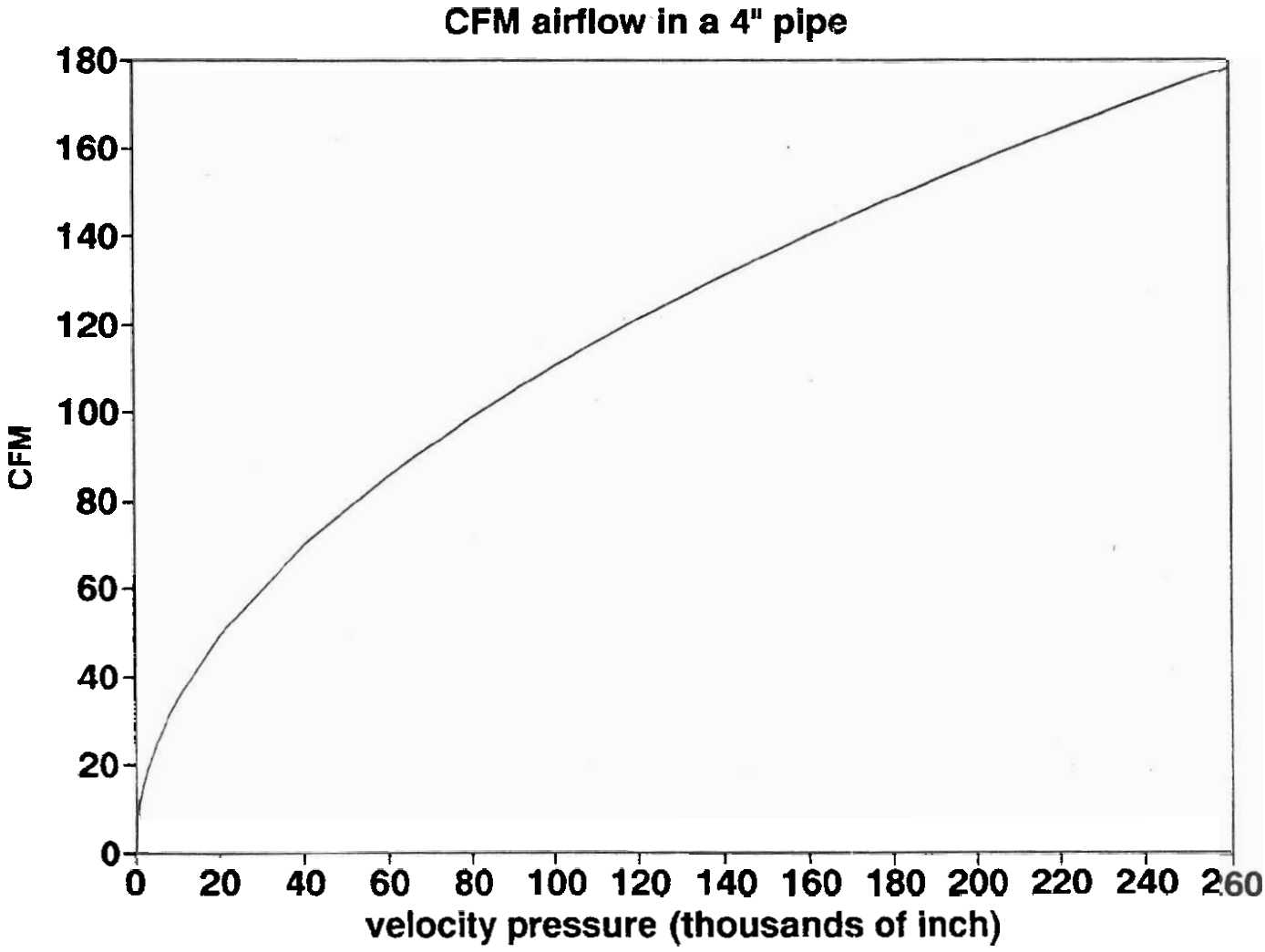
FP3 - 6 foot: _____

FP4 - 9 foot: _____

FP5 - 11 foot: _____

3. Compare the airflow and pressure differences measured with the system in each configuration and describe the results.

4. Provide a theory explaining what happened to the airflow and pressure measurements when pipe A was attached.


CFM airflow in a 4" pipe
CFM
180
160
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260
velocity pressure (thousands of inch)