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Practical Radon Control for Homes

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Introduction

What Is Radon?

Over the past several years people have become increasingly aware of the possibility of indoor air contaminants posing a health risk. One of these contaminants, radon, has received a great deal of attention from the news media, public health agencies, and homeowners.

Radon is a radioactive gas that is produced by the natural decay of radium. It can't be seen, smelled, tasted, or detected by ordinary chemical means because it is chemically inert. Because it is radioactive, radon is unstable and liable to spontaneously give off some mass and energy and become an entirely new radioactive element, polonium, which in turn produces yet another new radioactive element when it decays. This decay chain is shown in Figure 1.

As one radon atom decays, three alpha particles are produced within a short time period — one from the radon and one from each of the two polonium isotopes. They are released quickly after the radon decay because the half lives of the isotopes are all less than an hour. The mass given off as alpha particles allows radon to be detected and also poses the major health risk from exposure to radon and its short-lived decay products.

The health risk from radon is not from exposure to the outside of the body. An alpha particle cannot penetrate even the layer of dead skin on the outside of your body. Only when an alpha particle reaches the very thin tissue found in the lung (so thin that oxygen and carbon dioxide can pass through it) can it cause the damage that might later develop into a lung cancer. If a radon atom happens to decay while inside your lung you may get some exposure. This would only occur with a small fraction of the radon breathed in, because chemically inert radon moves freely in and out of your lungs and has a half life of 3.8 days. Radon's decay products, however, are not inert. They have a static charge and are chemically active so that they can readily attach themselves to the lung or to airborne particles which may become lodged in the lung. Some of the alpha particles given off during decay could happen to hit a cell nucleus in just the

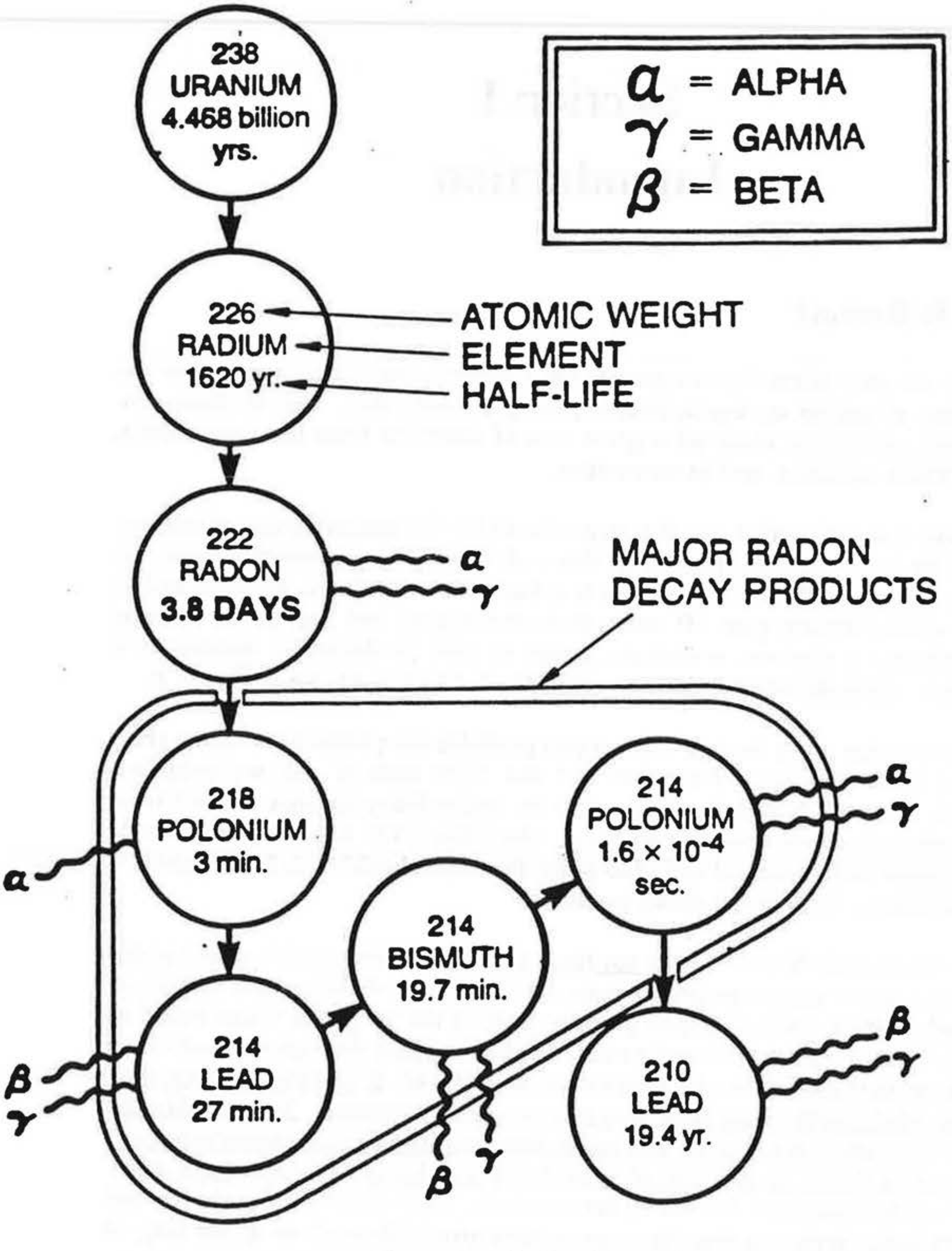


Figure 1 — Radium Decay Chart

right way to do just the right damage to the DNA molecule, so that eventually a lung cancer might develop sometime after age forty. You can see that there are a lot of "might haves" in the chain of events that leads from radon exposure to lung cancer. That is why not everyone who is exposed to radon develops lung cancer. There is simply an increased risk that when you die it will be from lung cancer and not something else. The amount of risk depends on the length and level of radon exposure.

Health Risks and Regulation

There is no debate as to whether exposure to radon and its short-lived decay products increase the risk of dying from lung cancer. The evidence for a health risk from radon is stronger than the evidence for exposure to many other carcinogens and includes a physical model for how the damage occurs, plus animal studies and epidemiology on uranium miners (with gold miners used as a control group). The major debate is about the amount of risk associated with different levels of exposure. In the low range of concentrations, where you would expect most house concentrations to be, there is no data available. On the other hand, some houses have been found with radon levels so high that living in those buildings will undoubtedly result in exposures similar to those experienced by uranium miners.

Little or no data exists to show the effects of chronic low-level exposure to carcinogenic substances. It is therefore assumed for regulatory purposes that any exposure carries some risk; for 0% risk of cancer you would have to avoid contact completely. It is clearly impossible to avoid all exposure to radon, because it is a naturally occurring component of the outdoor air. Each regulatory body therefore sets acceptable exposure levels based upon its own internal logic, so that the standards and guidelines found around the world vary considerably.

The best-known current radon guideline in the United States is probably 4 pCi/l. The U.S. Environmental Protection Agency (EPA) recommends that mitigation be undertaken in houses with annual average radon concentrations in the air exceeding 4 pCi/l, with increasing urgency at higher concentrations. This is a recommended action level, not an enforceable regulatory standard; it was chosen on the basis of several considerations, including the practical economics of mitigating the many houses which are at relatively low radon concentrations. Current "wisdom" is that one out of 100 people with a 70-year lifetime exposure at the 4 pCi/l level would die of lung cancer due to radon (independent of other factors such as smoking).

The EPA also regulates municipal water systems and establishes enforceable standards for contaminants with a goal (established by Congress) of holding the risk below one additional cancer death per year per 10,000 to 1,000,000 people. Municipal water suppliers delivering water with radon levels above the standards must notify their customers that the water is not safe to drink and must either buy the necessary cleaning systems or obtain an exemption based upon economic hardship. Based on its risk estimates and upon the availability of water cleaning technology, the EPA is in the process of developing a radon standard for municipal drinking water which will probably be finalized at around 1,000 pCi/l. The best data available at present suggests that 10,000 pCi/l in domestic water contributes 1 pCi/l to a house, so that at 1,000 pCi/l the water would add 0.1 pCi/l to the level in your house. The outdoor ambient radon level ranges from 0.1 to 0.2 pCi/l in most areas of the country.

Currently, radon levels higher than the EPA guideline of 4 pCi/l have been found in every state except Hawaii. Based on the measurements which have been made nationally in the past five years, it is expected that between 5 and 15% of the nation's housing stock is involved. Although this amounts to a very large number of buildings, it is a fairly small fraction of the total housing stock.

It is difficult to estimate the radon level in a house without measuring it or to predict whether a new house built on a given site will have a problem. A case could be made that, given enough soil measurements (radon, radium, airflow characteristics) at enough locations in the prospective building lot, an accurate prediction could be made. It is ordinarily more expensive to make such measurements than it would be to make the building a radon-resistant structure to begin with.

Risk Assessment and the EPA Guideline

The EPA guideline is just that — a guideline. It is neither law nor an enforceable standard. The decision as to what radon levels are acceptable will be made by home buyers and sellers, mortgage holders, relocation companies (or anyone else who is liable for providing housing), and possibly state health agencies. Where liability issues or resale value of a house are concerned, it is likely that the EPA guideline will become as good as a standard because it is something you can point to from the witness stand, should you ever find yourself defending a property for which you were responsible (as a builder, realtor, banker, relocation company, armed services, mental health residence, etc.). For lenders and homebuyers, the issue may be the ease of selling the house when it is put on the market. If it is below the EPA guideline, then a large percentage of the homebuying public is going to believe it's safe. We expect to see testing and mitigation occur as a regular part of real estate transactions in areas where radon has been found at fairly high levels in a number of houses.

In areas where radon levels have not been measured or have been measured and found to be low, the people who are most concerned are those who are thinking of their own health risk. These are the people who have read about the risk and judged it to be worth the $12 to $50 it costs to make a measurement and see if they have elevated levels, or those who have made the measurement and decided it was worth the expense to lower the levels of radon in their homes. Making this kind of judgement is very personal.

Every day you and I make risk assessments. As part of the risk assessment process, we weigh the seriousness of the risk involved. Would you view the risk of juggling three tennis balls in the same way you would view the risk of juggling three kitchen knives? Of course not. Even though it is the same activity, with the same probability of making a mistake, the consequences of missing are very different.

People evaluate and respond to risk in different ways. Some people prefer to drive large, heavy cars in which they feel protected and safe, while others buy small, light cars and trust themselves to maneuver out of trouble. Others may avoid driving whenever possible. Similarly, given the same risk data, some of us will judge a radon level of 4 pCi/l as too high, and others will judge 20 pCi/l as fairly safe.

So for now, the EPA guideline is the standard to use for evaluating houses you are in some way responsible for, be that as homeseller, realtor, builder, radon mitigation contractor, or banker. You may be personally comfortable with some other level of exposure for yourself and your family, depending upon your finances, the amount of time you spend in different areas of your house, your plans for the future, and other factors specific to you.

Measuring radon in houses

The EPA Protocols

The EPA has established four basic protocols for the measurement of radon in houses:

1. Granulated charcoal canisters are passive detectors which measure the radon concentration integrated over a 2 to 7 day period. They are frequently used for screening measurements and for short-term post-mitigation monitoring.

2. Alpha-track detectors are passive detectors which measure the radon concentration integrated over a period of months to a year or more. They are

sometimes used for screening measurements, but more frequently for follow-up and post-mitigation measurements. Alpha-track detectors can also be used as personal dosimeters for field researchers and mitigation contractors.

3. Grab samples are air samples collected over a period of minutes (usually 2-5 minutes). They provide a "snapshot" of instantaneous radon concentration. Grab samples collected in several locations during the same site visit are used for diagnostic purposes. Radon levels can vary dramatically over short time intervals, so that grab samples are not appropriate for screening or follow-up measurements.

4. Continuous radon monitoring is used to measure concentrations over a period of hours to days. This type of record is sometimes used for screening purposes for real estate transactions because it is sensitive to variations in ventilation.

A complete description of the EPA protocol for each of the radon measurement techniques is included in Appendix A.

Testing Equipment and Services

The EPA conducts a testing program of radon detection devices and services. Companies that offer services with proven accuracy are listed by the EPA in its "Cumulative Proficiency Report." A copy of that report, which includes a description of the services offered as well as names and address of all qualifying companies, is reproduced in Appendix B.

Types and Purposes of Radon Measurements

Radon measurements serve several purposes: screening measurements, to discover whether further measurement is warranted; follow-up measurements, to confirm the screening measurements; diagnostic measurements, which help to identify entry routes and suggest mitigation approaches; and post-mitigation measurements, to make sure that mitigation has been successful. Other types of measurements made for research purposes are not within the scope of this manual.

Screening Measurements

Screening measurements are taken to establish whether or not a house may have a radon problem. Charcoal canisters are often used for this test because they provide rapid feedback. It would be disturbing to wait months for an alpha-track detector to get an idea of your annual average exposure, only to find out that it is 250 pCi/l.

Most people prefer to screen under worst-case conditions, so that they will know the highest radon level that they are being exposed to. This generally means taking the measurement during the winter months, when the house is closed and combustion appliances exert suction on the substructure. The EPA suggests that winter conditions can be simulated by closing doors and windows, and others have proposed that a blower door can simulate the negative pressures found in winter. However, it is not possible to simulate the frozen soil and snow conditions which limit radon's available pathways and increase the likelihood that it will move laterally (sideways) into your house.

It is important to remember that short-term screening measurements only show radon levels during a brief slice of time, not your annual average exposure. Follow-up measurements should be done to confirm the results of the screening before mitigation work is done.

Follow-up Measurements

Follow-up measurements can be done using alpha-track detectors or charcoal canisters. Follow-up measurements are generally taken at several locations simultaneously (for example, the basement and upper levels) to confirm the screening measurement and learn about radon distribution within the house.

Diagnostic Measurements

Diagnostic measurements are used to evaluate mitigation techniques rather than to learn about occupant exposures. For this purpose, precision in measurement is less critical than the identification of relatively high or low levels at potential radon entry points. A detailed discussion of the building investigation process, including diagnostic measurement, appears later in this manual.

Post-mitigation Measurement

Charcoal canisters can be used to provide feedback on the immediate success or failure of mitigation work. Alpha-track detectors are appropriate for long-term post-mitigation measurement, and can be analyzed seasonally or annually to monitor the longevity of the mitigation.

Radon Sources and Pathways into the House

Movement through the soil

The ultimate source of radon in buildings is radium. Many types of soil and bedrock contain traces of uranium and radium sufficient to pose a problem in a house. However, radon only becomes a problem if there is an entry route into the house and a driving force to move the radon along that route.

If the radium is located in the soil or bedrock near the house, typical transport routes are:

- through a loose, sandy soil;
- through cracks and fractures in bedrock or a heavier soil; and
- through loose fill placed around the house as part of drainage systems or along utility entries.

Entry into the House

The two driving forces that move radon along one of these paths into a house are air pressure differentials and radon concentration differentials.

Air transport through cracks and holes

Air pressure differentials move air from the higher pressure to the lower pressure area. If the air pressure in a house is lower than the outside air pressure, then air will flow from outdoors to the inside of the house. Some of this outside air will flow in through the soil or through underground cracks and fissures in the soil or bedrock. If the air passes over any radium, it will carry radon along with it. If the radium concentration is high, even a low flowrate can be enough to produce a radon problem in the house.

The air in the basement of a house frequently has a lower pressure than the outside air because a number of devices and effects tend to exhaust air from the house. These exhaust air streams are induced both by natural forces and by powered fans and blowers. Natural forces act to exhaust air from a house when winds or temperature differences make the building act like a chimney; a suction is put on the lowest level of the house because air is leaving at the top. Air is also mechanically exhausted from houses by kitchen ranges, dryers, bath fans, and the draft requirements of combustion devices.

Anything that removes air from the house will act to lower the air pressure inside relative to the outside. How much it will be lowered can be judged by knowing the exhaust airflow and using fan door curves for the particular house. Because the same parameters that bring radon into the house affect the ventilation rate, no correlation has been seen between house airtightness and indoor radon concentrations (Turk et. al, Brennan). There is no evidence to support the popular belief that tightening houses for energy conservation has produced radon problems. Source strength and transport mechanism are the overriding variables determining radon concentration. None of the studies which have reported a correlation between airtightness and radon concentration measured the infiltration rate or the house tightness.

Diffusion through Surfaces

Radon will move through the air along the available transport routes even if there is no air flowing because of the difference between radon concentrations at the source of radium and in the basement air. In this situation, the transport mechanism is diffusion and is very similar to the mechanism by which water vapor diffuses through walls. The radon moves from the higher to the lower concentration at a rate which depends on the permeability of the material through which it moves.

If the radon entry rate is mainly dependent on concentration gradient diffusion, then the radium is probably quite close to the house.

Radon from Well Water

Another possibility is that the house has a drilled well to supply water and the well goes through rock which is emitting radon. Radon is like the bubbles in champagne; you can dissolve it in water but it would rather be in the air. When water heavily laden with radon (very roughly 10,000 pCi/l in water to see 1 pCi/l in house air) is used in a shower or laundry, the radon outgasses into the house air. This has been seen in several states and should be checked as a possibility, but it has not been the most frequently observed radon entry route.

Radon Sources within the House

Finally, another way radon enters a house is when the radium is actually located in the house and is emitting radon directly into the house air. Materials which sometimes contain radium include: exposed bedrock in crawlspaces or basements, rock collections, extensive rock fireplaces or walls (it takes quite a bit of exposed rock surface to result in a problem), radium dials on instruments or gauges, and concrete building materials that were manufactured using radium-bearing aggregate (uranium mine tailings are the most common problem aggregate). Sources within the home are not commonly the primary cause of severe radon problems.

Section II
Investigating Buildings & Selecting a Mitigation Technique

There are only a dozen or so tried and true (employed successfully in the field for a year or more) techniques for lowering radon concentrations in houses. When you inspect a building to decide how to correct a radon problem you need to look at factors that would lend themselves to one of the possible methods.

Radon control methods fall into one of the following categories:

- keep it out;
- if it gets in, dilute it.

In the "keep it out" category we have:

1) Depressurize the soil around or under the foundation using a fan (see Figures 2 through 8).

This reverses the flow of air coming from the soil into the house and keeps radon from entering. It is accomplished by applying suction under concrete slabs, on footing drains (interior or exterior), inside block walls, or under a barrier that is installed on exposed earth or stone. It can be applied to crawlspace, basement, or slab foundations. This technique can be effective for even very high-level buildings (2,500 pCi/l in some cases).

2) Isolate and ventilate a crawlspace or basement if it is not useful as living space (see Figure 9).

This method involves inhibiting radon entry by sealing openings between the foundation interior and the living area of the house and by providing active or passive ventilation to divert the radon-laden soil air to the outside without passing through the house. This technique has been proven effective for spaces

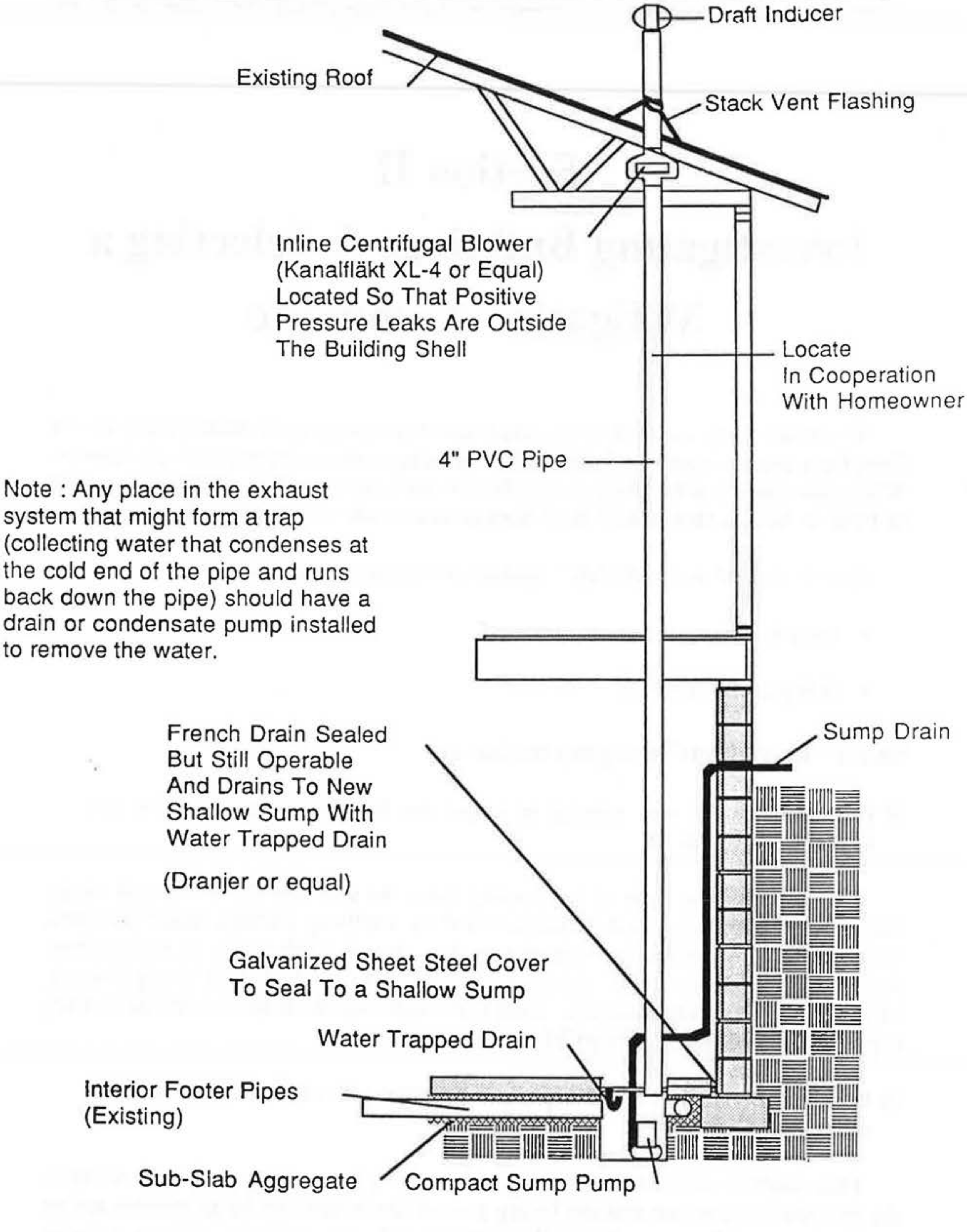


Figure 2 — Sub-slab suction at sump hole.

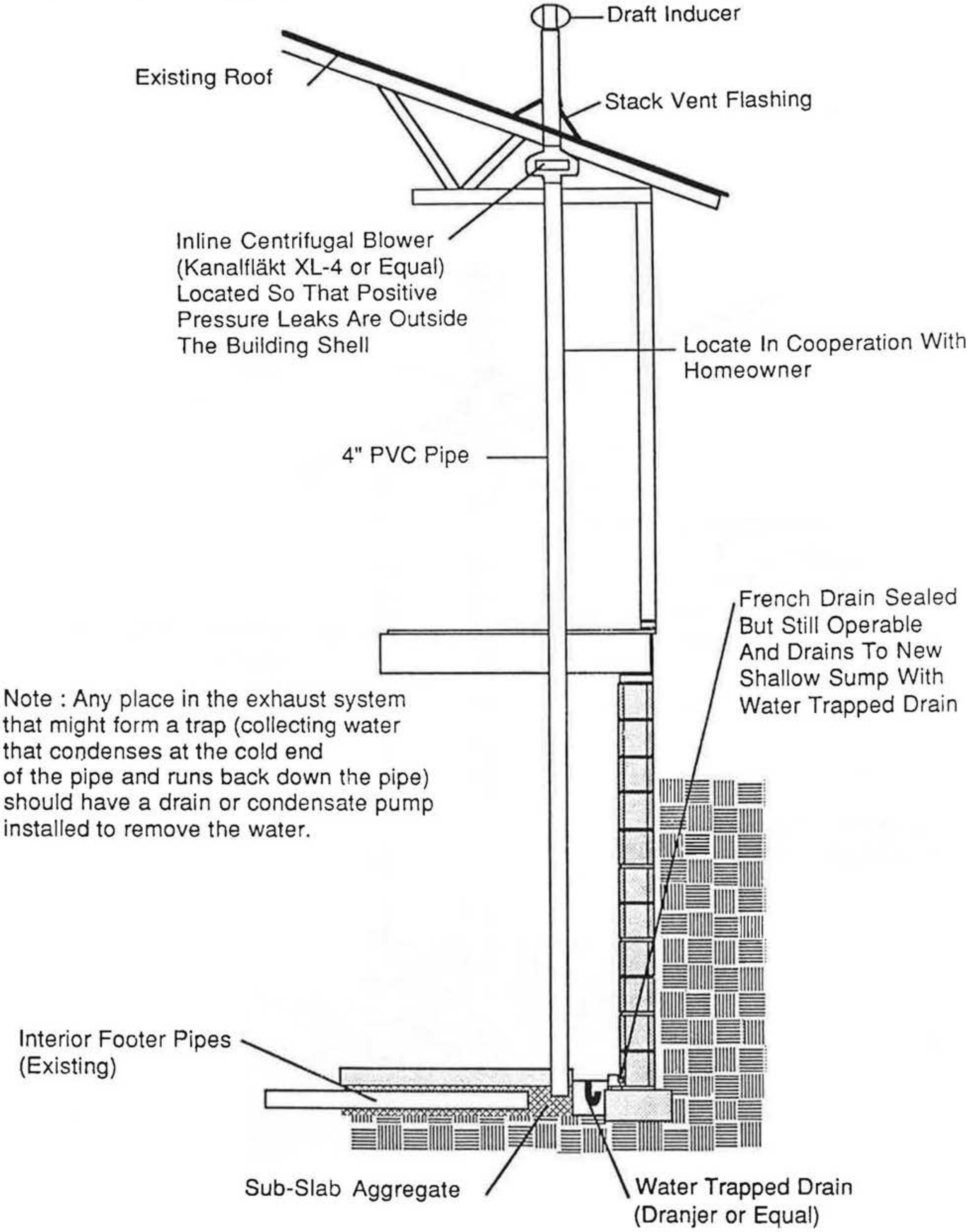


Figure 3 — Sub-slab suction at aggregate.

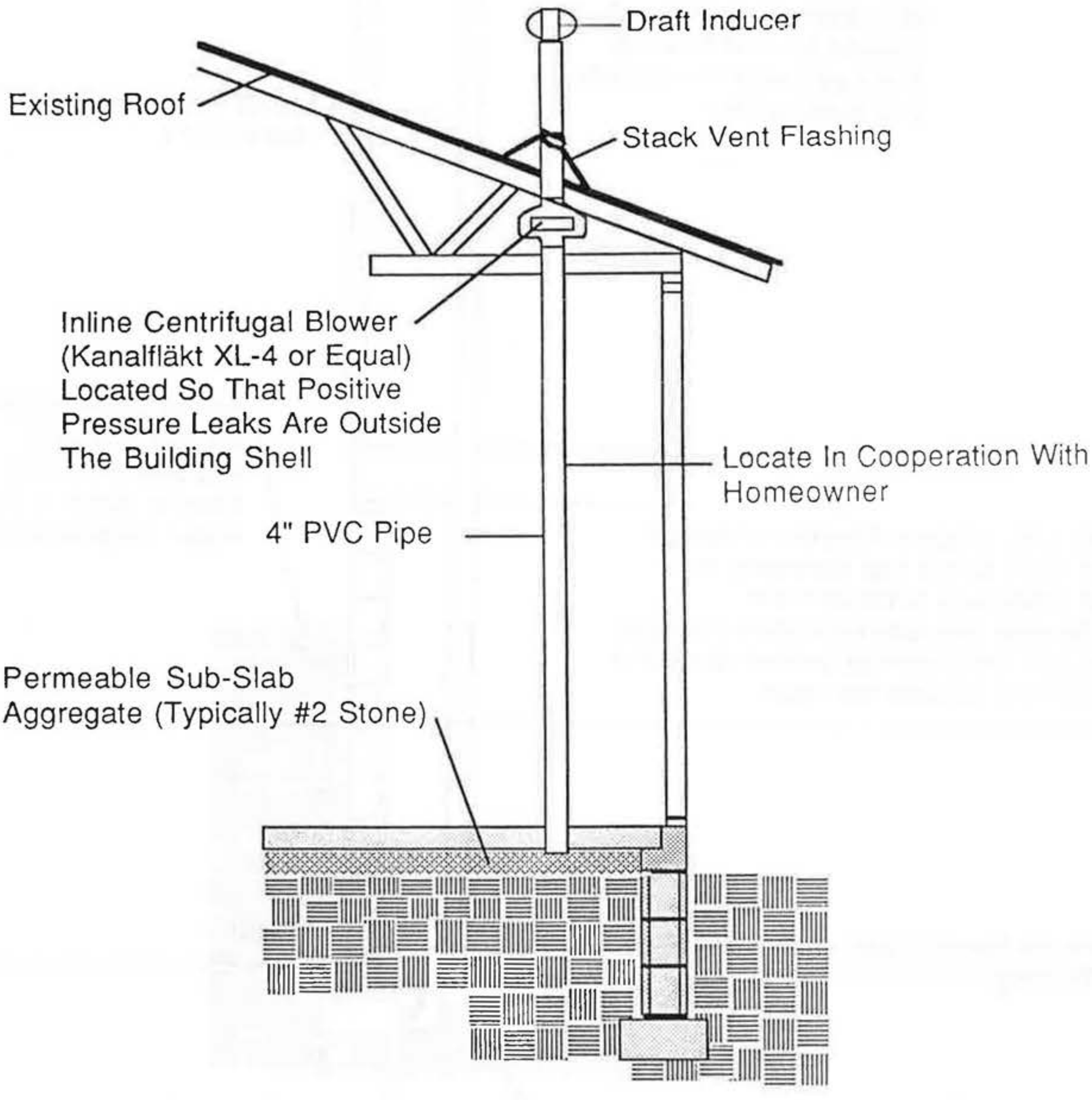


Figure 4 — Sub-slab suction. Slab on grade.

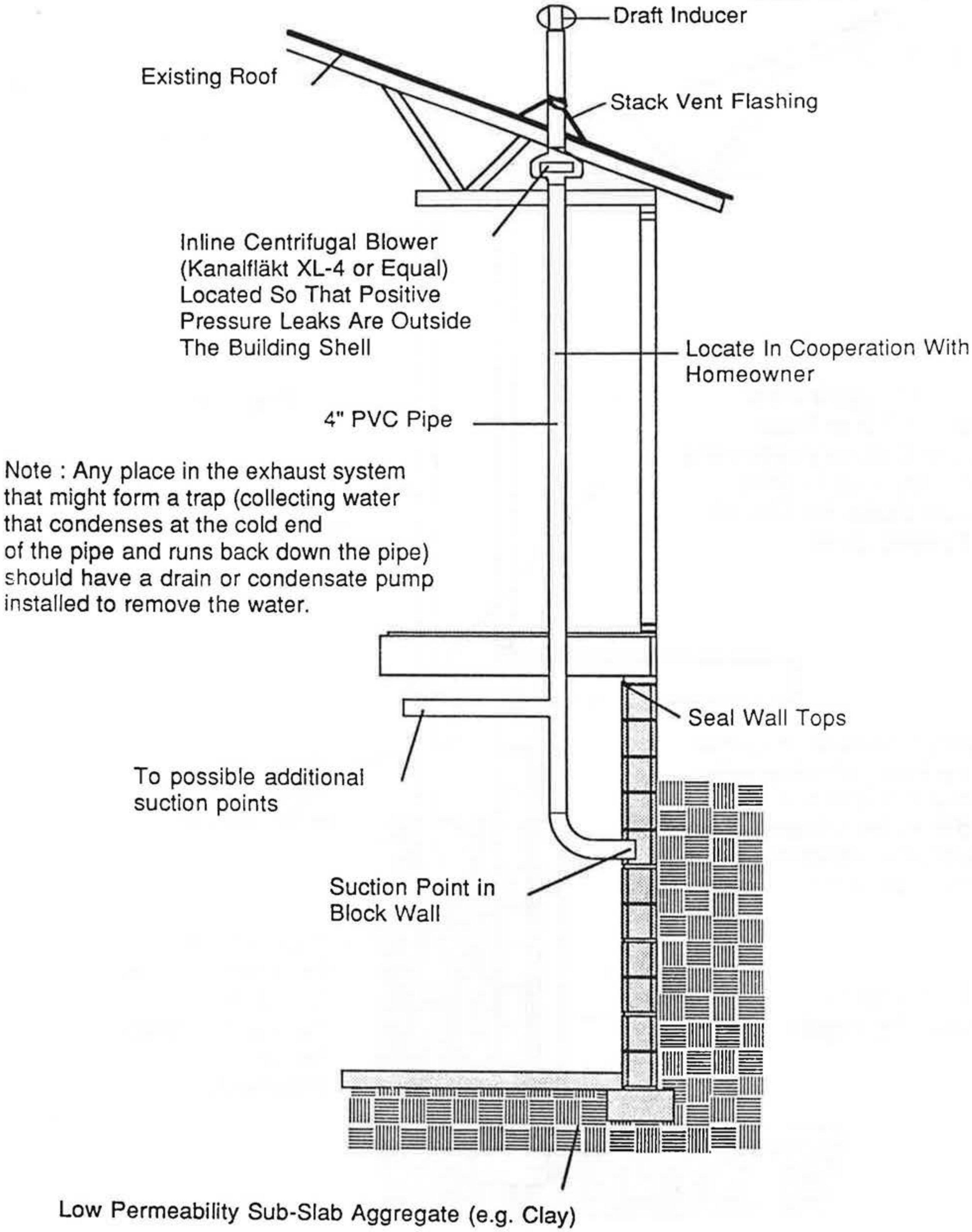


Figure 5 — Block wall suction; interior suction point.

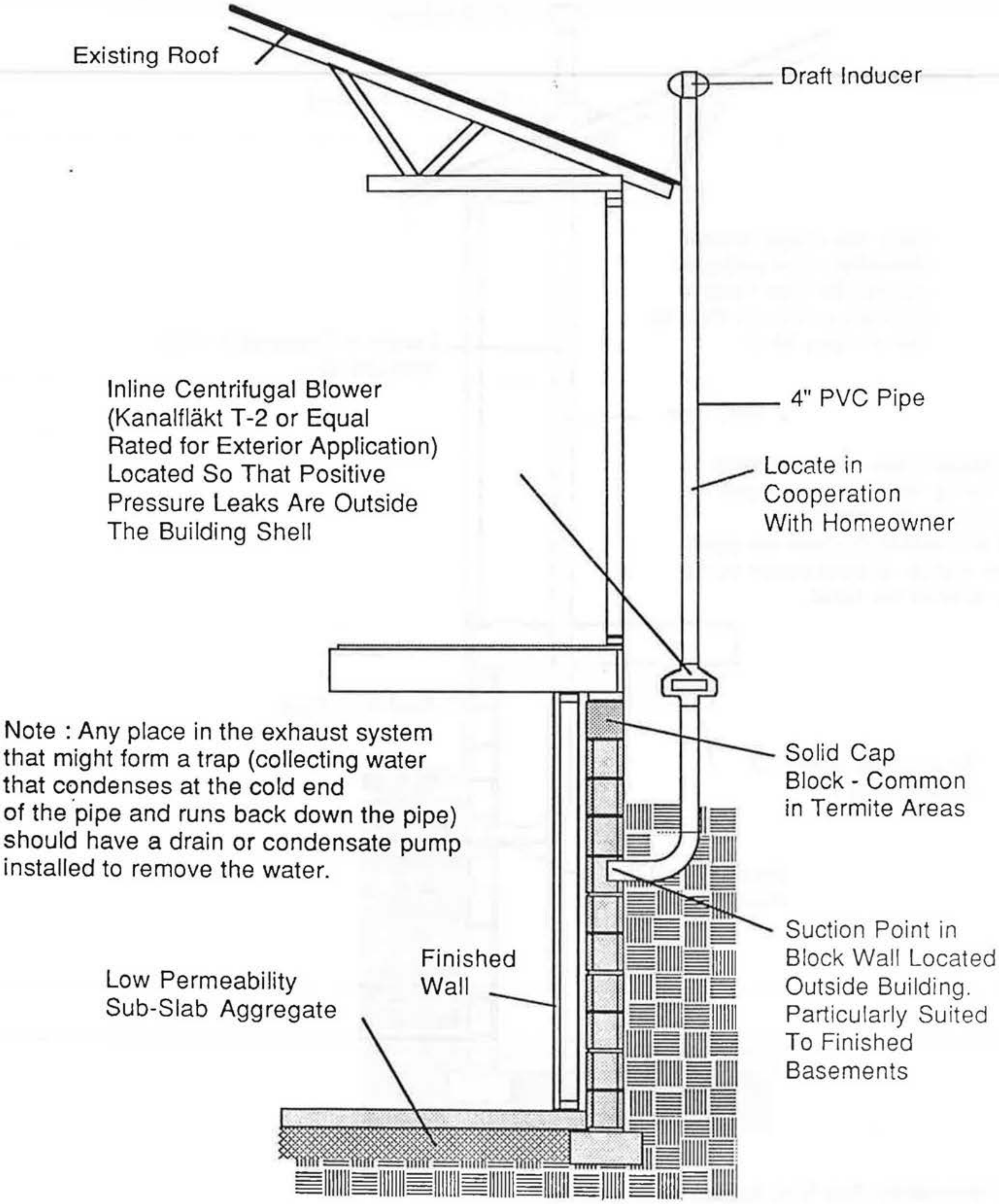


Figure 6 — Block wall suction; exterior suction point.

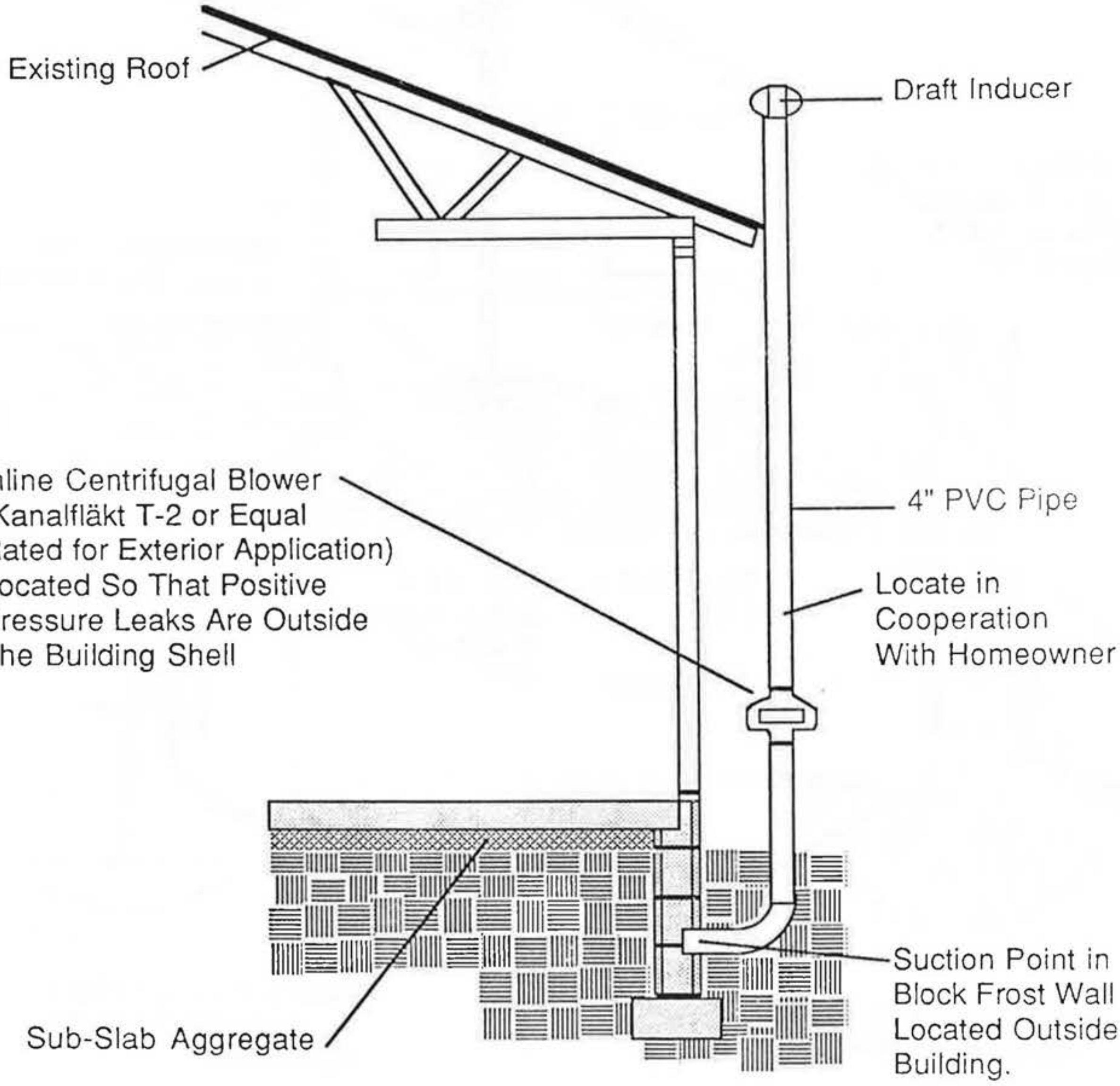


Figure 7 — Frost wall suction.

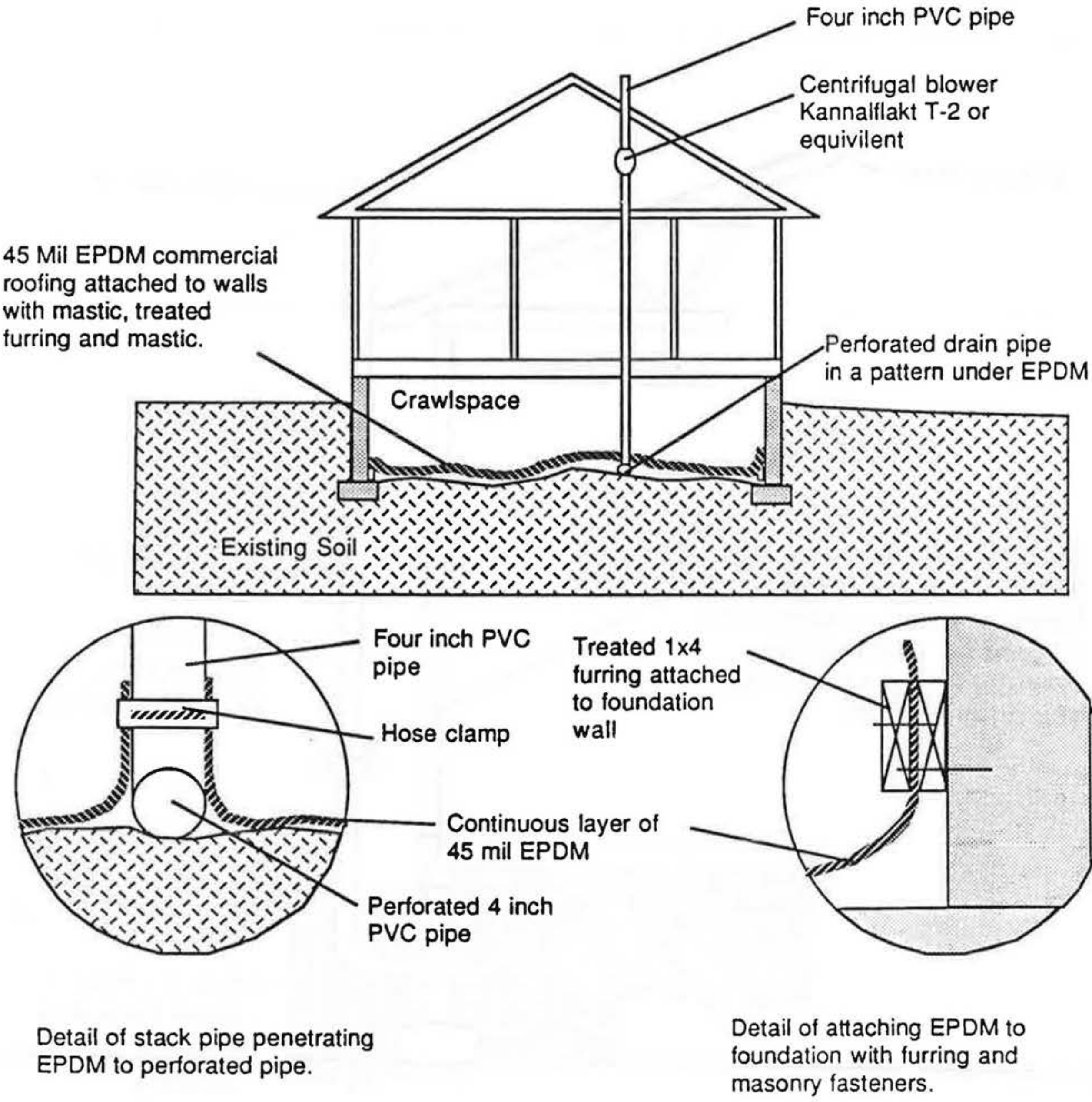


Figure 8 — Soil depressurization under installed barrier.

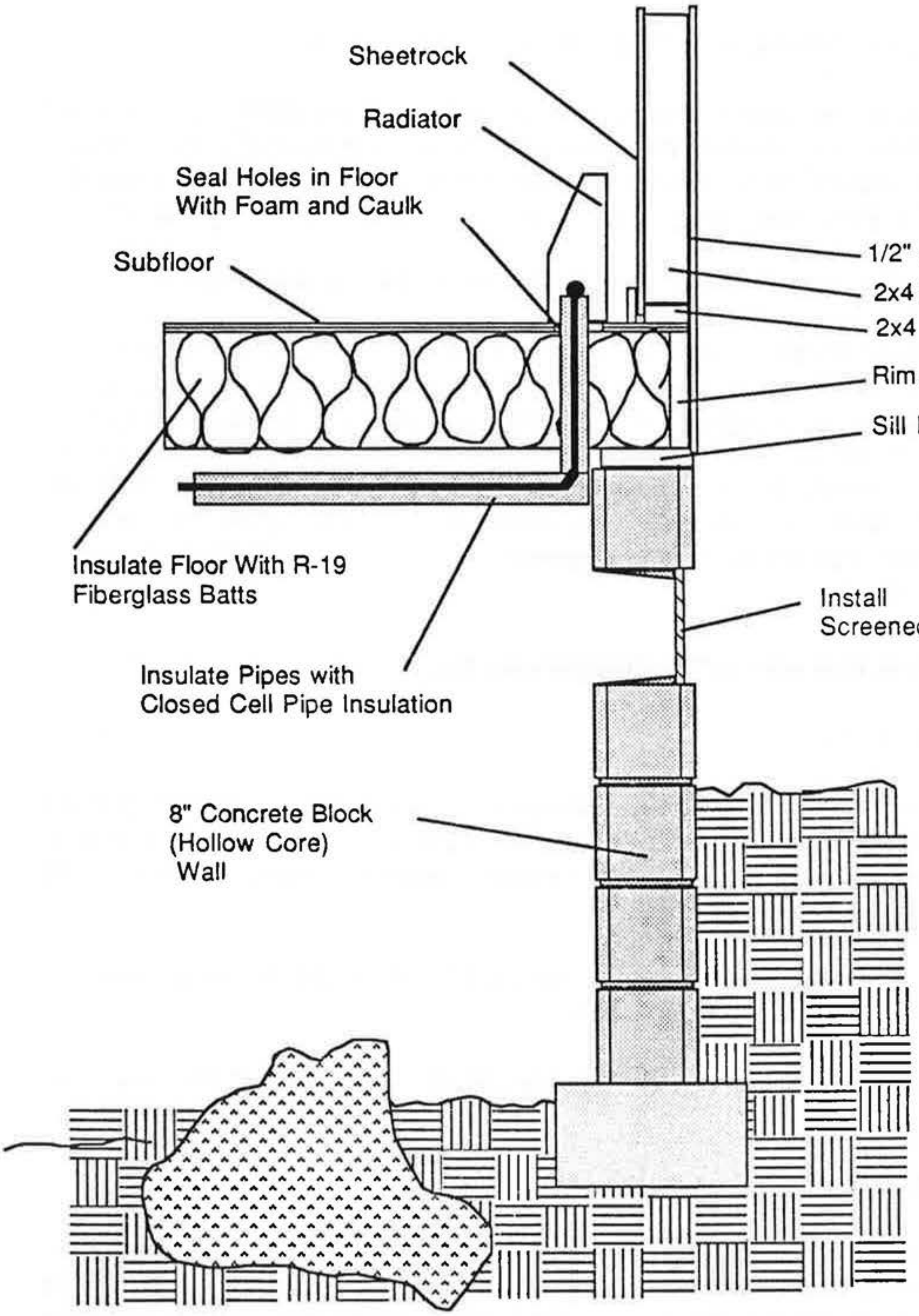


Figure 9 — Schematic for isolate and ventilate crawlspace.

where it is difficult to apply soil depressurization (stone-walled crawlspaces with no slab, for example).

3) Pressurize the basement with upstairs air (see Figure 10).

Pressurizing the basement inhibits or prevents radon entry by reversing the pressure differential between the house and the soil. It is an effective method but its use is limited to houses with basements that are tight enough and sufficiently well sealed from the upstairs air so that a small fan will do the job.

4) Isolate the house from the soil (see Figures 11-14 and Appendix B.).

This method involves sealing cracks and holes with caulk and/or foam plus covering permeable surfaces with parging and/or paint. This technique has had very spotty success, sometimes making large reductions and frequently making none. There is not enough experience to know when it will work well and when it will not; however, it is an important ancillary activity to all other techniques. Sealing of at least the obvious, easily accessed soil air entry routes often improves the performance of the other methods and should be a routine part of the mitigation process.

The "dilute it if it gets in" techniques include:

1) Open the windows.

This is good for up to a 90% reduction in many cases — remember you are increasing the leakage area of the house by about a factor of 40 when you do this — but is not a practical long-term solution in most climates because of the resultant increase in energy costs.

2) Provide a fresh air intake to the return air plenum of the forced air heating/cooling system (see Figure 15).

A six-inch diameter pipe will probably add about 100 cfm of dilution air to the house.

3) Install a balanced ventilation system.

This method provides dilution air without pressurizing or depressurizing the house. As long as the system is designed and installed correctly, this method always results in lower radon levels. Reductions range from 30% to 85%. In cold climates, a heat recovery ventilator (HRV) (air-to-air heat exchanger) recovers the heat from the exhaust air and uses it to preheat the incoming fresh air (see Figure 16).

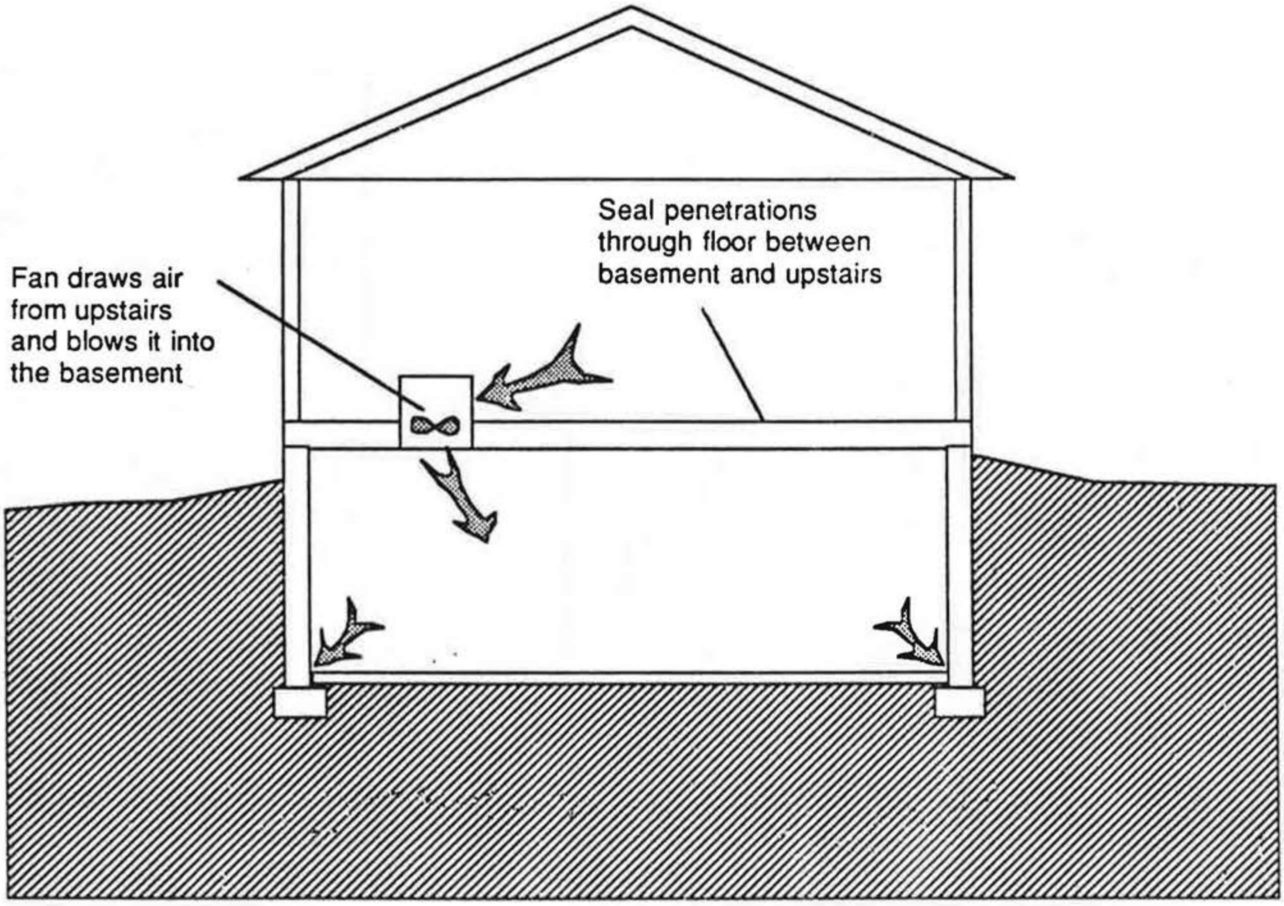


Figure 10 — Schematic for basement pressurization using upstairs air.

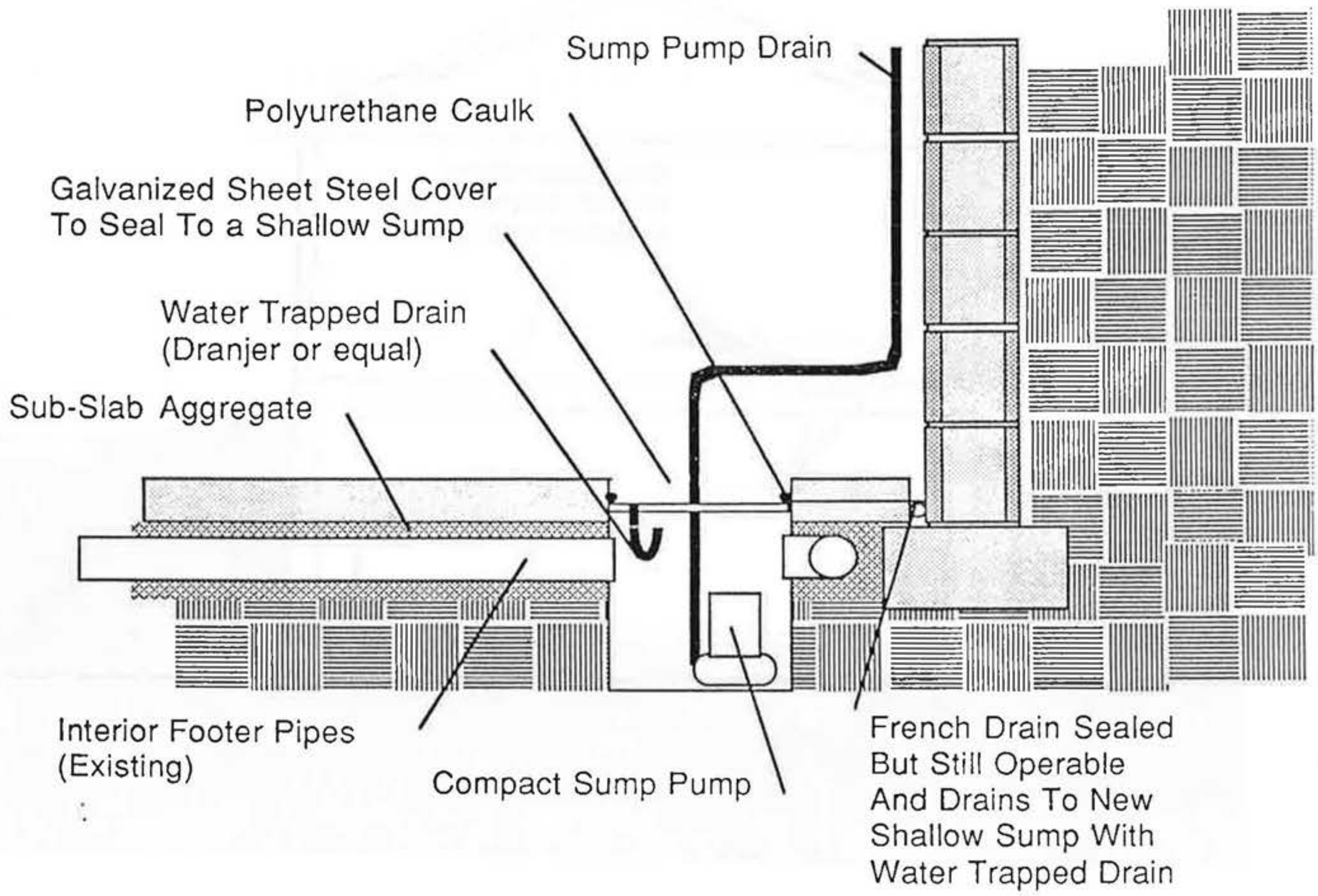


Figure 11 — Converting sump hole into a shallow sump.

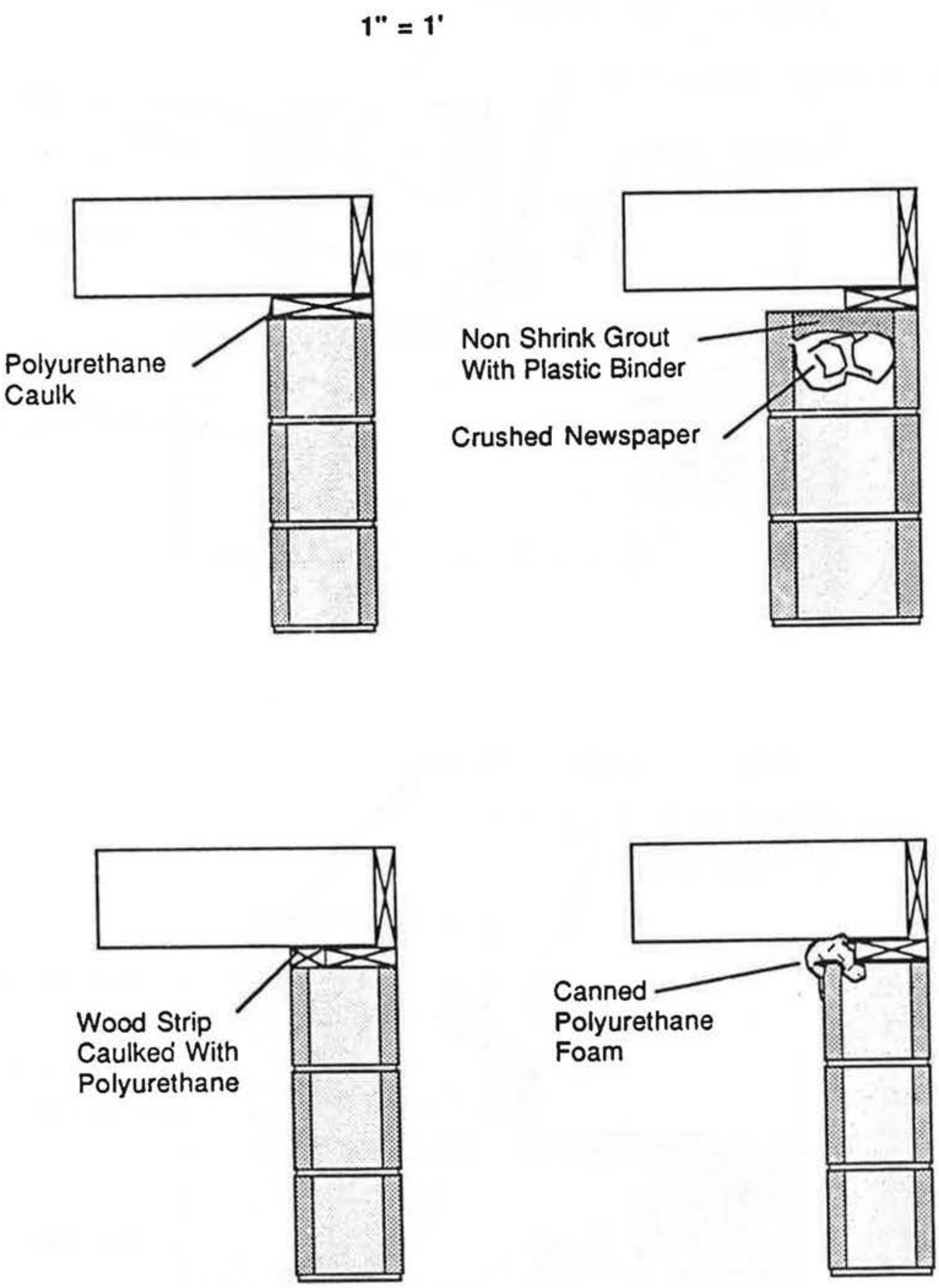


Figure 12 — Methods for sealing open block tops.

1-1/2"=1'-0"

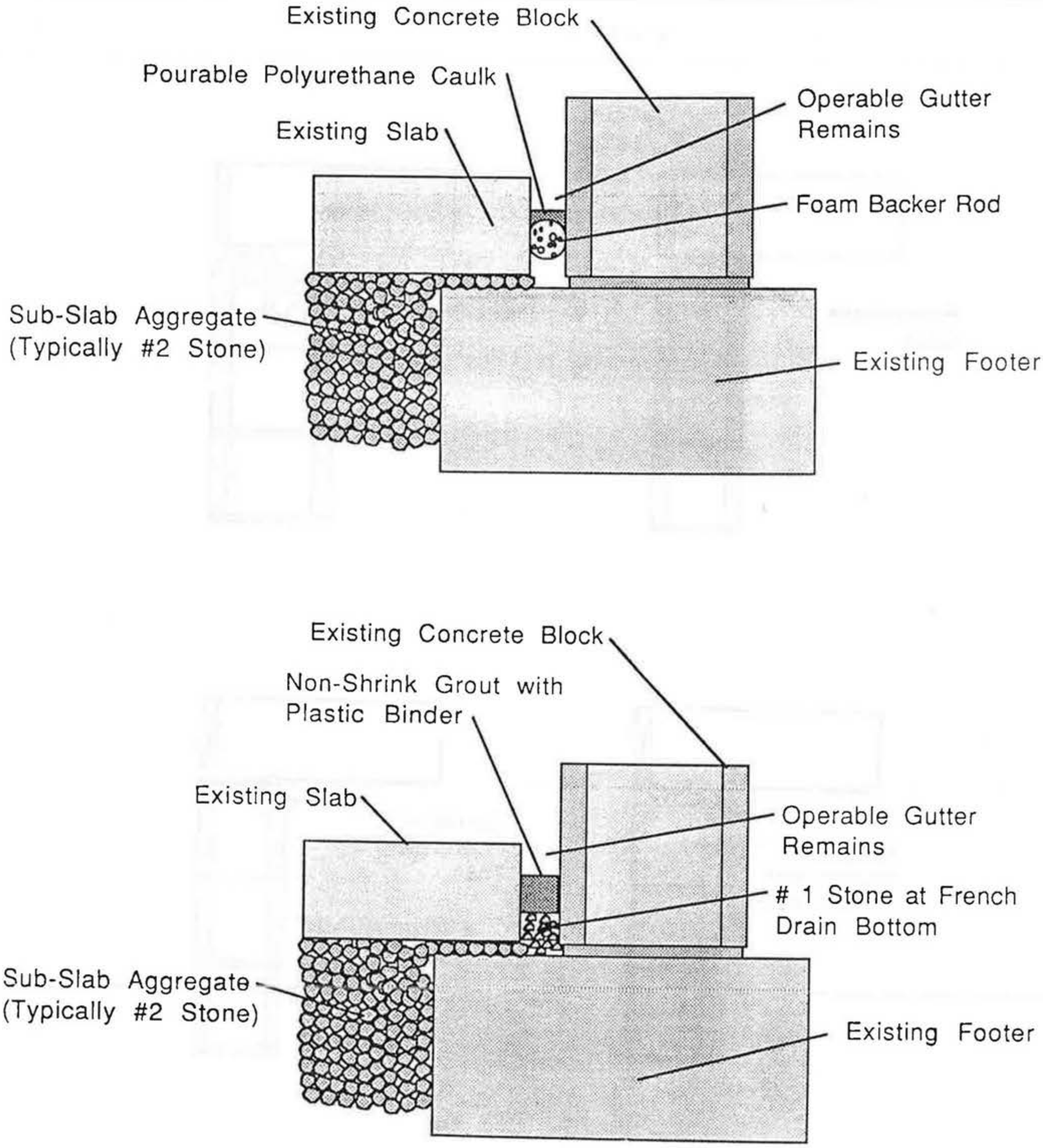
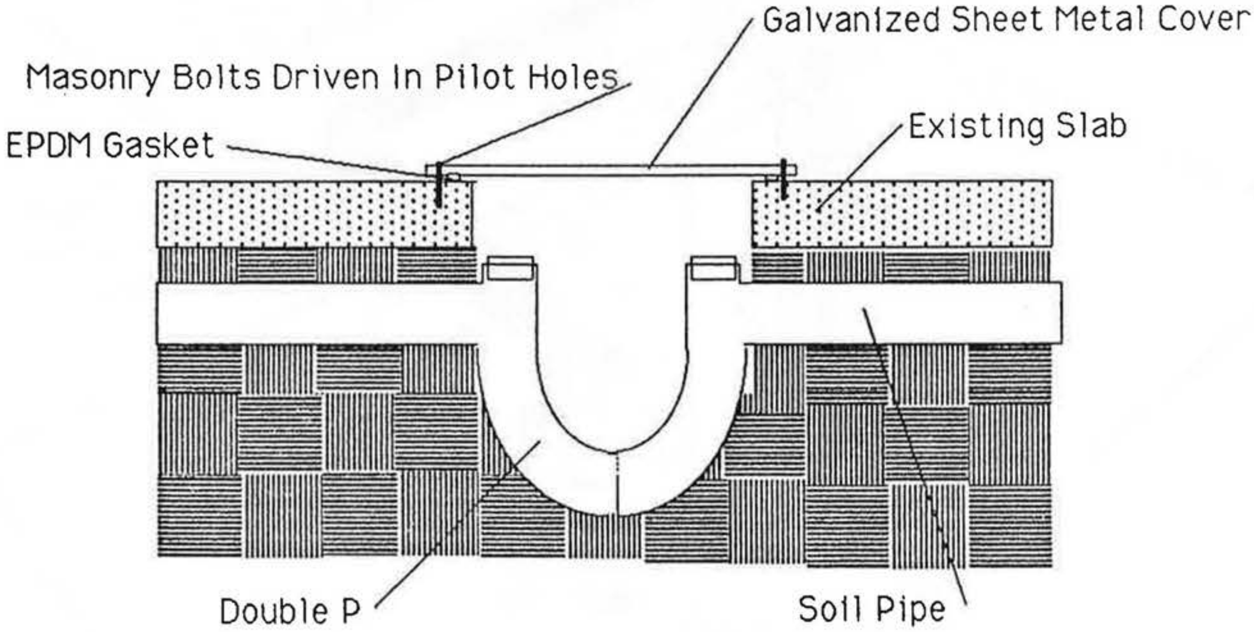


Figure 13 — Methods for sealing French drains.



It is important to seal the opening through the slab over the septic system Double P trap so that continued access is assured. A gasketed decay resistant cover held with removable fasteners is a good solution.

Figure 14 — Methods for sealing main house drain trap.

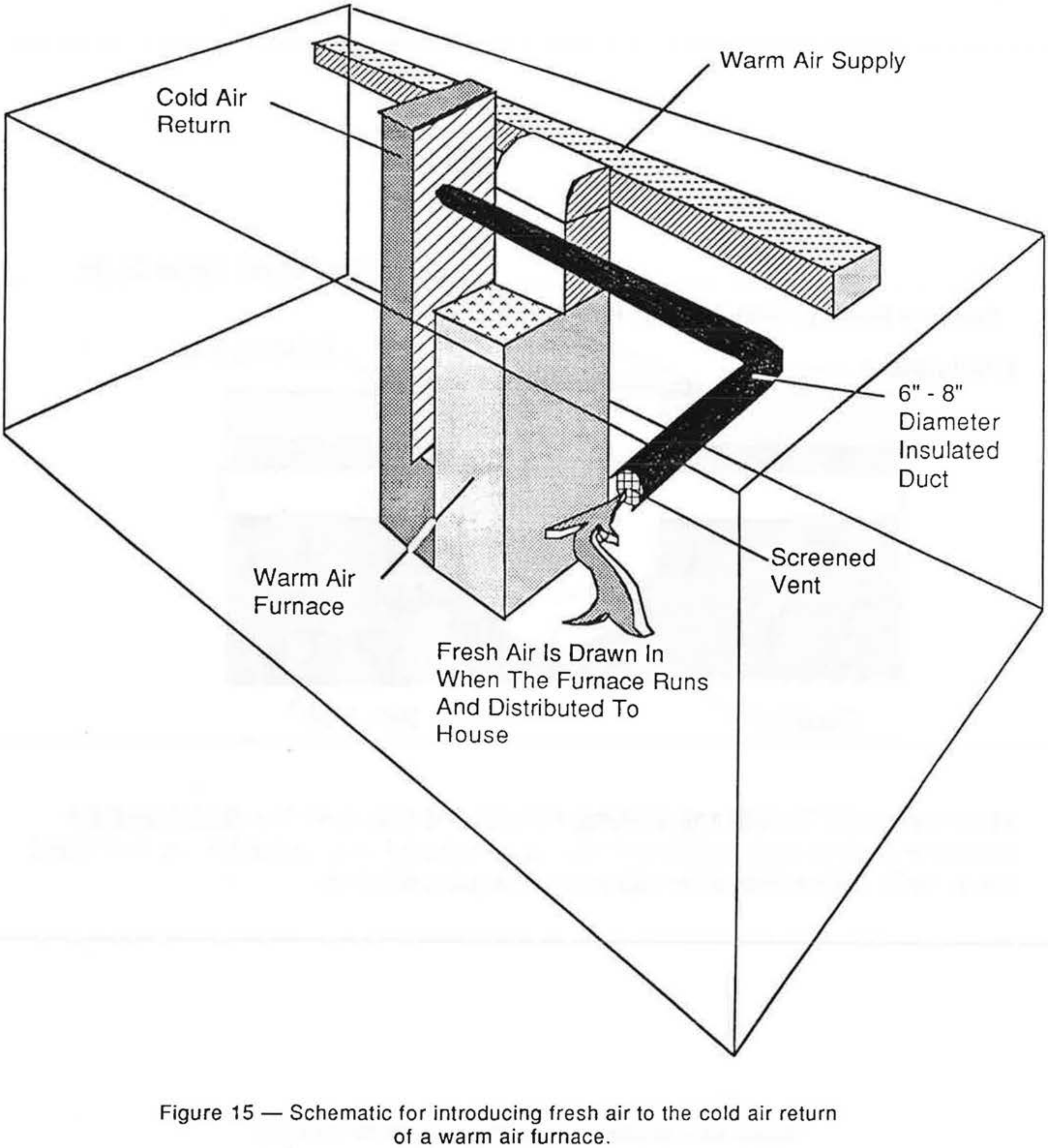


Figure 15 — Schematic for introducing fresh air to the cold air return of a warm air furnace.

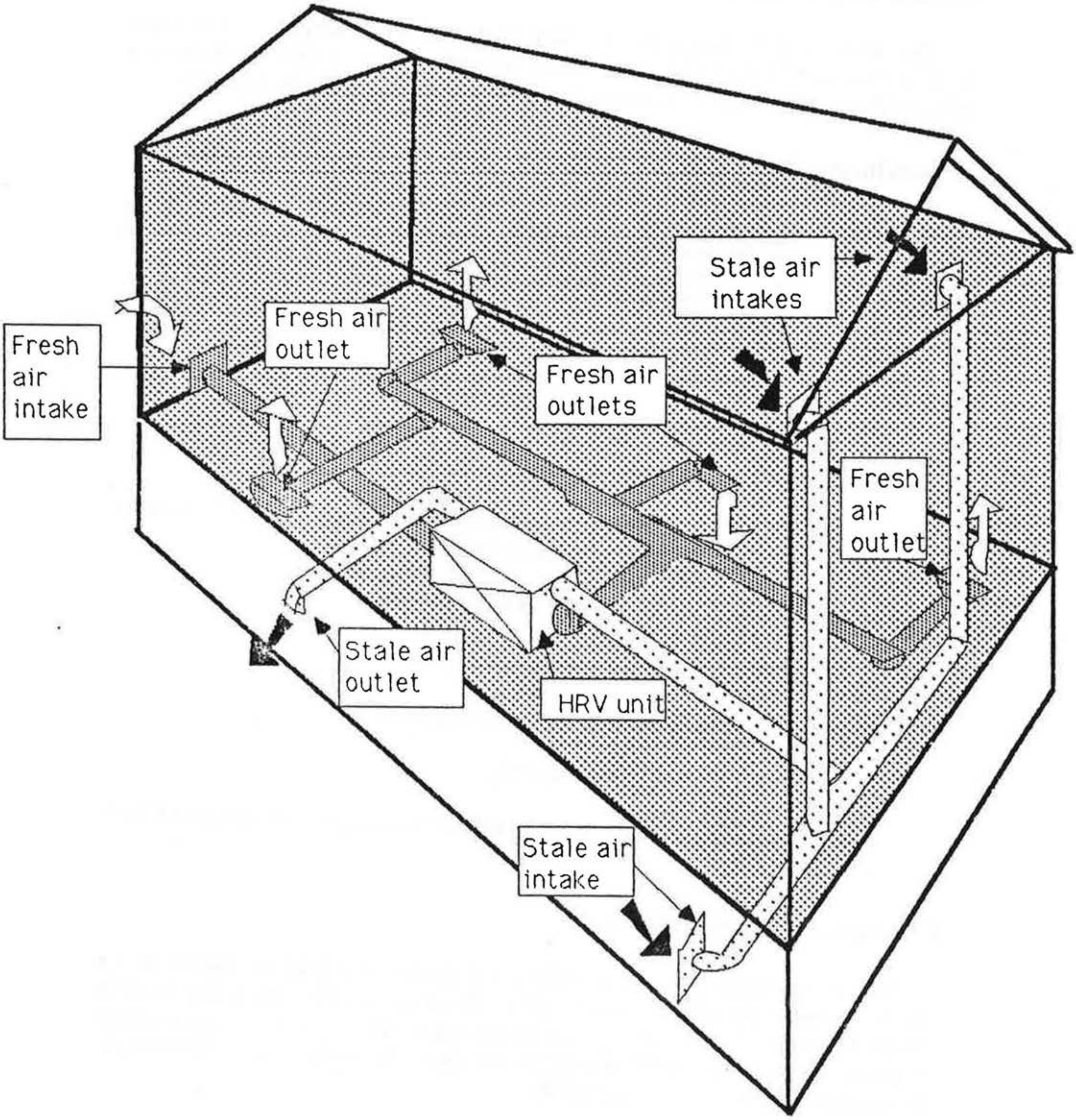


Figure 16 — Heat recovery ventilation schematic.
Inlet and exhaust locations should be designed in accordance with the recommendations made in the report.

House Inspection

The purpose of the house inspection is to decide which mitigation technique is most suitable for the house in question. Factors to be considered include ease of installation, level of effectiveness, maintenance requirements, and price.

Visual inspection

Most of the information used to select mitigation techniques is gathered by using your powers of observation. The various physical characteristics of the house tend to lead to specific mitigation techniques. For example, for soil pressurization you should look for:

- sump holes;
- footing drains (interior or exterior);
- concrete floor with permeable aggregate under the slab;
- cavities under the cellar floor (earth settled away from under slab, wooden floor on sleepers or basement slab); and,
- concrete block walls that are sealed or sealable.

For isolation and ventilation you should look for:

- large areas of exposed earth in crawl or basement;
- stone or poured concrete walls; and,
- crawlspace and basements that can be frozen safely or else protected from freezing.

The House Inspection Form

To make it easier for you to collect and review this kind of information a "House Information Form" is included in this report. The form is reprinted in full in Appendix C. You may not have access to all of the information called for on the form, or may wish to modify it to serve your own needs. The rationale for each section is presented below.

Water

☐ Public
☐ Individual Well

Water

Domestic water is more likely to be a radon source in houses with private water supplies than with public water. If water concentrations have not been measured before the building investigation, a gamma reading taken at the toilet bowl can give a rough idea of whether or not to look more closely at the water supply as a radon source.

Radon Measurement History

Location	Date Tested	Results
Water Concentration		
Toilet Bowl Gamma		

Radon Measurement History

The history of past radon measurements and the dates on which they were taken will give you a good idea of the amount of reduction necessary to bring radon to an acceptable level.

Exhaust Appliances
- Range Hood
- Cooktop Range
- Bath Fan
- Dryer to Outside
- Large Exhaust Fan
- Attic Fan
- Heat Recovery Ventilator

Bypasses
- Around Chimney
- Balloon Walls
- Soffits
- Plumbing Chase
- Recessed Lights
- Attic Entry

Heating and Cooling

	Gas	Oil	Electric	Wood	Kerosene	Stack Damper	Air Cleaner	Return Supply	Dedicated Combustion Air(Y,N)
Furnace									
Boiler									
Space									
DHW									
Fireplaces									
Air Conditioning									
Dryer									

- Rock Bed Storage

Mechanical Equipment and Stack Effect Bypasses

This section provides an inventory of the sources of negative pressure in the house. Mitigation approaches which depend upon manipulating pressure relationships must be designed to compensate for the operation of combustion and exhaust appliances. It may be necessary to seal thermal bypasses in order for pressurization to be successful.

- Crawlspace
- Space Vented
- Full Basement
- Slab on Grade
- PerCent Below Grade
- # Walkout Sides
- Water Present
- Water Damage Present

Walls
- Block
- Concrete
- Stone
- Perm. Wood

Wall Finish (%)
- None
- Paint
- Furring
- Stud Wall
- Sheetrock
- Paneling

Floor (%)
- Earth
- Slab
- Poly

Floor Finish (%)
- None
- Tile
- Carpet

SubSlab Material
- Stone
- Sand
- Clay
- Bedrock
- Can't Tell
- Poly Sheet

Penetrations (S,M,L)
- Water Entry
- Sewer Exit
- Pipes Thru Wall
- Wall Cracks
- Floor Cracks
- Gas Entry
- Pipes Thru Floor
- Main House Trap
- Beam Pocket
- Floor-Wall Crack

(Y/N)
- Open Block Tops
- Solid Block Tops
- Bathtub
- Shower
- Toilet
- Interior Block Walls
- Floor Drains
- Ducts Under Slab

Drainage(Y/N)
- Sump Hole
- Int. Pipe
- Ext.Pipe
- Pump
- Water Present
- Int. Footer Drain
- Ext. Footer Drain
- French Drain

This section is critically important to the selection of an appropriate mitigation approach. Several duplicate sections are presented to accommodate houses with multiple foundation types. A separate section should be filled out for each foundation type.

The type of foundation found in the house is intrinsic to the mitigation system design. Basement pressurization is obviously impossible in slab-on-grade structures. Earth-floored areas can only be mitigated with soil depressurization after the installation of a permeable layer and barrier over the exposed earth. Common sense suggests other limitations.

Finished basements can be difficult to evaluate when the floor-wall junction and cracks in the slab and walls are hidden behind finishing materials. Unfinished storage areas may give you a look at the condition of the floor-wall crack and a sense of the general characteristics of the foundation (mortar condition, workmanship).

The record of penetrations creates an inventory of locations for sealing. The far left column lists a number of common features and suggests that the openings around these penetrations be labelled as small, medium, or large (S, M, L). It may be practical during the first attempt at mitigation to seal any accessible opening which looks like a potential entry point. However, there may be locations which don't appear important but will need further consideration if a second phase is necessary. As you think about pipes through the floor, don't forget lally columns, which are often cast in place during construction. Other features which sometimes penetrate the slab are pipe supports for furnaces and oil tanks and the wooden structure of the basement stairs.

The second column in the penetrations section lists more potential entry points.

Closed block tops are common in many areas of the country; however, there may be points at which the block tops are open (around ash pits, window wells, and crawlspace access doors, for example). Open block tops prevent the development of a pressure field for block-wall suction systems and can limit the success of sub-slab suction systems.

Floor drains can be entry points. It is probably a good idea to install a Dranjer (see Appendix D) or equivalent to prevent gas entry if smoke movement or elevated radon levels are observed at the floor drains. It may also be necessary to seal around the openings where floor drains or waste piping from bathroom fixtures penetrate the slab.

Ductwork under the slab can be a tricky problem because it cannot be abandoned without reworking the air distribution system. Supply ductwork will have only positive pressure leaks and is therefore only a problem when the air distribution fan is not running. It can be mitigated by setting the fan to run continuously. Return-air ductwork, on the other hand, may be drawing in radon when the system is in operation.

The third column of this section lists possible drainage features. These are often entry routes but also indicate solutions to the radon problem. As collection points for radon, drainage features such as sump holes can easily be tied into sub-slab suction systems. Drainage systems must be sealed (along with other openings to the earth) as part of mitigation. However, the sealing must be done in a way which preserves their function. The standard details shown later in the text show how to accomplish this goal.

The fourth column of this section refers to the nature of the sub-slab material, which is observed when test holes are drilled. Identifying this material will help you to evaluate sub-slab communication.

Instrumented Test Results

Sub-slab Vacuum Test

Location	Smoke	ΔP (" WC)	Freon	Radon Conc.	Feet From Suction (Point A)
FA					

Overall Rating of Sub-slab Communication (X)

- ☐ Good
- ☐ Spotty
- ☐ Some
- ☐ None
- ☐ Freon Only

In addition to the house inspection, there are a couple of instrumented tests that can provide very helpful information in assessing how effective a mitigation technique might be.

Vacuum Cleaner Suction Test

The vacuum cleaner suction test can reveal how easily and how extensively air can move about underneath a slab or in a block wall. This test is used to assess the feasibility and effectiveness of soil depressurization.

The tools for this test are:

- heatless chemical smoke sticks;
- an air pressure differential gauge;
- an electropneumatic rotary hammer;
- a vacuum cleaner;
- Freon (R-22) refrigerant in a pressurized can (15# is a convenient size);
- a halogen detector to "sniff" the Freon; and,
- a flashlight.

(See Appendix D for names and addresses of suppliers for some of these tools and materials.)

The test is conducted by drilling several holes (using an electropneumatic rotary hammer) through the slab or wall, applying suction to one of the holes with a vacuum cleaner (the Eureka Mighty Mite II is our favorite), and testing at the other holes with heatless chemical smoke sticks or air pressure differential gauges to see if the pressure field developed by the vacuum extends to the locations of the other holes.

A typical floor investigation is shown in Figure 17. FA and FB are 1-1/4" floor holes to accommodate the nozzle of the vacuum. These holes are located at the center of the slab and at the edge. The hole near the center of the slab allows you to test pressure field development in any direction without the suction being short-circuited by air leakage at the floor-wall crack. The other test hole is placed near the edge of the slab because there is often settling of fill material under the slab along the edge of the footer, which makes an ideal cavity for depressurization. If only a center hole were drilled, this edge channel would go undetected.

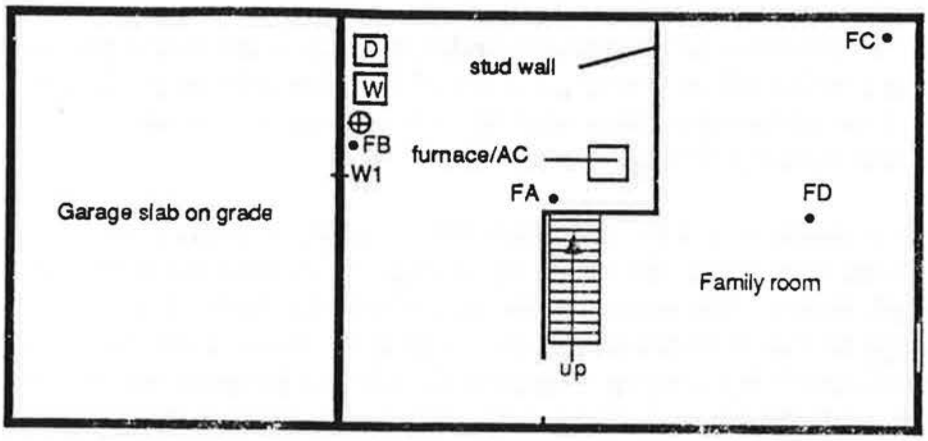
As you choose locations for the suction holes, try to avoid major floor cracks and holes which could leak air and prevent development of a pressure field. Suction holes and test holes should be vacuumed out after they are drilled, so that cement dust is removed and air can flow as freely as possible. You may wish to take a radon grab sample of air from below the slab before cleaning the hole; if so, keep track of the filter of your instrument and change it when it gets clogged.

FC and FD in Figure 17 are 3/8" holes to check with smoke sticks or gauges. In some houses, more than two 3/8" holes may be necessary to get a good understanding of what is happening. It is also possible to drill 3/8" test holes into concrete block walls one or two feet above the floor and test communication between the sub-slab suction point and the wall.

Heatless chemical smoke is very sensitive to air movement and is easily disturbed by turbulence in the room. It is important to use only a small amount and to apply the smoke exactly at the opening of the test hole. A flashlight will help you to see what's happening. It is a good idea to check the smoke movement with the vacuum cleaner off, as well as with it running, so that you can see the direction in which the smoke moves under normal conditions. You might find that the basement happens to be under positive pressure on the day of your visit. When the smoke goes rapidly into the hole while the vacuum cleaner is applying suction, it indicates good pressure field development under the slab.

If you find that a pressure field has developed everywhere, then depressurizing the soil under the slab is a good option. If the smoke moves sluggishly into the hole, more than one suction point may be needed for development of an adequate pressure field. If the smoke doesn't move at all or if it comes back into the house, then the pressure field developed by the vacuum cleaner does not extend to your test hole. You may want to drill another test hole closer to your suction point and try again.

There are two potential conditions which result in failure to develop a pressure field. One occurs when the soil is very dense (clay or fine silts) and no air flows through it. In such a case there is a very strong, localized pressure field right under the vacuum cleaner nozzle (on the order of 80 inches of water pressure differential with zero cfm airflow). The other condition occurs when there are a great many holes or cracks in the slab, so that all the air the vacuum cleaner can move is supplied (80 cfm airflow with no pressure drop). In this case there is likely to be good communication under the slab, but a pressure field won't develop until the holes through the slab are sealed. This is common where there



⊕ This symbol indicates a potential location for a sub-slab suction point.

Note: The letter F followed by another letter indicates the location of a hole drilled through the slab (example: FA).
The letter W followed by a number indicates the location of a hole drilled into the block wall (example: W1).

Figure 17 — Basement floor plan.

is a French drain and clean #2 stone under the slab. It can also occur when the slab is extensively cracked near the vacuum hole.

The large holes make it possible to physically inspect the sub-slab aggregate. If it consists of clean 3/4" to 1-1/2" diameter stone pebbles, then you are in luck — it is likely that a single suction point almost anywhere in the slab will take care of the problem. If the aggregate is sandy or there is an air space under the slab where the gravel or earth has settled, then there is still a good chance that sub-slab depressurization will be an effective technique. But if the sub-slab aggregate is wet clay, you will probably have to seek another method.

Freon gas is heavier than air and can be used as a tracer gas in conjunction with the vacuum cleaner test. It can be used to determine whether there is too much or too little air movement under the slab to develop a pressure field. The test is conducted by introducing some Freon at a far point in the sub-slab system, then applying suction with the vacuum cleaner to see if any Freon can be detected coming through the vacuum.

In a house with a French drain, for example, you can take a pressurized tank of Freon and crack the valve open slightly so that the refrigerant floods the French drain. Alternately, you can bleed the Freon into a test hole slowly enough so that it does not overflow across the slab. Turn on the halogen detector and zero it by waving it through the air in a location distant from the Freon. Then, with the vacuum cleaner operating, see whether the halogen detector can sense Freon in the air from the vacuum cleaner outlet. If you don't get any Freon after two or three minutes, you may want to turn the vacuum cleaner off and test in the suction hole. (If only a small amount of Freon is coming through, the detector might miss it in the fast-moving air.)

For Block Wall Depressurization:

The vacuum cleaner suction test can also be used to test block walls. When applying this method to a block wall there are fewer variables to take into account because there are fewer requirements for developing a pressure field in the wall. These variables are: openings that let in enough air to supply the airflow the fan requires, and blockages inside the wall such as wall intersections, corners, and places where the wall has been cored and reinforced. Cracks or open block tops can be sealed, and additional suction points can be used to extend the pressure field around corners and intersections.

The Fan Door Test

Floor Area [ ] Volume - Whole house [ ]
- Basement [ ]

Basement Fan Door Test	Whole House Fan Door Test	
Airflow Reversal	[ ] Shielding Class	[ ] ACH at 50 Pascals
[ ] CFM	[ ] Terrain Class	[ ] ELA at 4 Pascals
[ ] Pascals	[ ] Wind Speed	

A calibrated fan door, also known as a blower door, is used to evaluate the potential for basement pressurization or dilution by ventilation. As the form indicates, it is necessary to calculate the basement and whole-house volumes as part of these tests. The algorithms for analyzing the results of the test are provided by the fan door manufacturers, often in the form of packaged software.

For Basement Pressurization:

A fan pressurization test is conducted to determine whether basement pressurization is a feasible mitigation technique and to identify the characteristics of the fan required to do the job.

The tools for this test are:

- a calibrated fan door, or "blower door," and
- heatless chemical smoke sticks.

All exterior doors and windows should be closed during the test. This test should not be run if there is a fireplace or woodstove operating on the upper level of the house, because it will cause backdrafting.

The blower door is installed in the doorway between the basement and the upstairs so that it blows air from upstairs down into the basement, pressurizing the basement. A smoke stick is used to check the airflow at one or more test holes (the same holes that were used for the vacuum test) before the fan door is turned on. The smoke should flow into the basement with the fan door off. The fan door is then turned on and the fan speed is gradually increased until the smoke begins to flow out of the basement. The fan pressure and basement pressure are recorded. The manufacturer's data is used to calculate the pressure and airflow at which the smoke direction reversed and soil air could no longer enter the basement. That information is entered on the House Information Form and will later be used to select a suitable fan for mitigation by basement pressurization. In our experience, basement pressurization is not a practical mitigation approach if more than 300 cubic feet per minute of air are required; however, it may be possible to seal between the basement and the upper level until 300 cfm is adequate.

For Whole-house Ventilation to Dilute the Radon:

A conventional fan pressurization test can provide a rough estimate of the natural infiltration rate of the whole-house.

During the whole-house fan test, the fan door is placed in an exterior door of the house and the house pressure and fan pressure are recorded at different fan speeds. The fan door manufacturer's data is used to calculate the airflow at 50 pascals. Given that number, a rule of thumb is that the natural infiltration rate is 1/20 of the airflow at 50 pascals. Using the simple model that doubling the ventilation rate should halve the concentration, you can estimate how much increased mechanical ventilation would be necessary to reduce the radon concentration to acceptable levels. Most increased ventilation techniques add from 100 to 300 cfm of dilution air. Depending upon the winter heating and summer air conditioning demands of the house, it may be desirable to use a heat recovery ventilation unit or install a heating coil to temper the incoming air.

Floor Plans

It is useful to generate floor plans of the house during the inspection process. Along with room dimensions, these sketches should show important features such as locations for sealing, potential suction points for soil depressurization systems, test hole locations, and closets and other possible routes for ductwork.

Selecting a Mitigation Method

Armed with the results of the house inspection and the above tests, you can use the flowcharts in Figures 18 through 20 to arrive at a list of options that are suitable for the house under consideration.

There are three flowcharts; one for floor depressurization, one for wall depressurization, and one for basement pressurization.

Wall Depressurization

The flowchart for walls can be used on houses with basements, crawlspace, or slab on grade. The chart applies to the basement walls, crawlspace walls, or the frostwall of a slab on grade. Starting at the top of the page, you simply work your way from box to box, answering the questions and following the routes indicated. If you are analyzing a house with block walls, then you move along the line from the "walls" box left to the "block" box, then if the walls are unsealable (say because they are finished on the inside with a stud wall and are inaccessible), you bear right to the "unsealable" box and then down to the "block wall suction not indicated" box. If the walls were sealed already or could easily be sealed, then you would have gone to the "sealed or sealable" box then down to the "grab sample" box, where if the results of radon grab samples were low you would be diverted to the "block wall suction not indicated" box; but if they were high you would move to the "walls closed at top," "walls open at top," or "walls cored and reinforced" level. You would continue following all the paths that apply until you end up with one or more of the bottom line boxes (with the striped borders) suggesting actions to be taken.

Floor Depressurization

The floor depressurization flowchart works the same way — you begin at the top and follow the relevant paths until you end up with one or more actions indicated at the bottom of the page. Sometimes the same action will be indicated by more than one path. For example, you could get to "sub-slab suction indicated" by three different paths.

Basement Pressurization

The basement pressurization flowchart works the same as the floor and wall flowcharts. The information necessary to use this chart is obtained from the fan door test.

Whole-house Ventilation

The whole-house fan door test is not well-suited to a flow chart, but mitigation by dilution can be evaluated using the following formula:

R2 = R1 x (Airflow1 / Airflow2)

Where:

R1 is the pre-mitigation radon level in pCi/l;

R2 is the post-mitigation level in pCi/l;

Airflow1 is the pre-mitigation air exchange rate; and,

Airflow2 is the post-mitigation air exchange rate.

If Airflow2 must be more than 12,000 cubic feet per hour greater than Airflow1 to reach the desired radon level, then mitigation by dilution is not a very good solution.

Using this formula with the data from your house inspection will yield a list of options that have a reasonably good chance of working on the house in question.

Once you have identified your options, rank them according to your current prioritization list and then factor in the considerations that do not appear on flowcharts and forms, such as noise level, maintenance, operating costs, obtrusiveness, asbestos in the basement, etc.

The order of preference we currently use to select a mitigation method is as follows:

Keep it out

For habitable space:

1) soil depressurization on sub-slab

2) soil depressurization on block walls

3) basement pressurization

For non-habitable space:

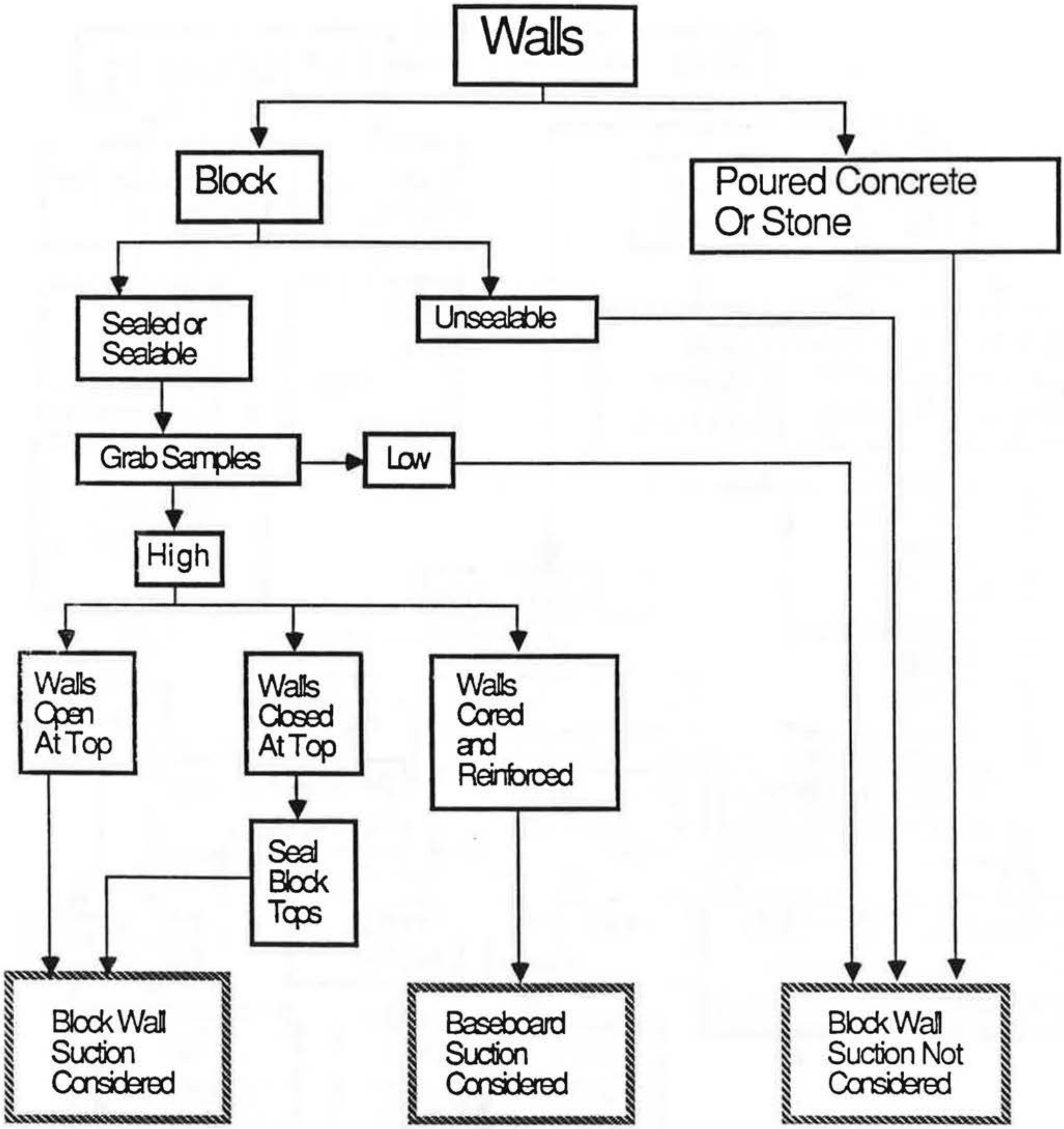


Figure 18 — Wall depressurization flowchart.

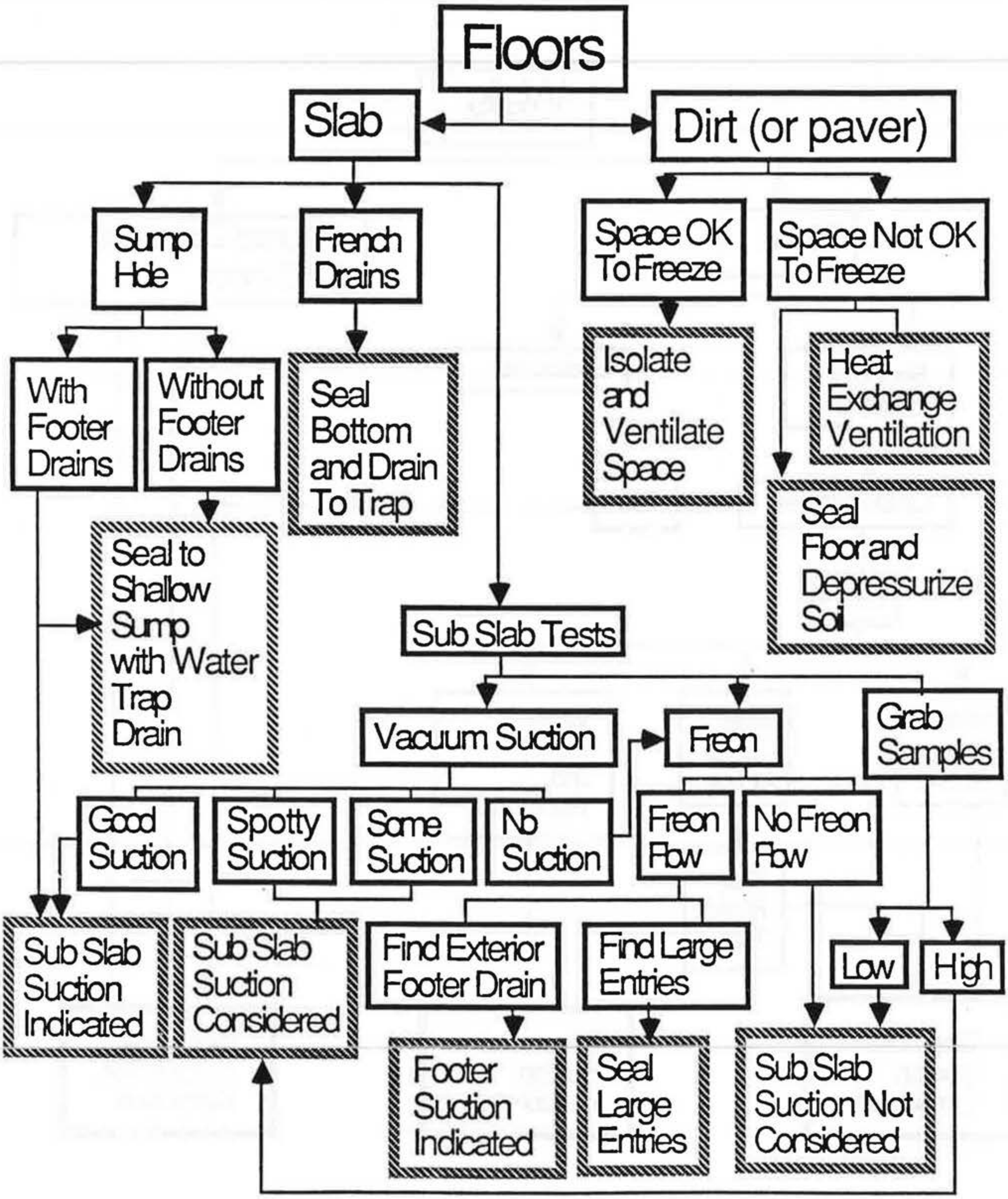


Figure 19 — Floor depressurization flowchart.

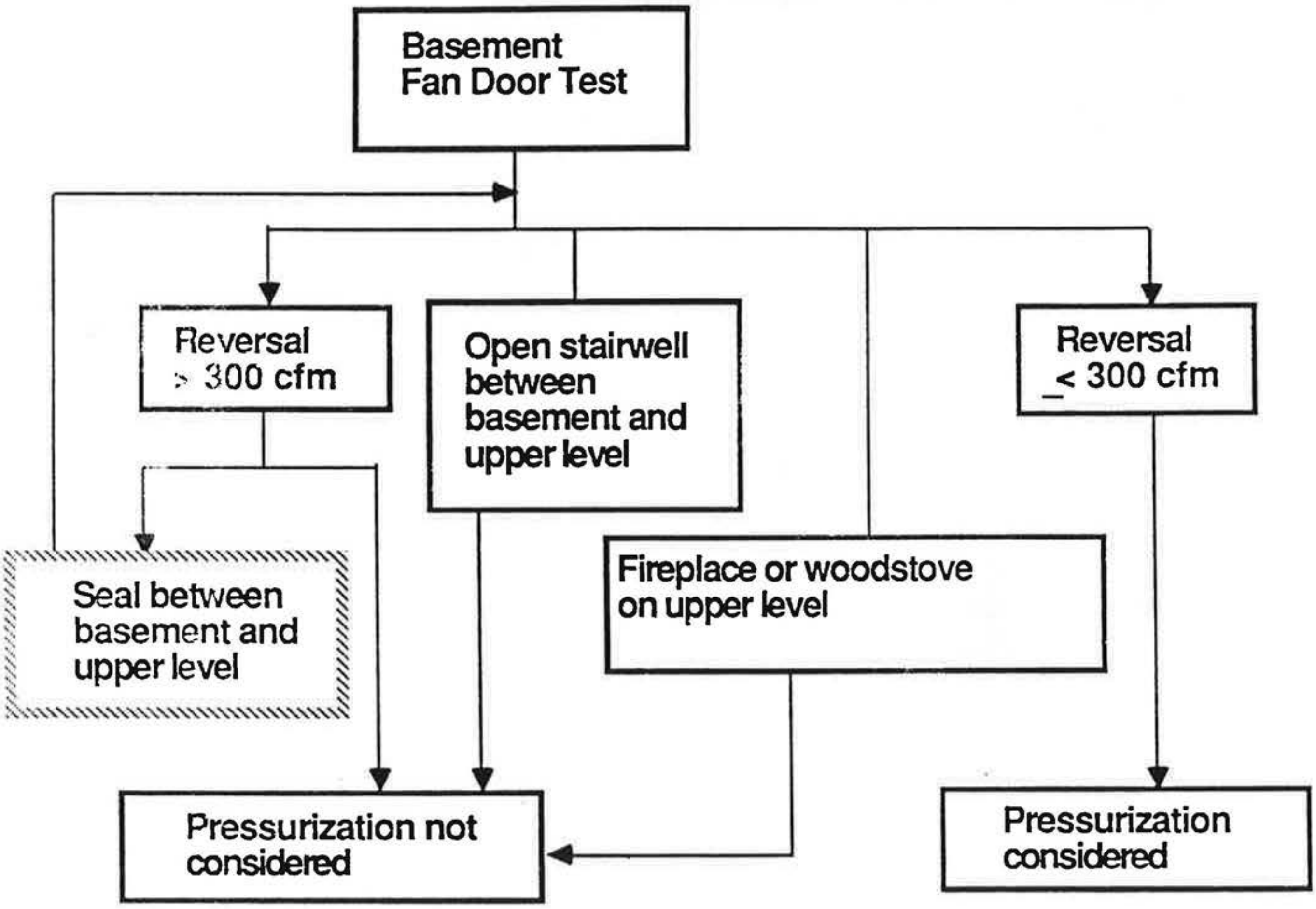


Figure 20 — Basement pressurization flowchart.

1) depressurize the soil under a barrier (e.g., plastic film)

2) isolate and ventilate the non-habitable crawlspace or basement

If it gets in, dilute it

1) provide fresh air intake to the return air plenum of the heating/cooling system

2) install a balanced ventilation system

Section III
Installing Mitigation Techniques

Attention to detail and testing during installation to verify that a mitigation system is working well are important keys to successful mitigation efforts. In this section we will review each strategy and point out the details you must be aware of and the kinds of testing you can do to check on system performance as you are installing the equipment.

For Soil Depressurization Methods

There are several ways that the soil can be depressurized. What you need is some sort of network of cavities, a layer of permeable material, or a perforated pipe. The key is to develop a low-pressure field on the outside of the foundation so that soil air is collected and diverted away from the house. As outlined in Section II, there are a number of areas where soil depressurization can be applied. They include:

- sump holes (see Figure 2);
- footing drains (interior or exterior);
- concrete floor with permeable aggregate under the slab (see Figures 3 and 4);
- cavities under the cellar floor (earth settled away from under slab, wooden floor on sleepers on basement slab); and,
- concrete block walls that are sealed or sealable at the top (see Figures 5-7).

Soil depressurization can also be applied beneath a barrier that is installed by the mitigation contractor. This might consist of a new concrete slab, treated plywood, or a durable membrane (such as EPDM roofing or 20-mil polyethylene). The barrier should be placed on top of something that would allow an extensive pressure field to be developed, such as #2 stone, drainage board, treated furring, or perforated pipe (see Figure 8). These techniques are most suitable for large expanses of bare earth, floors made of pavers on earth, or an extensively cracked or soft concrete slab. Sometimes it is worthwhile to improve the floor of a space for reasons other than radon control (i.e., turn that earth-floor basement into a workshop) so that you get additional benefit from a radon control method.

Important Considerations for all Soil Depressurization Methods

Distribution Pipes

Four-inch PVC is usually large enough for most powered soil depressurization techniques. There are situations where smaller diameter pipe can be used, but these systems are only now being experimented with. It is important to keep the number of elbows to a minimum and to make sure that everything is sealed tightly. An air leak on the negative pressure side of the fan weakens the pressure field developed and a leak on the positive pressure side of the fan is a source of high radon concentration air.

Fan or blower location

Fans or blowers should be mounted outside of the building shell (attic, garage, or outside) because any positive pressure leak may introduce high concentrations of radon to the space where the fan is located. Any fan used outdoors should be rated for exterior applications. Exhaust outlets should be higher than the highest eave so that radon-rich air does not have the opportunity to come in contact with people or to re-enter the house.

Fan or blower type

Fans for soil depressurization should have the ability to move 100 to 250 cfm in free air and still move some air against static pressures up to 1" to 2" W.G. Important secondary selection factors are noise level and power consumption. One final consideration in fan selection is that the fan should be easy to install in four-inch PVC pipe or mount directly to the house wall or roof.

Low pressure alarm

Some type of device should be installed to alert the homeowner if the pressure field induced by the fan fails. This could be an inclined manometer (Dwyer Mark II or equivalent) or a low-pressure alarm consisting of a pressure differential sensor and a light or chime. The fan switch and manometer should be located in consultation with the homeowner.

Condensation

In cold climates there is a good chance that water will condense in any part of the exhaust pipe that is located outside. In order to avoid this you can plan the system so that the condensate simply runs back down the inside of the pipe into the soil or you can plan a collection system and use a condensate pump of the type normally used in air conditioning systems.

Pressure checks

During and immediately after installation of the system, pressure differential measurements should be made between basement air and the soil you are trying to depressurize to determine the strength and extent of the pressure field generated. If an inadequate pressure field is found, depressurization may be improved by sealing more cracks and holes in the foundation or by adding more suction points in the weak areas.

Sealing cracks and holes

Sealing of cracks and holes that are obvious and easily accessible should be a routine part of soil depressurization methods. Your goal is to make the fan or blower extend the pressure field on the outside of the foundation and under the slab as far as possible. For example, if a fan that moves 100 cfm in free air has a large hole through the slab near the suction point, it may be able to draw all 100 cfm it needs from that hole with essentially no pressure drop. That means there is no pressure differential and the system will not work. So seal the leaks you can get to easily. Even a 1/16" perimeter crack at the floor-wall joint can have a dramatic impact on the strength and extent of the pressure field. It is also possible that you will happen to seal an important entry route that would make a difference on its own (see Figures 11-14).

Location of suction points

For sub-slab systems (prioritized):

1) sump hole with footing drains;

2) any location with clean 3/4" to 1-1/2" stone under slab;

3) near edge of slab when there are footing drains or marginal communication to the center of slab; and,

4) near the common wall between basement and slab on grade areas, (split-level houses, attached garages, or patios). Block walls at these locations often contain high radon concentrations and you may want to tap into them in combination with sub-slab suction.

The number of suction points depends on results of the pressure tests conducted during the house inspection.

For block-wall systems:

1) walls with highest radon concentrations;

2) largest walls ; and

3) walls with a slab on grade adjacent to them.

For suction under installed barriers:

Suction points should be located where it is easy to install the fan and the exhaust pipe.

Only one suction point should be needed because you have control over the extent of the stone or drainage board or perforated-pipe system.

Barriers should be selected for their durability, ease of installation, and price. Concrete is the most durable and results in a useful floor. It is also the most expensive and is frequently difficult to install. It is best used for full basements that can become useful rooms. Film barriers are better priced and can be placed into some pretty tight crawlspaces, but must be durable if they are to withstand foot traffic. The single-ply commercial roofing materials (EPDM, neoprene, etc.) offer superior durability over polyethylene, though at a higher cost.

Isolation and Ventilation Methods

The benefits of isolating and ventilating a basement or crawlspace are twofold. First, you construct a barrier to radon entering the building through cracks and holes in the floor between the living space and the basement or crawlspace. Second, you dilute the concentration of radon in the crawlspace and provide an easy escape path for the radon (see Figure 9).

These techniques are best suited for buildings with spaces that would never be used as living area. Root cellars, stone basements, and crawlspaces are good examples. It is also helpful if it doesn't matter if the space freezes.

Ventilation for isolated spaces has been successfully implemented by using passive vents or powered positive, negative, or balanced ventilation. All have been shown to work to some degree.

Passive vents

Passive vents work by allowing dilution air to enter through vents on the windward side and radon-laden air to leave on the leeward side. When there is no wind, radon will pass through the vents by concentration gradient diffusion. With no definitive research on the amount of vent area needed, it is suggested that the rule of thumb for vent area to control moisture in crawlspaces be used. For crawlspaces without moisture barriers that is a net free vent area of 1 square foot for every 150 square feet of earth. At least one vent should be located on each wall as far as possible from anything that shouldn't freeze.

Power vents

Power ventilators have been used successfully to control radon in crawlspaces and basements. If they are used to exhaust air from the crawlspace, then the space should be sealed as tightly as possible to avoid air leaks into the space from outside or from the living area. The system functions by preventing crawlspace air from entering the house. This can be checked using smoke sticks. This is very similar to sub-slab depressurization in its principle of operation. The radon concentration in the crawlspace or basement may actually increase even as the house concentration goes down. The trick is to seal things so well that a small fan will be adequate to maintain the airflow direction from the house into the crawlspace.

A heat recovery ventilator can be used for balanced ventilation of a crawlspace or basement (see Figure 16). The concentration in the crawlspace or basement will go down and so will the concentration in the house air. It is easy to install in crawlspaces because it only requires a simple distribution duct — supply air at one end and exhaust air at the other. Seal all other openings to the outside and upstairs.

There have been some successes with crawlspace pressurization. Smoke sticks or pressure gauges may be used during installation to verify that the air pressure in the crawlspace or basement is higher than the outside air. This method is not as well understood as the other ventilation techniques described here. It is thought that the positive pressure relative to the outside air prevents soil air from entering the crawlspace. This technique may not work very well if the source of radon is actually in the crawlspace or if the primary transport mechanism is diffusion. There are some concerns about other contaminants which may be blown into the living space from the pressurized crawlspace.

Sealing openings in the separating floor

The following places are typical penetrations that must be dealt with:

- openings around plumbing drains, vents, and water supplies, especially tubs, showers, and toilets;
- openings around electrical wires;
- framing openings like balloon-framed walls;
- entry doors or traps; and
- HVAC ductwork.

HVAC ductwork presents its own special problems because there are many difficult joints to seal. Any hole or opening into a return air duct is especially important because of the powered suction which pulls crawlspace air into the system.

Freeze protection

This is the most difficult requirement to satisfy with this mitigation method. Water pipes and pumps must be protected from freezing during cold weather. Water pipes should be insulated and/or protected with electric heat tape.

Another approach is to maintain temperatures in the space above freezing. Although heating the space is usually impractical due to energy costs, a heat recovery ventilator can be used to preheat incoming fresh air. This will also tend to keep the floors above the space warmer.

Of course, if no freeze-sensitive elements are contained in the space, freeze protection will not be necessary.

Location of fans

The main concern in locating fans is that they be high enough to remain clear of snow or leaves.

Safety Precautions for Mitigation Work

It is important to take precautions to limit the amount of radon exposure experienced by mitigation crews. There are three steps to protection:

1. Ventilate the area where you are working. (A window fan is very good for this except, of course, when it's -20°F outside.)

2. Wear a fitted respirator with HEPA/activated carbon filters. (These don't do much for radon but will screen out nearly all of the dust, decay products, and random organic or biological aerosols.)

3. Keep track of exposures. (Right now, the simplest thing to do is to use an alpha track detector as a badge — it's not great, but it's a lot better than not knowing.)

Some precautions:

- Assume the crawlspace is high in radon.

- Assume any slab penetration is high in radon.

- Be alert for other hazards (asbestos, pesticides, bare electrical wires). The EPA is recommending to its project staff that they limit their exposure to less than WLM per year and that fitted respirators be worn for concentrations over 1 working level.

Appendix A -
Testing Methods
U.S. Environmental Protection Agency
Radon Measurement Protocols

United States
Environmental Protection
Agency

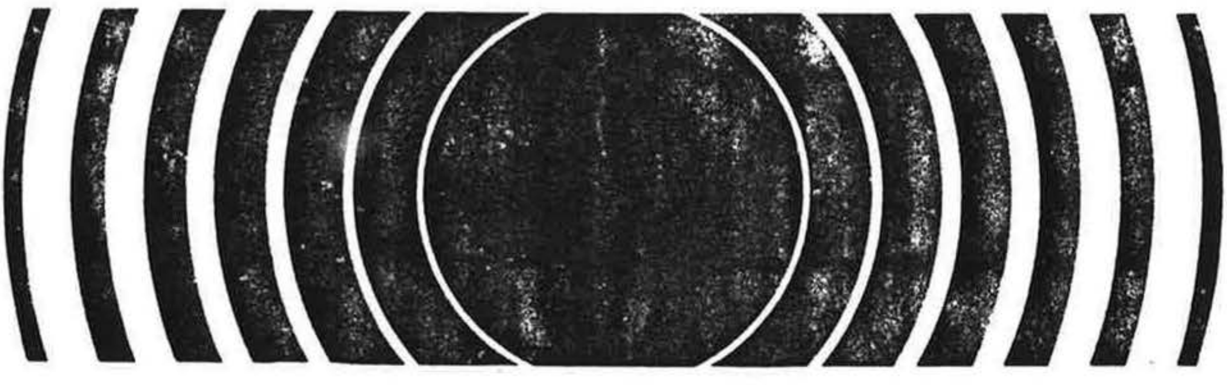
Office of
Radiation Programs
Washington, D.C. 20460

EPA 520/1-86-04
April 1986

Radiation

EPA

Interim Indoor Radon and Radon Decay Product Measurement Protocols



EPA 520/1-86-04

INTERIM INDOOR RADON AND RADON DECAY PRODUCT MEASUREMENT PROTOCOLS

U.S. Environmental Protection Agency

Office of Radiation Programs

February 1986

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E. Sensintaffar

CONTENTS

CONTENTS--Continued

Section 1: GENERAL CONSIDERATIONS

1.1 Introduction and Background

Increases in the risk of lung cancer due to exposure to radon and its decay products are of growing concern to State and Federal health officials. There is increased awareness that indoor radon concentrations may be greater than had once been estimated and that there are areas in the country where the indoor levels are such that even short-term exposures can cause a significant increase in risk. It is extremely important to locate houses with the potential for causing high exposures. However, the urgency to measure concentrations in houses can result in unreliable or misleading data.

There are many Federal, State, university, and private organizations now performing measurements or planning measurement programs. Consistent procedures must be followed to permit valid intercomparison of measurement results from different programs.

Problems encountered when measuring indoor radon and radon decay product (RDP) concentrations include variability due to (1) nonstandardized procedures, (2) different house conditions prior to and during the measurement, (3) seasonal and other weather conditions, and finally, different interpretations of the results. The protocols in this document reduce the uncertainty caused by these sources of variability by providing standardized measurement procedures and criteria for house and weather conditions that can exist prior to and during the measurement. The primary objective of the protocols is to provide procedures for making reproducible measurements, with a known and limited variability.

This document first presents some general considerations relevant to all the instruments discussed, then outlines seven technique-specific procedures. The procedures provide information needed by an experienced user to calibrate, deploy, and operate the instruments as well as to develop an adequate quality assurance program for instrument use. Each technique-specific protocol includes sufficient information to allow it to be used independently of the entire document.

1.2 Standardized Measurement Conditions

These protocols specify that measurements be made when the radon and radon decay product concentrations are likely to be the most stable, e.g., in a closed building with a minimum level of ventilation. Such measurements will generally be higher than the average concentrations to which the occupants are exposed. Specifying that measurements be made under standardized conditions is necessary for the following two reasons.

First, the primary objective of the protocols is to produce measurement results that can be related to either potential or actual exposures in the house and that have the smallest possible variability with the technique, i.e., that are reproducible. The most reproducible measurements are those taken when the house conditions are standardized, with the house closed, and after sufficient time has been allowed for the concentrations to stabilize. To achieve such a measurement, the ventilation rates should be as low as possible. Reproducible results are of utmost importance when measuring indoor radon or RDP concentrations in a home before and after it undergoes remedial action, so that the effectiveness of the remedial action can be measured. Having a high degree of confidence that the results of a measurement represent the radon or RDP concentration in a building under standardized conditions is important when deciding whether remedial action is necessary or when comparing the measurement results to guidance levels.

Second, it is important to quantitatively estimate the variability associated with the result of a measurement. This variability can be estimated only from data taken under similar conditions, and since average living conditions are difficult to define and to reproduce, specifying standard conditions allows for valid application of the estimates of error.

The following paragraphs discuss how these standard conditions are to be achieved.

1.2.1 House Conditions

The measurement should be made under "closed-house" conditions. To a reasonable extent, windows and external doors should be closed (except for normal entrance and exit). Normal entrance and exit includes a brief opening and closing of a door, but an external door should not be left open for more than a few minutes. In addition, external-internal air exchange systems (other than a furnace) such as high-volume attic and window fans should not be operating. For measurement periods of 3 days or less, these conditions should exist for 12 hours prior to beginning the measurement. It may be difficult to verify these conditions or to implement them for an extended period, but they should be adhered to as closely as is reasonable.

Closed-house conditions will generally exist as normal living conditions in northern areas of the country when the average daily temperature is less than 40°. Depending on the area, this can encompass the winter period from late fall to early spring.

There are two reasons why measurements in northern climates should be made during the winter season. First, during the winter, closed-house conditions exist as normal living conditions. Thus, there is a greater assurance that the proper conditions will exist prior to and during the measurement period. Second, information on factors that influence indoor radon concentrations indicate that concentrations during the winter are generally higher than during the summer.

If, however, it is necessary to make measurements during the summer when closed-house conditions are not the normal living conditions, then it will be necessary to establish some means for providing reasonable assurance that closed-house conditions will exist prior to and during the measurements.

Organizations performing measurements in southern areas that do not experience extended periods of cold weather should evaluate seasonal variations in living conditions and identify if there are time periods when closed-house conditions normally exist. If such periods exist, that is when measurements should be conducted. Air conditioning systems that recycle interior air can be operated during the closed-house conditions.

To better address measurements made during summer months in cold climates and at any time in warm climates, additional data are needed.

Measurements of 3 days or less should not be conducted if severe storms with high winds are predicted. Severe weather will affect the measurement results in the following ways. First, a high wind will increase the variability of radon concentration because of wind-induced differences in air pressure between the house interior and exterior. Second, rapid changes in barometric pressure increase the chance of a large difference in the interior and exterior air pressures, therefore changing the rate of radon influx. Weather predictions available on local news stations will provide sufficient information to determine if this criterion is satisfied.

1.2.2 Location Selection

The location of the measurement within a room should be decided with the objective of measuring the most stable concentrations. The following criteria should be applied, in order of importance, when selecting the measurement location within a room.

1. The measurement should be taken in an area away from drafts caused by heating, ventilation, air conditioning (HVAC) vents, doors, windows, and fireplaces. This will reduce the influence of changes in ventilation and condensation nuclei concentration on radon and RDP concentrations.

2. The measurements should be taken away from exterior house walls to reduce the effect of ventilation through cracks in the walls.

3. The passive device or the air intake of an instrument should be placed at least 50 centimeters (20 inches) above the floor to reduce possible effects of plate-out or drafts near the floor.

1.3 Quality Assurance Objectives

The object of quality assurance is to ensure that data are scientifically sound and of known precision and accuracy. There are several aspects of quality assurance that should be included in any measurement program. These are: controlled calibrations, replicate measurements, background measurements, and routine sensitivity checks.

Controlled calibrations are samples collected or measurements made in a known radon environment such as a calibration chamber. Detectors requiring laboratory readout, such as charcoal canisters, alpha-track detectors, and RPISU samplers, would be exposed in the calibration chamber and then analyzed. Instruments providing immediate results, such as continuous working-level monitors and continuous radon monitors, should be operated in a chamber to establish calibration.

There are two types of calibration measurements that should be made for alpha-track detectors and charcoal canisters. The first are the measurements that must be conducted to determine and verify the conversion factors used to derive the concentration results. These measurements, commonly called spiked samples, are done at the beginning of the measurement program and periodically thereafter. The second calibration measurements are performed to monitor the accuracy of the system. These are called blind calibration measurements and consist of detectors that have been exposed in a radon calibration chamber. They are not labelled as such when sent to a processing laboratory.

Background measurements, or blanks, should also be frequently conducted. Such measurements should be made using unexposed passive detectors or should be instrument measurements conducted in very low (outdoor) radon concentration environments and separated from the operating program. These should be generally equivalent in frequency to the spiked samples and should also not be identified as blanks when submitted for analysis to external laboratories. In addition to these background measurements, the organization performing the measurements should calculate the lower limit of detection (LLD) for the measurement system. This LLD is based on the system's background and can restrict the ability of some measurement systems to measure low concentrations.

Duplicate measurements provide an estimate of the precision of the measurement results. Duplicate measurements should be included in at least 10 percent of the samples. If enough measurements are made, the number of duplicates may be reduced, as long as enough are used to analyze the precision of the method.

A quality assurance program should include written procedures for obtaining the preceding objectives. Also a system for monitoring the results of the four types of quality assurance measurements should be continuously maintained and available for inspection.

The EPA has established a Radon/Radon Progeny Measurement Proficiency Evaluation and Quality Assurance (RMP) Program. This program will enable participants to demonstrate their proficiency at measuring radon and radon decay product concentrations and to have their quality assurance programs evaluated. Contact the Radon Quality Assurance Coordinator at (919) 541-7131 for further information about this program.

Section 2: RADON MEASUREMENT PROTOCOLS

2.1 PROTOCOL FOR USING A CONTINUOUS RADON MONITOR TO MEASURE INDOOR RADON CONCENTRATION

2.1.1 Purpose

This protocol provides guidance for using a continuous radon monitor (CRM) to measure indoor radon concentrations accurately and to obtain reproducible results. Following the protocol will help assure uniformity among measurement programs and allow valid intercomparison of results. Measurements made in accordance with this protocol will produce measurements of radon concentrations representative of standardized closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

2.1.2 Scope

This protocol covers, in general terms, the sample collection and analysis method, the equipment needed, and the quality control objectives of measurements made with a CRM. It is not meant to replace an instrument manual, but rather provides guidelines that should be incorporated into standard operating procedures. More information about the procedures may be obtained from the U.S. EPA Office of Radiation Programs (ANR-460), 401 M Street, S.W., Washington, D.C., 20460.

2.1.3 Method

A CRM samples the ambient air by pumping air into a scintillation cell after passing it through a particulate filter that removes dust and radon decay products. As the radon in the air decays, the ionized radon decay products plate out on the interior surface of the scintillation cell. The radon decay products decay by alpha emissions, and the alpha particles strike the ZnS(Ag) coating on the inside of the scintillation cell, causing scintillations to occur. The scintillations are detected by the photomultiplier tube in the detector, which generates electrical signals. The signals are processed by the electronics, and the results are either stored in the memory of the CRM or printed on paper tape by the printer. The CRM must be calibrated in a known radon environment to obtain the conversion factor used by the electronics to convert count rate to radon concentration.

The CRM may be a flowthrough-cell type or the periodic-fill type. In the flowthrough-cell type air continuously flows into and through the scintillation cell. The periodic-fill type fills the cell once each preselected time interval, counts the scintillations, then begins the cycle again.

2.1.4 Equipment

In addition to the CRM, equipment needed includes a readout device and printer (if not part of the CRM), an air-flow rate meter, and aged air or nitrogen to pump through the CRM to measure the background count rate.

2.1.5 Pre-development Testing

The CRM should be carefully tested before and after each measurement to:

- Verify that the correct input parameters and the unit's clock are set properly.
- Verify the operation of the pump.

After every 1000 hours of operation the unit should be examined to check the background count rate by purging with clean, aged air or nitrogen in accordance with the procedures identified in the operating manual for the instrument. In addition, the background count rate should be more frequently monitored by operating the instrument in an outdoor or other low radon environment.

In addition, participation in a laboratory intercomparison program should be conducted at least semiannually to verify that the conversion factor used by the CRM is accurate. This is done by comparing the unit's response to a known radon concentration. At this time, the correct operation of the pump should be verified and the flow rate measured.

2.1.6 Measurement Criteria

The following house conditions should exist prior to and during a measurement, to standarize the measurement conditions as much as possible.

- The measurement should be made under closed-house conditions. To the extent reasonable, windows and external doors should be closed (except for normal entrance and exit) for 12 hours prior to and during the measurement period. Normal entrance and exit includes opening and closing of a door, but an external door should not be left open for more than a few minutes. These conditions are expected to exist as normal living conditions during the winter in northern climates. For this reason and other reasons discussed in section 1.2.1, measurements should be made during winter periods whenever possible.

- Internal-external air exchange systems (other than a furnace) such as high-volume attic and window fans should not be operating during the measurement and for at least 12 hours before the measurement is initiated.

- In southern climates or when the measurements must be made during a warm season, the standardized closed-house conditions are satisfied by meeting the criteria just listed. These criteria can be most conveniently satisfied if the measurement is begun in the morning, after the occupant has been instructed to keep the windows closed during the night and not to open them until the measurement has been completed. Air conditioning systems that recycle interior air may be operated. The closed-house conditions must be more rigorously verified and maintained, however, when they are not the normal living conditions.

- The measurement should not be conducted if severe storms with high winds are predicted during the measurement period. Weather predictions available on local news stations will provide sufficient information to determine if this condition is satisfied.

2.1.7 Deployment and Operation

2.1.7.1 Location Selection

The following criteria should be applied to select the location of the CRM within a room.

- The measurement should not be made near drafts caused by heating, ventilating and air conditioning (HVAC) vents, doors, windows, and fireplaces.

- The measurement location should not be close to the outside walls of the house.

- The unit should be placed on a table or stool so that the air intake is at least 50 centimeters (20 inches) from the floor.

2.1.7.2 Operation

The CRM should be programmed to run continuously, recording the hourly integrated radon concentration measured and, if applicable, the total integrated average radon concentration. The sampling period should generally not be less 24 hours. An increase in operating time decreases the uncertainty associated with the measurement result.

Care should be taken to eliminate data that is produced before equilibrium conditions have been established in a flow-through cell. Generally, conditions stabilize after the first several hours during which the measurements are very low and should be discarded. After this period, the periodic results should be averaged to obtain an integrated measurement result.

2.1.7.3 Documentation

It is important that the operator of the CRM records enough information about the measurement in a permanent log so that data interpretations and comparisons can be made. This information includes:

- Start and stop times and date of the measurement.
- Information about how the standardized conditions, as previously specified, were satisfied.
- Exact location of the instrument, on a diagram of the room and house, if possible.
- Other easily obtained information that may be useful, such as the type of house, type of heating system, existence of crawl space, occupants smoking habits, and operation of humidifiers, air filters, electrostatic precipitators, or clothes dryers.

2.1.8 Quality Assurance

The elements of a quality assurance program for the CRM are:

- Calibration in a radon-exposure calibration chamber at least every 6 months, or after instrument repair or modification.
- Background count-rate checks before and after approximately 1000 hours of operation.

The EPA has established a Radon/Radon Progeny Measurement Proficiency Evaluation and Quality Assurance (RMP) Program. This program will enable participants to demonstrate their proficiency at measuring radon and radon decay product concentrations and to have their quality assurance programs evaluated. Contact the Radon Quality Assurance Coordinator at (919) 541-7131 for further information about this program.

2.2 PROTOCOL FOR USING ALPHA-TRACK DETECTORS TO MEASURE INDOOR RADON CONCENTRATION

2.2.1 Purpose

This protocol provides guidance for using an alpha-track detector (ATD) to obtain accurate and reproducible measurements of indoor radon concentrations. Following the protocol will help ensure uniformity among measurement programs and allow valid intercomparison of results. Measurements made in accordance with this protocol will produce measurements of radon concentration representative of standardized, closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

2.2.2 Scope

This procedure covers, in general terms, the equipment, procedures, and quality control objectives to be used when performing the measurements. This document provides guidelines to be adopted into standard operating procedures. More information about the procedures may be obtained from the U.S. EPA Office of Radiation Programs (ANR-460), 401 M Street, S.W., Washington, D.C., 20460.

2.2.3 Method

An alpha-track detector (ATD) consists of a small piece of plastic enclosed in a container with a filter-covered opening. Alpha particles emitted by the radon decay products in air strike the plastic and produce submicroscopic damage tracks. At the end of the measurement period, the detectors are returned to a laboratory, where the plastic is placed in a caustic solution that accentuates the damage tracks so they can be counted using a microscope or an automated counting system. The number of tracks per unit area is correlated to the radon concentration in air, using a conversion factor derived from data generated at a calibration facility.

Many factors contribute to the variability of the ATD results, including differences in the detector response within and between batches of plastic, non-uniform plateout of decay products inside the detector holder, differences in the number of tracks used as background, variations in etching conditions and differences in readout. The variability in ATD results decreases with the number of net tracks counted, so counting more tracks over a larger area of the detector will reduce the uncertainty of the result. In addition, deploying duplicate ATDs will reduce the error. However, if cost considerations make it necessary to deploy single ATDs, the data obtained should be evaluated and used taking into consideration the relative errors associated with counting the area and number of net tracks specified to the processing laboratory.

2.2.4 Equipment

Alpha-track detectors are available from commercial suppliers. These suppliers offer contract services in which they provide the detector and subsequent data readout and reporting for a fixed price. Establishing an in-house capability to provide packaged detectors, a calibration program, and a readout program would probably not be practical or economically advantageous. Therefore, details for establishing the analytical aspects of an ATD program will be omitted from this protocol. If additional details are desired, they have been reviewed by Fleischer and Lovett (F165; Lo69).

Assuming ATDs are obtained from a commercial supplier, the following equipment is needed to initiate monitoring in a house:

- The alpha track detector in an individual, sealed container, such as an aluminized plastic bag to prevent extraneous exposure before deployment,
- A means to attach the ATD to its measurement location, if it is to be hung from the wall or ceiling,
- Instruction sheet for the occupant, and a shipping container and, if it is to be mailed, a prepaid mailing label for returning the detector to the laboratory,
- At the time of retrieval, some means (such as tape) will be needed to reseal the detector prior to returning it to the supplier for analysis.

2.2.5 Predeployment Considerations

The plans of the occupant during the proposed measurement period should be considered before deployment. The ATD measurement should not be made if the occupant knows he will be moving during the period. Deployment should be delayed until the new occupant is settled in the house. Likewise, the measurement should be delayed if the occupant is planning remodeling, changes in the heating, ventilating and air conditioning (HVAC) system, or other modifications that may influence the radon concentration during the period.

2.2.6 Measurement Criteria

The following house conditions should exist during the measurement period, to standardize the measurement conditions as much as possible.

- To a reasonable extent, the house should be closed, with all windows and external doors closed (except for normal extrance and exit) during the measurement period. These conditions are expected to exist as normal living conditions during the winter in northern climates. For this reason and other reasons discussed in section 1.2.1, ATD measurements (other than 12-month measurements) should be conducted during the winter whenever possible.

- Internal-external air exchange systems (other than a furnace) such as high-volume attic and window fans should not be operated.

- In warm conditions, the standardized conditions are satisfied by the criteria just listed. Air conditioning systems that recycle interior air can be operated. The closed-house criteria must be more rigorously verified and maintained, however, when they do not exist as normal living conditions. For a 3-month sampling period, however, a few days with the windows open will not invalidate the measurement.

A 12-month ATD measurement will provide information about the concentrations in the house during an entire year, so the closed-house conditions do not have to be satisfied for a valid 12-month deployment.

2.2.7 Deployment

2.2.7.1 Timely Deployment

A group of ATDs should be deployed into houses as soon as possible after delivery from the supplier. Groups should not order more ATDs than they can reasonably expect to install within the following few months to minimize chances of high background exposures. If the storage time exceeds more than a few months, the background exposures from a sample of the stored detectors should be assessed. Consult the manufacturer's instructions regarding storage and background determination.

2.2.7.2 Location Selection

The following criteria should be applied to select the location of the detector within a room.

- A position must be selected where the ATD will not disturbed during the measurement period.

- The detector should not be placed near drafts caused by HVAC vents, windows, doors, etc. Avoid locations near excessive heat, such as fireplaces.

- The detector should not be placed close to the outside walls of the house.

It is usually convenient to suspend the detector from the ceiling. The detector should be positioned at least 20 centimeters (8 inches) below the ceiling. If the detector is installed during a site visit, the final site selected should be shown to the home occupant to be certain it is acceptable for the duration of the measurement period.

The sampling period is begun when the protective cover or bag is removed. Cut the edge of the bag or remove the cover so that it can be reused to reseal the detector at the end of the exposure period. Inspect the detector to make sure it is intact and has not been physically damaged in shipment or handling.

Fill in the information called for with the detector. Also, record the detector serial number in a log book along with a description of the location in the house in which the detector was placed. If during the exposure period it is necessary to relocate the detector, make certain it is noted in the log book, along with the date it was relocated.

2.2.8 Retrieval of Detectors

At the end of the measurement period, the detector should be inspected for damage or deviation from the conditions entered in the log book at the time of deployment. Any changes should be noted in the log book. The date of removal is entered on the data form for the detector and in the log book. The detector is then resealed using the protective cover or bag with the correct serial number for that detector or the cover originally provided. If a bag is used, the open edge of the bag is folded several times and resealed with tape. If the bag or cover has been destroyed or misplaced, the detector should be wrapped in several layers of aluminum foil and taped shut. After retrieval, the detectors should be returned as soon as possible to the analytical laboratory for processing.

2.2.9 Documentation

It is important that enough information about the measurement is recorded in a permanent log so that data interpretations and comparisons can be made. Information that should be recorded includes:

- The start and stop dates of the measurement.
- Whether standardized conditions, as previously specified, are satisfied.
- Exact location of the ATD(s), on a diagram of the room and house if possible.

- Other easily gathered information that may be useful, such as the type of house, type of heating system, existence of crawl space, occupants smoking habits, operation of humidifiers, air filters, electrostatic precipitators, and clothes dryer.

2.2.10 Analysis Requirements

2.2.10.1 Sensitivity

The sensitivity of an ATD system is dependent upon the area of the detector that is counted for alpha tracks. Table 2-1 illustrates this dependence of precision on the number of net tracks counted. The organization performing the measurements should verify that the area or number of net tracks counted by the ATD processor provides an adequate sensitivity at the radon concentration at which a decision is made. In the past, the EPA and the Centers for Disease Control have used 4 pCi/l as a decision point, and it is recommended that enough net tracks be counted to allow for a reasonable sensitivity at this concentration. As can be seen from Table 2-1, if few net tracks are counted, a very poor precision is obtained. Thus, it is critical that the organization performing the measurements with an ATD arranges for an adequate sensitivity.

Table 2-1

DEPENDENCE OF PRECISION ON NUMBER OF NET TRACKS COUNTED

Number of Net Tracks Counted	2 Sigma Error (%)[a]
4	100
6	82
10	63
15	52
20	45
50	28
75	23
100	20

(a) This is the minimum error for the number of net tracks indicated; the absolute error is dependent on the actual number of background tracks counted.

Figure 3 — Sub-slab suction at aggregate.

Section 3: RADON DECAY PRODUCT MEASUREMENT PROTOCOLS

3.1 PROTOCOL FOR USING A CONTINUOUS WORKING LEVEL MONITOR TO MEASURE INDOOR RADON DECAY PRODUCT CONCENTRATION

3.1.1 Purpose

This protocol provides guidance for using a continuous working level monitor (CWLM) to obtain accurate and reproducible measurements of indoor radon decay product concentrations. Following the protocol will help assure uniformity among measurement programs and allow valid intercomparison of results. Measurements made in accordance with this protocol will produce measurements of radon decay product (RDP) concentrations representative of standardized closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

3.1.2 Scope

This protocol covers, in general terms, the sample collection and analysis method, the equipment needed, and the quality control objectives of measurements made with a CWLM. It is not meant to replace an instrument manual, but provides guidelines that should be incorporated into standard operating procedures. More information about the procedures may be obtained from the U.S. EPA Office of Radiation Programs (ANR-460), 401 M Street, S.W., Washington, D.C., 20460.

3.1.3 Method

A CWLM samples the ambient air by filtering airborne particles as the air is drawn through a filter cartridge at a low flow rate of about 0.1 to 1 liter per minute. An alpha detector such as a diffused-junction or surface-barrier detector counts the alpha particles produced by the RDP as they decay on the filter. The detector is normally set to detect alpha particles with energies between 2 and 8 MeV. The alpha particles emitted from the radon decay products Po-218 and Po-214 are the significant contributors to the events that are measured by the detector. The event count is directly proportional to the number of alpha particles emitted by the RDP on the filter. The unit typically contains a microprocessor that stores the number of counts and elapsed time. The unit can be set to record the total counts registered over specified time periods. The unit must be calibrated in a calibration facility to convert count rate to working level (WL) values. This may be done initially by the manufacturer and should be done periodically thereafter by the operator.

3.1.4. Equipment

In addition to the CWLM, equipment needed includes replacement filters, a readout or programming device (if not part of the CWLM), an alpha-emitting check source, and an air-flow rate meter.

3.1.5 Predeployment Testing

The CWLM should be carefully tested before and after each measurement to:

- Verify that a new filter has been installed and the input parameters and clock are set properly,
- Measure the detector's efficiency with a check source such as Am-241 or Th-230 and ascertain that it compares well with the technical specifications for the unit,
- Verify the operation of the pump.

After every 100 hours of operation, the unit should be checked to measure the background count rate using the procedures that may be identified in the operating manual for the instrument.

In addition, participation in a laboratory intercomparison program at least semiannually will verify that the conversion factor used in the microprocessor is accurate. This is done by comparing the unit's response to a known RDP concentration. At this time, the correct operation of the pump should also be verified by measuring the flow rate.

3.1.6 Measurement Criteria

The following house conditions should exist prior to and during a measurement to standarize the measurement conditions as much as possible.

- The measurement should be made under closed-house conditions. To the extent reasonable, windows and external doors should be closed (except for normal entrance and exit) for 12 hours prior to and during the measurement period. Normal entrance and exit includes an opening and closing of a door, but an external door should not be left open for more than a few minutes. These conditions are expected to exist as normal living conditions during the winter in northern climates. For this reason and other reasons discussed in section 1.2.1, measurements should be made during winter whenever possible.

Figure 5 — Block wall suction; interior suction point.

- Internal-external air exchange systems (other than a furnace) such as high-volume attic and window fans should not be operating during the measurement and for at least 12 hours before the measurement is initiated.

- In southern climates or when the measurements must be made during a warm season, the standardized closed-house conditions are satisfied by meeting the preceding criteria. These criteria can be most conveniently satisfied if the measurement is begun in the morning, after the occupant has been instructed to keep the windows closed during the night and not to open them until the measurement has been completed. Air conditioning systems that recycle interior air may be operated. The closed-house conditions must be more rigorously verified and maintained, however, when they are not the normal living conditions.

- The measurement should not be conducted if severe storms with high winds are predicted during the measurement period. Weather predictions available on local news stations will provide sufficient information to determine whether this criterion is satisfied.

3.1.7 Deployment and Operation

3.1.7.1 Location Selection

The following criteria should be applied to select the location of the CWLM within a room.

- The measurement should not be taken near drafts caused by heating, ventilating and air conditioning (HVAC) vents, doors, windows, and fireplaces.

- The measurement location should not be close to the outside walls of the house.

- The unit should be placed on a table or stool so that the air intake is at least 50 centimeters (20 inches) from the floor.

3.1.7.2 Operation

The CWLM should be programmed to run continuously, recording the hourly integrated WL measured and, when possible, the total integrated average WL. The sampling period should not be less 24 hours for most purposes. The longer the operating time, the smaller the uncertainty associated with the measurement result. The integrated average WL over the measurement period should be used as the measurement result.

3.1.7.3 Documentation

It is important that the operator of the CWLM records enough information about the measurement in a permanent log so that data interpretations and comparisons can be made. This will include:

- The time and date of the start and end of the measurement,
- Whether standardized conditions, as specified, are satisfied,
- Exact location of the instrument, on a diagram if possible.
- Other easily gathered information that may be useful, such as the type of house, type of heating system, existence of crawl space, occupants smoking habits, and operation of humidifiers, air filters or electrostatic precipitators, and clothes dryers.

3.1.8 Quality Assurance

The elements of a quality assurance program for the CWLM are:

- Calibration in a radon decay product exposure calibration chamber at least every 6 months, or after instrument repair or modification, and
- Checks using an Am-241 or Th-230 similar-energy alpha check source (before and after each measurement),
- Background count-rate checks (after each 100 hours of operation).

The EPA has established a Radon/Radon Progeny Measurement Proficiency Evaluation and Quality Assurance (RMP) Program. This program will enable participants to demonstrate their proficiency at measuring radon and radon decay product concentrations and to have their quality assurance programs evaluated. Contact the Radon Quality Assurance Coordinator at (919) 541-7131 for further information about this program.

3.2 PROTOCOL FOR USING RADON PROGENY INTEGRATING SAMPLING UNITS (RPISU) TO MEASURE INDOOR RADON DECAY PRODUCT CONCENTRATIONS

3.2.1 Purpose

This protocol provides guidance for using a RPISU to produce accurate and reproducible measurements of indoor radon decay product concentrations. Following the procedure will help ensure uniformity in measurement programs and allow valid intercomparison of results. Measurements made in accordance with this protocol will produce measurements of radon decay product concentrations (RDP) representative of standardized closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

3.2.2 Scope

This protocol covers, in general terms, the equipment, procedures, analysis, and quality control objectives for measurements made with RPISUs. It is not meant to replace an instrument manual, but provides guidelines to be adopted into standard operating procedures. More information about the procedures may be obtained from the U.S. EPA Office of Radiation Programs (ANR-460), 401 M Street, S.W., Washington, D.C., 20460.

3.2.3 Method

The RPISU contains an air sampling pump that draws a continuous flow of air through a detector assembly. The detector assembly includes a filter and at least two thermoluminescent dosimeters (TLDs). One TLD measures the radiation emitted from radon decay products collected on the filter, and the other TLD is used for background gamma correction. The pump and detector assembly are operated inside the structure for 3 to 7 days.

Analysis of the detector TLDs is performed in a laboratory utilizing a thermoluminescent dosimeter reader. Interpretation of the results of this measurement requires a calibration for the detector and an analysis system based on exposures to known concentrations of radon decay products.

3.2.4 Equipment

The RPISU sampling system includes the sampling pump and the detector assembly. Analysis requires a thermoluminescent dosimeter reader.

3.2.4.1 Sampling Pump

The air sampling pump must be capable of moving air at a flow rate ranging from 0.1 to 4 lpm through the detector assembly.

The pump must be suitably quiet to allow operation in an occupied residence without creating a major annoyance. The pump should also include a running-time meter. High-flow-rate pumps require an automatic shut-down system if the flow rate is reduced to less than an adequate rate or if the pump overheats. A calibrated flow meter to measure the flow rate through the detector must also be available.

3.2.4.2 Detector Assembly

The detector assembly includes a holder suitable to contain the filter and TLDs that will allow entry of air to the filter. One TLD is placed directly adjacent to the face of the filter to detect alpha radiation coming from the particles collected on the filter. The other TLD is placed behind a stainless steel shield to measure the gamma and beta radiation received during exposure, storage, and shipment. The filter for the detector should present a uniform surface with pore sizes no larger than 0.8 microns.

3.2.4.3 Thermoluminescent Dosimeter Reader

The TLD reader is an instrument that heats the TLDs at a uniform and reproducible rate and simultaneously measures the light emitted by the thermoluminescent material. The readout process is carefully controlled, with the detector purged with nitrogen to prevent spurious emissions. The TLD reader should be periodically tested using dosimeters exposed to a known level of alpha or gamma radiation prior to analyzing the RPISU dosimeters. TLDs are prepared for reuse by cleaning and annealing at prescribed temperatures in an oven.

3.2.5 Predeployment Considerations

Prior to installation in the house, the pump should be checked to assure that it is operable and capable of maintaining an adequate flow through the detector assembly. Extra detector assemblies should be available during deployment in case a problem is encountered.

Arrangements should be made with the occupant of the house to assure that entry to the house can be made at the time of delivery and to determine availability of a suitable electrical outlet near the sampling area in the selected room.

3.2.6 Measurement Criteria

The following house conditions should exist during a measurement period to ensure that the conditions are as standardized as possible.

- To a reasonable extent, the house should be closed, with all windows and external doors shut (except for normal entrance and exit) for 12 hours prior to and during the measurement period. Normal entrance and exit includes a brief opening and closing of a door, but an external door should not be left open for more than a few minutes. These conditions are expected to exist as normal living conditions during the winter in northern climates. For this reason and other reasons discussed in section 1.2.1, measurements should be made during the winter whenever possible.

- Internal-external air exchange systems (other than a furnace), such as high-volume attic and window fans, should not be operated for at least 12 hours prior to and during the measurement.

- In southern climates or when measurements must be made during a warm season, the closed-house conditions are satisfied by meeting the preceding criteria. This condition can be most conveniently satisfied by beginning a sampling period in the morning after the occupants have been instructed to keep the windows closed and not to open them until the measurement is completed. Air conditioning systems that recycle interior air may be operated. The closed-house conditions must be more rigorously verified and maintained, however, when they are not the normal living conditions.

- The measurement should not be conducted if severe storms with high winds are predicted for the measurement period. Weather predictions available on local news stations will provide sufficient information to determine if this criterion is satisfied.

3.2.7 Deployment and Operation

Install the RPISU and check the air flow rate with a calibrated flow meter. Record the location, date, starting time, running time meter reading, and flow rate on the detector assembly envelope and in a log. Observe the RPISU for a few minutes after starting, to assure continued operation; also inform the occupants about the RPISU and request that they report any problems or pump shut down. The occupant should be aware of the length of time the RPISU will be operated, and an appointment should be arranged to retrieve the unit. The criteria for the standardized measurement conditions should be repeated to the occupants.

The sampling period should be at least 72 hours. A longer operating time decreases the uncertainty associated with the measurement result.

3.2.7.1 Location Selection

The following criteria should be used to select the location of the RPISU within a room:

- The RPISU should not be placed close to the outside walls of the house.
- The air intake (sampling head) should be placed at least 20 centimeters (8 inches) from surfaces that may obstruct flow.
- The RPISU should not be placed near drafts caused by HVAC vents, windows, fireplaces, or doors.

3.2.8 Retrieval

Prior to pump shut-down the flow rate should be measured with a calibrated flow meter and the unit should be observed briefly to assure that it is operating properly. If the sampling pump is not operating, attempt to restart it even briefly to perform flow measurements. Return the detector assembly to its envelope and record the date, time, running time meter reading, and flow rate both on the detector assembly envelope and in a log book. Also, record any other observed conditions that might affect the measurement. Remove the RPISU sampling pump and any ancillary equipment.

3.2.9 Analysis

Analysis of the RPISU detector assembly should be performed in a laboratory under controlled conditions. The analysis should be delayed for at least 3 hours after the sampling is completed to allow for decay of radon decay products collected on the filter.

Prior to analysis, the TLDs should be removed from the detector assembly, and the filter should be checked for observable holes or leakage. The TLD identification numbers should be checked against the recorded numbers, and, if specified by the TLD supplier, the TLDs should be cleaned using the manufacturers recommended procedures.

The TLDs are then analyzed in the TLD reader using established procedures. Note that the side of the TLD that received the exposure from the filter should be placed adjacent to the photomultiplier tube.

Dosimeter numbers (if available) and readings for both the alpha TLD and background (gamma/beta) TLD should be recorded as well as all other pertinent information on the detector assembly envelope or data sheet.

3.2.10 Documentation

It is important that enough information about the measurement is recorded in a permanent log so that data interpretations and comparisons can be made. This will include:

- The time and date of the start and end of the measurement,
- Whether standardized conditions, as previously specified, are satisfied,
- Exact location of the instrument, on a diagram, of the room and house, if possible,
- Other easily gathered information that may be useful, such as the type of house, type of heating system, existence of crawl space, occupants smoking habits, and operation of humidifiers, air filters, electrostatic precipitators, or clothes dryers.

3.2.11 Quality Assurance

The quality assurance program for measurements of radon decay product concentrations in terms of working levels comprises three elements: (1) calibration or accuracy testing, (2) duplicate measurements and (3) control dosimeters to measure exposure during shipment and storage.

The EPA has established a Radon/Radon Progeny Measurement Proficiency Evaluation and Quality Assurance (RMP) Program. This program will enable participants to demonstrate their proficiency at measuring radon and radon decay product concentrations and to have their quality assurance programs evaluated. Contact the Radon Quality Assurance Coordinator at (919) 541-7131 for further information about this program.

3.2.11.1 Calibration

Calibration of RPISU dosimeters requires exposure in a controlled radon-exposure chamber where the radon decay product concentration is known during the exposure period. The detector assembly must be exposed in the chamber using a flow rate similar to the normal operating flow rate for the RPISU sampling pumps. The environmental conditions in the chamber during all exposures should be similar to those that are found in the tested houses. Calibration should include exposure of a minimum of four detectors exposed at different RDP concentrations representative of the range found in field measurements. The relationship of thermoluminescent dosimeter reader units to working level for a given sample volume and the standard error associated with this measurement should be determined. Calibration of the RPISUs also includes testing of air-flow meters to ensure accuracy of the flow rate measurement.

After the initial calibration, periodic processing of exposed detectors should be done to assure that the detection system has not changed.

3.2.11.2 Duplicates

The organization performing the measurements should make duplicate measurements with RPISUs in enough houses to test the precision of the measurement. This number should be at least 10 percent of the houses tested. The two RPISUs should be located in the same area in the house, and all handling and analysis of the detectors should be identical. Data from duplicate detectors should be evaluated using the procedures recommended for internal quality control programs for replicate analysis (Ro65, EPA80). The method should achieve a coefficient of variation of 10 percent (1 sigma) or less. Consistent failure in duplicate agreement indicates an error in the measurement process that should be investigated.

11.3 Control Dosimeters

Control dosimeters for RPISUs are included in each detector assembly. The purpose of these control dosimeters is to identify any exposure from sources of radiation other than the radon decay products accumulated on the filter and from nonradiation-induced thermoluminescence. Typically the value for the control dosimeters is less than 5 percent of the value for the primary dosimeter unless the RDP concentration is very low. If the value for the control dosimeter exceeds approximately 5 percent of the value for the primary dosimeter for concentrations greater than 0.01 WL and on a regular basis, the cause should be investigated.

3.3 PROTOCOL FOR THE DETERMINATION OF INDOOR RADON DECAY PRODUCT CONCENTRATION BY GRAB SAMPLING

3.3.1 Purpose

This protocol provides guidance for using the grab sampling technique to provide accurate and reproducible measurements of indoor radon decay product (RDP) concentrations. Following the protocol will help ensure uniformity among measurement programs and allow valid intercomparison of results. Measurements made in accordance with this procedure will produce measurements of RDP concentration representative of standardized, closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

3.3.2 Scope

This procedure covers, in general terms, the equipment, procedures, and quality control objectives to be used when performing measurements. This document provides guidelines to be incorporated into standard operating procedures. More information about the procedures may be obtained from the U.S. EPA Office of Radiation Programs (ANR-460), 401 M Street, S.W., Washington, D.C., 20460.

3.3.3 Method

Grab sampling measurements of RDP concentrations in air are performed by collecting the decay products from a known volume of air on a filter and by counting the activity on the filter following collection. Several methods for performing such measurements have been developed and have been described by George (Ge80b). Comparable results may be obtained using all these methods. This procedure, however, will describe two methods that have been most widely used with good results. These are the Kusnetz procedure and the modified Tsivoglou procedure.

The Kusnetz procedure (Ku56; ANSI73) may be used to obtain results in working levels (WL) when the concentration of individual decay products is unimportant. Decay products from up to 100 liters of air are collected on a filter in a 5-minute sampling period. The total alpha activity on the filter is counted at any time between 40 and 90 minutes after the end of sampling. Counting can be done using a scintillation-type counter to obtain gross alpha counts for the selected period. Counts from the filter are converted to disintegrations using the appropriate counter efficiency. The disintegrations from the decay products collected from the known volume of air may be converted into working levels using the appropriate "Kusnetz factor" (see Appendix B, Table B-1) for the counting time utilized.

The Tsivoglou procedure, as modified by Thomas (Ts53; Th72), may be used to determine WL and the concentration of the individual RDPs. Sampling is the same as that used for the Kusnetz procedure; however, the filter is counted three separate times following collection. The filter is counted between 2 and 5 minutes, 6 and 20 minutes, and 21 and 30 minutes following completion of sampling. Count results are used in a series of equations to calculate concentrations of the three RDPs and working level. These equations and an example calculation appear in Appendix B.

3.3.4 Equipment

Equipment required for RDP concentration determination by grab sampling consists of:

- An air pump capable of collecting samples at the desired flow rate.
- A filter holder to accept a 25 to 47-mm diameter, 0.8-micron membrane or glass fiber filter.
- A calibrated flow meter to determine air flow through the filter during sampling.
- A clock for accurate timing of sampling and counting.
- A scintillation counter (such as the Randam[a] Electronics Model SC-5, or the EDA[a] Instruments Model RD-200) and a zinc sulfide scintillation disc.
- A National Bureau of Standards (NBS)-traceable alpha calibration source to determine counter efficiency

3.3.5 Premeasurement Considerations

Prior to collection of the sample, proper operation of the equipment must be verified, and the counter efficiency and background must be determined. This is especially critical for the Tsivoglou procedure, in which the sample counting must begin 2 minutes following the end of sampling.

The air pump, filter assembly, and flow meter must be tested to assure there are no leaks in the system. The scintillation counter must be operated with the scintillation tray (where applicable) and scintillation disc in place to determine background for the counting system. Also, the counter must be operated with an NBS-traceable alpha calibration source in place of

(a) Use of trade names does not constitute EPA endorsement.

a filter in the counting location, to determine system counting efficiency. Both the system background and system efficiency are used in the calculation of results from the actual sample.

3.3.6 Measurement Criteria

The following conditions should exist prior to and during the sampling to ensure that the conditions are as standardized as possible.

- The sampling should be made under closed-house conditions. To a reasonable extent, external doors and windows should be closed during the 12 hours prior to the measurement (except for normal entrance and exit). Normal entrance and exit includes a brief opening and closing of a door, but an external door should not be left open for more than a few minutes. No windows or doors should be open during the sampling period. These conditions are expected to exist as normal living conditions during the winter in northern climates. For this reason and other reasons discussed in section 1.2.1, measurements should be conducted during the winter whenever possible.

- Internal-external air exchange systems (other than a furnace) such as high-volume attic and window fans should not be operated for at least 12 hours prior to and during the sampling.

- In southern climates or when measurements must be made during a warm season, the closed-house conditions are satisfied by meeting the preceding criteria. This condition can be most conveniently satisfied if the sampling is done after the occupant has been instructed to keep the windows closed and all internal-external ventilation systems off during the night and until after the measurement is made. Air conditioning systems that recycle interior air should not be operated prior to the measurement, if reasonable. No ventilation systems should be operated during the measurement. The closed-house conditions must be more rigorously verified and maintained, however, when they are not the normal living conditions.

- The sampling should not be conducted if severe storms with high winds have occurred in the previous 12 hours or are present at the sampling time.

3.3.7 Documentation

It is important that enough information about the measurement is recorded in a permanent log so that data interpretations and comparisons can be made. This information includes:

- The time and date of the start and end of the measurement,
- Whether standardized conditions, as previously specified, are satisfied,
- Exact location of the measurement, on a diagram, of the room and house, if possible,
- Other easily gathered information that may be useful, such as the type of house, type of heating system, existence of crawl space, occupants smoking habits, and operation of humidifiers, air filters, electrostatic precipitators, and clothes dryers.

3.3.8 Sampling Operations

3.3.8.1 Location in Room

The sample should be collected in an area away from drafts. The sample should not be collected near heating, ventilation, or air conditioning (HVAC) vents, leaking windows and doors, clothes dryer or stove vents, fireplaces, etc. The sample should not be taken near the outside walls of the house. If possible, entrance into a basement room for sampling should be made through an interior stairway rather than an exterior door to reduce the ventilation caused by the opening of the door.

3.3.8.2 Sampling

A new filter should be placed in the filter holder prior to entering the house. Care should be taken to avoid puncturing the filter and to avoid leaks. The sampling is begun by starting the pump and the clock simultaneously. Note the air flow rate and record it in a log book. Also record the time the sampling was begun. The sampling period should be 5 minutes, and the time from the beginning of sampling to the time of counting must be precisely recorded.

3.3.9 Analysis

Analysis may be done using the Kusnetz, modified Tsivoglou, or other procedure described elsewhere (Ge80b). If the Tsivoglou procedure is used, the counting must be started 2 minutes following the end of sampling. Analysis using the Kusnetz procedure must be performed between 40 and 90 minutes following the end of sampling. A counting time of 10 minutes during this period is usually used.

Remove the filter from the holder using forceps and carefully place it facing the scintillation phosphor. The side of the filter on which the decay products were collected must face the phosphor disc. The chamber containing the filter and disc should be closed and allowed to dark-adapt prior to starting counting. For the Tsivoglou method this procedure of placing the filter in the counting position must be done quickly, since the first of the three counts must begin two minutes following the end of sampling. If the counter used has been shown to be slow to dark-adapt, the counting should be done in a darkened environment. Additional details on the procedure and calculations may be found in the references (Ku56; Ts53; Th72).

3.3.10 Grab Sampling Results

3.3.10.1 Sensitivity

For a 5-minute sampling period (10 to 20 liters of air) on a 25-mm filter, the sensitivity using the Kusnetz or modified Tsivoglou counting procedure should be approximately 0.0005 working level (Ge80b).

3.3.10.2 Precision

The coefficient of variation should not exceed 30 percent at RDP concentrations of 0.005 WL or greater. This precision should be monitored using the results of duplicate measurements described in section 3.3.11.2 of this protocol. Sources of error in the procedure may result from inaccuracies in measuring the volume of air sampled, characteristics of the filter used, and measurement of amount of radioactivity on the filter.

3.3.11 Quality Assurance

The quality assurance program for RDP concentration measurements by grab sampling includes calibration and duplicate measurements.

The EPA has established a Radon/Radon Progeny Measurement Proficiency Evaluation and Quality Assurance (RMP) Program. This program will enable participants to demonstrate their proficiency at measuring radon and radon decay product concentrations and to have their quality assurance programs evaluated. Contact the Radon Quality Assurance Coordinator at (919) 541-7131 for further information about this program.

3.3.11.1 Calibration

Pumps and flow meters used to sample air must be routinely calibrated to assure accuracy of volume measurements. This may be performed using a dry-gas meter or other flow measurement device of traceable accuracy. This should be done every 6 months or after any instrument repair or modification.

The radiological counters should have calibration checks run daily to determine counter efficiency. This is particularly important for portable counters taken into the field that may be subject to rugged use and temperature extremes. These checks are made using an NBS-traceable alpha calibration source such as Thorium-230.

At least once per year, grab measurements should be made in a calibration chamber with known RDP concentrations to verify the calibration factor. These measurements should also be used to test the collection efficiency and self-absorption of the filter material being used for sampling. A change in the filter material being used during the year requires checking the new material for collection efficiency in a calibration chamber.

3.3.11.2 Duplicates

Duplicate grab samples should be collected with sufficient frequency to test the precision of the measurement. The number of duplicates should be at least 10 percent of the total samples collected. Care should be taken to ensure that the samples are duplicates to the greatest extent possible. The filter heads should be relatively close to each other and away from drafts. Care should also be taken to ensure that one filter is not in the discharge air stream of the other sampler.

Data from duplicate samples should be evaluated using the procedures recommended for internal quality control programs for replicate analysis (Ro65, EPA80). The method should achieve a coefficient of variation of 30 percent (1 sigma) or less. Consistent failure in duplicate agreement indicates an error in the measurement process that should be investigated.

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APPENDIX A

SUPPLEMENTARY INFORMATION FOR GRAB RADON SAMPLING

EQUIPMENT

Equipment to measure radon concentration using grab sampling into scintillation cells is available from several commercial suppliers. Equipment required includes:

- Scintillation cells
- Pump to evacuate single valve cells or to flow air through double valve cells
- Filter holder and filter to remove particulates
- Detector-scaler-high voltage assembly for counting
- Timer
- Calibration cell or check source
- Aged air or nitrogen

GENERAL METHOD DESCRIPTION

- Air to be sampled for radon is either flushed through a cell using a low volume air pump or is drawn into an evacuated cell through a filter.
- The sample in the cell is allowed to equilibrate to optimize counting efficiency.
- The cell is placed on a photomultiplier tube and scintillations counted.
- Radon concentration is calculated based on the sample counts and corrected using appropriate ingrowth and decay factors.

PROCEDURE

The procedure described below is that used by the U.S. Environmental Protection Agency Office of Radiation Programs in its field measurement programs. It is designed for measurements made using the Randam[a] Electronics Model SC-5 cell counters and associated cells or the EDA[a] Instruments Model RD-200 System.

(a) Use of trade names does not constitute EPA endorsement.

However, equipment is available from several suppliers, and it may be necessary to modify the procedure slightly to accomodate these differences. For example, the correct cell volume must be used in the calculations. A general procedure using the Randam or EDA equipment includes:

1. The cells to be used are flushed with aged air or nitrogen to remove traces of previous sample. It may be necessary to store cells for 24 hours prior to reuse if the cell had contained a high activity sample. Place each cell in counter, wait 2 minutes for the system to become dark adapted, and count background of the cell for 10 minutes. Record background data for each cell.

2. At the site to be surveyed, collect the sample by flowing air into the longer tube in the top of the EDA cell (double valve) for a period sufficient to allow 10 air exchanges. For the Randam (single valve) cells it is only necessary to open the valve on the evacuated cells and allow 10 to 15 seconds for complete filling. Cells must be filled with air forced through a filter to prevent entry of airborne particulates.

3. The filled cells must be allowed to equilibrate for 4 hours prior to counting. The cells should not be exposed to bright light prior to counting.

4. The cells are placed in the counters, the systems are allowed to dark adapt for 2 minutes, and the cells are counted. Counting time will vary based on the activity in the cell, however, at least 1,000 counts is desirable to provide good statistics.

5. The activity in the sample is calculated and corrected for ingrowth and decay as described below.

<u>CALCULATION OF RESULTS</u>

The radon concentration in picocuries per liter is determined using the following formula:

$$pCi/l = \frac{cpm(s) - cpm(bkg)}{E} \times \frac{C}{A} \times \frac{1}{V}$$

where

cpm(s) = Counts per minute for the sample

cpm(bkg) = Counts per minute for background

E	=	Efficiency of system determine for each cell as described in Section 11.1 of the protocol. For the EDA and Randam cells the factor is typically 4-5 cpm/pCi.
C	=	Correction for decay during counting from table A-1.
A	=	Correction for decay of radon from time of collection to start of counting from table A-1.
V	=	Volume of counting cell in liters,

V = 0.170 l for EDA cells
V = 0.125 l for Randam cells

SAMPLE CALCULATION

The following sample calculation demonstrates the procedure for calculating results.

- Background Count for system = 10 counts in 10 minutes or 1 cpm
- Sample Count for 120 minutes = 1200 counts or 10 cpm
- System Efficiency (E) from cell calibration = 4.62 cpm/pCi
- Count time correction (C) for 120 minutes = 1.00757
- Delay time correction (A) for 4 hours = 0.97026
- Volume correction (V) for EDA cell = 0.170 l

$$pCi/l = \frac{10\ cpm - 1\ cpm}{4.62\ cpm/pCi} \times \frac{1.00757}{0.97026} \times \frac{1}{0.170\ l} = 11.9$$

Table A-1

Radon Correction Factors

A. - Correction for radon decay from time of collection to start of counting

C. - Correction for radon decay during counting

	A.			C.
Time	Minutes	Hours	Days	Hours
0	1.00000	1.00000	1.00000	1.00000
1	0.99987	0.99248	0.83431	1.00378
2	0.99975	0.98507	0.69607	1.00757
3	0.99962	0.97761	0.58074	1.01136
4	0.99950	0.97026	0.48451	1.01517
5	0.99937	0.96296	0.40423	1.01899
6	0.99925	0.95572	0.33726	1.02281
7	0.99912	0.94854	0.28138	1.02665
8	0.99899	0.94140	0.23475	1.03050
9	0.99887	0.93432	0.19586	1.03435
10	0.99874	0.92730	0.16341	1.03821
11	0.99862	0.92033	0.13633	1.04209
12	0.99849	0.91340	0.11374	1.04597
13	0.99837	0.90654	0.09490	1.04986
14	0.99824	0.89972	0.07917	1.05377
15	0.99811	0.89295	0.06605	1.05768
16	0.99799	0.88624	0.05511	1.06160
17	0.99786	0.87958	0.04598	1.06553
18	0.99774	0.87296	0.03836	1.06947
19	0.99761	0.86640	0.03200	1.07342
20	0.99749	0.85988	0.02670	1.07738
21	0.99736	0.85342	0.02228	1.08135
22	0.99724	0.84700	0.01859	1.08532
23	0.99711	0.84063	0.01551	1.08931
24	0.99699	0.83431	0.01294	1.09331
25	0.99686	0.82803	0.01079	1.09732
26	0.99673	0.82181	0.00901	1.10133
27	0.99661	0.81563	0.00751	1.10536
28	0.99648	0.80950	0.00627	1.10939
29	0.99636	0.80341	0.00523	1.11344
30	0.99623	0.79737	0.00436	1.11749
31	0.99611	0.79137	0.00364	1.12155
32	0.99598	0.78542	0.00304	1.12562
33	0.99586	0.77951	0.00253	1.12971
34	0.99573	0.77365	0.00211	1.13380
35	0.99561	0.76784	0.00176	1.13790
36	0.99548	0.76206	0.00147	1.14201
37	0.99536	0.75633	0.00123	1.14613
38	0.99523	0.75064	0.00102	1.15026
39	0.99511	0.74500	0.00085	1.15440
40	0.99498	0.73940	0.00071	1.15854
41	0.99486	0.73384	0.00059	1.16270
42	0.99473	0.72832	0.00050	1.16687
43	0.99461	0.72284	0.00041	1.17105
44	0.99448	0.71741	0.00035	1.17523
45	0.99435	0.71201	0.00029	1.17943
46	0.99423	0.70666	0.00024	1.18363
47	0.99410	0.70134	0.00020	1.18784
48	0.99398	0.69607	0.00017	1.19207
49	0.99385	0.69084	0.00014	1.19630
50	0.99373	0.68564	0.00012	1.20054
51	0.99360	0.68049	0.00010	1.20479
52	0.99348	0.67537	0.00008	1.20905
53	0.99335	0.67029	0.00007	1.21332
54	0.99323	0.66525	0.00006	1.21760
55	0.99310	0.66025	0.00005	1.22189
56	0.99298	0.65528	0.00004	1.22619
57	0.99286	0.65036	0.00003	1.23050
58	0.99273	0.64547	0.00003	1.23481
59	0.99261	0.64061	0.00002	1.23914
60	0.99248	0.63579	0.00002	1.24347

APPENDIX B

SUPPLEMENTARY INFORMATION FOR GRAB RADON DECAY PRODUCT SAMPLING

EQUIPMENT

a. Air sampling pump - A pump capable of maintaining a flowrate of 2 to 25 liters per minute through the selected filter is required. The flowrate should not vary significantly during the sampling period. A calibrated air flow measurement device is also required.

b. Filters and filter holder assembly - Membrane type filters are recommended with a pore size not exceeding 0.8 microns and a filter holder assembly suitable for the type of filters being used. Adapters for attachment of the filter holder to the pump are also required.

c. Alpha counting system - A detector and scaler timer system is required that can accurately measuring the alpha particles emitted by radon decay products on a filter. The counting system must be calibrated and the efficiency should not vary significantly with alpha energy over the range of 4 to 7 MeV. Downward-looking detectors with a mylar seal are very energy dependent, and if such detectors are used the efficiency is best determined using Po-214.

d. Timer - A stopwatch or timer to measure the sampling time and time after sampling is required.

GENERAL DESCRIPTION OF METHODS

Two methods commonly used are described below. There are several other methods reported in the literature. Sampling in these methods requires collection of radon decay products on a filter and measuring the alpha activity of the sample with a calibrated detector at time intervals that are specific for each method. The results of the alpha measurement and the sample volume are treated with calculations that are also specific for each method to determine the working level.

PROCEDURE

a. Sample Collection:

i. Install the filter in the filter holder assembly and attach to the pump.

ii. Operate the pump for exactly 5 minutes pulling air through the filter. Record starting time and air flow rate.

iii. Stop the pump at the end of the 5 minute sampling time and start or reset the stopwatch.

Note: Sample counting and analysis for two different techniques are described.

b. Sample Counting - Modified Tsivoglou Technique

i. Carefully transfer the filter from the filter holder assembly to the detector. Orient the collection side of the filter toward the face of the detector.

ii. Operate the counter for the following time intervals, after sampling stopped: 2 to 5 minutes, 6 to 20 minutes, and 21 to 30 minutes. Record the total counts for each time period.

c. Sample Counting - Kusnetz Technique

i. Carefully transfer the filter from the filter holder assembly to the detector. Orient the collection side of the filter toward the face of the detector.

ii. Operate the counter over any 10 minute time interval between 40 minutes and 90 minutes after sampling starts. Record the total counts for the sample and the time (in minutes after sampling) at the center of the 10 minute time interval.

d. Data Analysis - Modified Tsivoglou Technique

The concentration in pCi/l of each of the radon decay products, Po-218, Pb-214, and Po-214 can be determined by using the following calculations:

$$C_2 = \frac{1}{FE}(0.16746\ G_1 - 0.0813\ G_2 + 0.0769\ G_3 - 0.0566R)$$

$$C_3 = \frac{1}{FE}(0.00184\ G_1 - 0.0209\ G_2 + 0.0494\ G_3 - 0.1575R)$$

$$C_4 = \frac{1}{FE}(-0.0235\ G_1 + 0.0337\ G_2 - 0.0382\ G_3 - 0.0576R)$$

Note: The constants in these equations are based on a 3.11 minute half-life of Po-218, and are therefore slightly different than those used by Thomas (Th72).

The working level associated with these concentrations can then be calculated using the following relationship:

$$WL = (1.028x10^{-3}xC_2+5.07x10^{-3}xC_3+3.728x10^{-3}xC_4)$$

where:

- C_2 = concentration of Po-218 (RaA) in pCi/l
- C_3 = concentration of Pb-214 (RaB) in pCi/l
- C_4 = concentration of Po-214 (RaC') in pCi/l
- F = sampling flow rate in lpm
- E = counter efficiency in cpm/dpm
- G_1 = gross alpha counts for the time interval 2 to 5 minutes
- G_2 = gross alpha counts for the time interval 6 to 20 minutes
- G_3 = gross alpha counts for the time interval 21 to 30 minutes
- R = background counting rate in cpm

Reference: (Th72).

e. Data Analysis - Kusnetz Technique

Calculate WL as follows:

$$WL = \frac{C}{K_{(t)}V\ E}$$

where

- C = Sample cpm - Background cpm
- $K_{(t)}$ = Factor determined from Table B-1 for time from end of collection to midpoint of counting
- V = Total sample air volume in liters from:

  flow rate (l/m) x sample time (m)
- E = Counter efficiency in cpm/dpm.

TABLE B-1

Kusnetz Factors (PHS57)

Time	$K_{(t)}$
40	150
42	146
44	142
46	138
48	134
50	130
52	126
54	122
56	118
58	114
60	110
62	106
64	102
66	98
68	94
70	90
72	87
74	84
76	82
78	78
80	75
82	73
84	69
86	66
88	63
90	60

MODIFIED TSIVOGLOU TECHNIQUE

SAMPLE PROBLEM

F = Sampling Flow Rate = 3.5 lpm

E = Counting Efficiency = 0.47 cpm/dpm

G_1 = 880

G_2 = 2660

G_3 = 1460

R = 0.5

$$C_2 = \frac{1}{3.5 \times 0.47} (0.16746x880-0.0813x2600+0.0769x1460-0.0566x0.5)$$

C_2 = 26.3 pCi/l

$$C_3 = \frac{1}{3.5 \times 0.47} (0.00184x880-0.0209x2660+0.0494x1460-0.1575x0.5)$$

C_3 = 11.0 pCi/l

$$C_4 = \frac{1}{3.5 \times 0.47} (-0.0235x880+0.0337x2660-0.0382x1460-0.0576x0.5)$$

C_3 = 8.0 pCi/l

$$WL = (1.028x10^{-3}x26.3+5.07x10^{-3}x11.0+3.728x10^{-3}x8.0)$$

WL = 0.113

KUSNETZ TECHNIQUE

SAMPLE PROBLEM

- Background Count = 3 counts in 5 minutes or 0.6 cpm

- Standard Count = 5,985 counts in 5 minutes or 1,197 cpm

- Efficiency = $\frac{1,197 \text{ cpm} - 0.6 \text{ cpm}}{2,430 \text{ dpm}}$ = 0.49 (known source of 2430 dp

- Sample Volume = 4.4 liter/minute x 5 minutes = 22 liters

- Sample Count at 45 minutes (time from end of sampling period to midpoint of counting period) = 560 counts in 10 minutes or 56 cpm

- $K_{(t)}$ at 50 minutes from Table B-1 = 130

$$WL = \frac{56 \text{ cpm} - 0.6 \text{ cpm}}{130 \times 22 \text{ l} \times 0.49} = 0.04$$

Appendix B
Testing Equipment and Services
U.S. Environmental Protection Agency
Proficiency Program.

United States
Environmental Protection
Agency

Office of
Radiation Programs
Washington, D.C. 20460

EPA 520/1-87-015
July 1987
Revised September, 1987

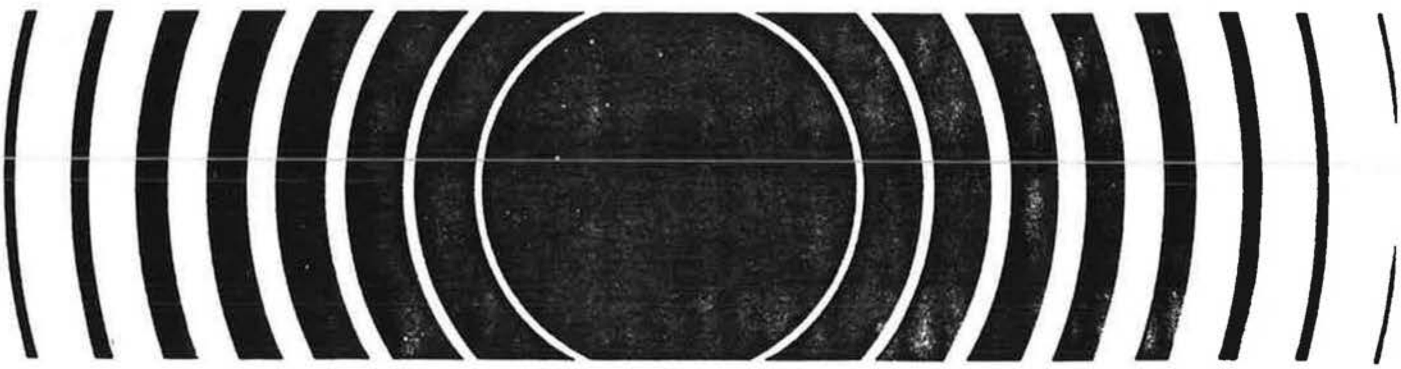
Radiation

€PA

Radon/Radon Progeny Measurement Proficiency Program

Cumulative Proficiency Report

(This publication valid through February 1988)



CUMULATIVE PROFICIENCY REPORT

(This publication is valid through February 1988)

EPA Test Round 4

Prepared by

Research Triangle Institute
Radon Technical Information Service
Research Triangle Park, NC 27709

Prepared for the

Office of Radiation Programs
U.S. Environmental Protection Agency
Washington, DC 20460

EPA Contract No.: 68-01-7350

July 1987

For Colorado Proficiency Report, changes are as follows:

- Table 1; add listing for: M.V.E., Inc.; 1911 Lelaray Street; Colorado Springs, CO 80809; (303) 635-5736, with AT and CC methods.

For Kansas, Missouri, Nebraska, and Oklahoma Proficiency Reports (PR's), changes are as follows:

- Table 1; under listing for Radon and Environmental Professionals, change first listed telephone number to: (913) 749-7420.

INTRODUCTION

Recent public concern over the health effects from exposure to radon has greatly increased the demand for companies qualified to measure radon and radon progeny in indoor air. In response to States' requests for assistance, the U.S. Environmental Protection Agency's Office of Radiation Programs has developed the Radon/Radon Progeny Measurement Proficiency (RMP) Program. Under this program, any company offering measurement services -- directly, or indirectly through another company -- is invited to demonstrate its proficiency in measuring radon gas and radon progeny levels.

The program's immediate objective is to assist States and the public in selecting companies that have demonstrated competence in measuring indoor radon and radon progeny. This is achieved by evaluating, on a semiannual basis, the proficiency of companies' detector operations and the quality of their data management. The companies that demonstrate their proficiency are listed in the RMP proficiency reports. The program's long-term objectives are to promote standard measurement procedures among measurement companies and to establish quality assurance procedures for all measurement companies.

The RMP Program is not designed for accrediting measurement companies. Nor does it certify, recommend, or endorse participating companies. The inclusion of a company in this report should not be interpreted as a certification or accreditation of that company. This report is only a source of measurement companies that have demonstrated capabilities for measuring radon and radon progeny levels.

The testing periods are referred to as test "rounds". Each round consists of two tests -- a performance test and a follow-up test. A company enrolls its measurement method(s) (e.g., activated charcoal adsorption) for evaluation. EPA tells the company to submit a specific number and type of detectors (e.g., five charcoal canisters) for exposure to known levels of radon and radon progeny. After exposure in a federal radon chamber, EPA returns the detectors to the company without revealing the radon gas or radon progeny levels. The company analyzes the detector(s) and reports its measurement results to EPA. EPA compares the measurement results with the known levels of exposure. If a company fails any of the program requirements in the performance test, it must retest in the follow-up test. The same detector submittal and exposure procedures are followed for the follow-up test. Companies that fail this second attempt may participate in the next test round.

Only companies having met all the program requirements for a method in either the performance or the follow-up test are listed in this Cumulative Proficiency Report. The companies that meet all the program requirements in the initial performance test are listed with an "L1" indicator under the appropriate method(s). Companies that meet all the requirements in the follow-up test are listed with an "LA" indicator under the appropriate method(s). A company's method that fails after having been listed in a previous round's report is omitted entirely from this report and will not be reinstated until its next successful performance in a round. When the method passes again, its performance indicators for the previous three rounds as well as for the present round will be listed. Upon reinstatement, the round during which the method had failed will be marked with an "NL" indicator, signifying its omission from that round's report.

Table 1 lists all the proficient companies serving each State. Numerous companies distribute mail-in detectors and make measurements nationwide. The companies offering nationwide service are under the "Nationwide" heading, and precede the individual State headings.

Table 2 lists the companies' performance indicators for each round over a two-year period. In addition, it indicates if they are "primary" or "secondary" companies, and shows whether they have submitted acceptable quality assurance (QA) plans.

A primary company either owns analysis capabilities or makes all measurements and analyses with its own instrumentation and operators. This type of company may or may not offer measurement services directly to the public. A secondary company's services may range from detector distribution to home inspection and consultation. This type of company must use one of the primary companies for its analyses. In a case where a company offers primary services for one method but not another, the performance indicators in Table 2 are underscored to mark the method(s) for which it is a primary company. EPA has asked, but has not required, that participating companies submit for review a copy of their QA plans. An X under the column headed "QA Plan" in Table 2 indicates that the company has submitted a plan that complies with the QA criteria recommended by this program.

SELECTION OF MEASUREMENT METHOD

Several different measurement methods may be used to determine the radon or radon progeny concentrations in houses. In practice, the choice of a method is often dictated simply by availability -- if an adequate method is available, you use it. If alternative methods are available, then the cost or the duration of the measurement may become the deciding factor.

EPA has developed measurement protocols for seven different methods, and believes that any of them, <u>when used in accordance with EPA protocols</u>, can produce valid results. This does not mean that all measurements made according to the suggested protocols will produce results with identical certainties. However, it does mean that the listed methods are capable of producing adequate results for screening or follow-up purposes.

Each method has its own advantages and disadvantages. Users must decide which method is best suited to their situations. The following sections detail the characteristics of the seven methods, pointing out some of the advantages and disadvantages of each one. This summary is not exhaustive, but is intended to guide the user in making an informed selection of a measurement method.

<u>Continuous Radon Monitoring (CR) and Continuous Working-Level Monitoring (CW)</u>

These measurement methods are similar in that they use an electronic detector to accumulate and store information related to the periodic (usually hourly) average concentrations of radon gas or radon progeny (working level). They are installed in houses according to guidelines in the EPA protocol, and then turned on, or programmed for, the desired operating time -- a minimum of six hours for screening and twenty-four hours for follow-up measurements. At the end of the test, the monitor must be retrieved, and the results must be analyzed by a skilled instrument operator.

Advantages

- Relatively short measurement duration.
- Hourly results can track the variation of concentrations in the house.
- Very precise (most Models).
- Results are available on-site (for CW).

Disadvantages

- Relatively expensive, cost may range from $100 to $300, depending on the type of services provided.
- Requires a skilled instrument operator.
- This, as does any short-term measurement, requires careful control of closed-house conditions twelve hours before and during the test.
- Because of the highly reactive nature of radon progeny, the continuous working-level measurements are much more susceptible to sampling error than radon gas measurements.

Alpha-Track Detection (AT)

The alpha-track method measures radon. An AT detector is a small sheet of special plastic material enclosed in a filtered container. The container collects the radon progeny on the filter paper while the radon gas enters the container. As the gas and some of the short-lived progeny decay, they emit alpha particles that permanently mark the plastic sheet.

The detectors are installed in the home according to guidelines in the EPA protocol. They are left for periods of up to three months for screening and twelve months for follow-up measurements. At the end of the desired testing period, they must be returned to the distributor or analytical laboratory for processing and evaluation.

Advantages

- Relatively low-cost services; cost may range from $20 to $60.
- No special skills required for making the measurement.
- Can be distributed by mail.
- Completely passive, needs no external power.
- Can measure the long-term average concentrations over a twelve-month period, which is the optimal measurement of long-term concentrations.

Disadvantages

- Relatively long measurement period necessary; three months is the recommended minimum for currently available detectors.

Activated Charcoal Adsorption (CC)

The charcoal adsorption method measures radon gas. The detectors for this method consist of variously configured containers filled with a measured amount of activated charcoal. The container is often perforated or screened to keep the charcoal from falling out, and to filter out radon progeny. All charcoal adsorbers are stored in airtight containers when not being used for sampling.

Charcoal adsorbers can be received through the mail from a distributor. They are installed in the home for up to seven days according to guidelines in the EPA protocols.

At the end of testing, an adsorber is resealed and returned to the distributor or analytical laboratory for processing and evaluation.

Advantages

- Low cost for services; costs may range from $10 to $25.
- Can be distributed by mail.
- No special skills needed for making the measurement.
- Completely passive, needs no external power.
- With proper analysis, can yield precise results.

Disadvantages

- Some charcoal adsorbers are more sensitive than others to temperature and humidity.
- Limited to short-term testing.
- Requires, as does any short-term measurement , careful control of closed-house conditions twelve hours before and during the test.

Radon Progeny Integrating Sampling Unit-RPISU (RP)

The RP method measures radon progeny. RP detectors have a flow-rate air pump that pulls air continuously through a detector assembly. Depending on the model, the unit can be installed and operated by homeowners or skilled operators for three days or longer, according to guidelines in the EPA protocol. At the end of that time, the homeowner sends it to the distributor, or an operator removes the unit and returns it to the analysis laboratory for processing and evaluation.

Advantages

- Directly measures concentrations of radon decay products.
- Relatively short measurement period.
- The detector assembly and some entire units can be sent by mail.
- There is extensive experience in the use of RPISU's; therefore, measurement errors are well established.

Disadvantages

- Relatively expensive; cost may range from $40 to $150, depending on type of service provided.
- May be limited to locations with AC power.
- Some units may be installed and picked up by a skilled instrument operator.
- Because of the highly reactive nature of radon decay products, measurements are much more susceptible to sampling error than radon gas measurements.

Grab Radon (GR) and Grab Radon Progeny(GW)

The grab sampling methods measure concentrations of radon gas or radon progeny concentrations. The radon grab sample is collected in as special flask holding 100 to 2,000 cubic centimeters of air. The radon progeny grab sample is collected by drawing air through a filter, upon which progeny, if present in the air, are collected. Both samples can be acquired simultaneously with some detector systems. All sampling should be done in accordance with guidelines in the EPA protocols.

For results of the grab radon test, operators must return to their offices to analyze the exposed detectors, and must delay the analysis for at least four hours after the testing.

For most grab working-level tests (radon progeny), operators can perform the analysis on location in an hour or less.

Advantages

- Results are quickly obtained.
- Equipment can be portable.
- Some detector systems can sample both radon gas and radon progeny simultaneously.
- Can acquire and evaluate several samples per day.
- Conditions during the measurement are known to the operator.

Disadvantages

- Relatively expensive; costs may range from $80 to $300, depending on the type of services offered.
- Very short measurement periods may not be representative of the long-term average concentrations.
- Requires a skilled operator.
- Requires, as does any short-term measurement, careful control of closed-house conditions twelve hours before and during the test.
- Because of the highly reactive nature of radon progeny, grab radon progeny measurements are much more susceptible to sampling error than radon gas measurements.

PROGRAM REQUIREMENTS

For each method, participants must send with their applications a copy of the operating instructions they provide homeowners and/or those used by an instrument operator. These instructions must reflect the measurement procedures found in the EPA documents, "Interim Indoor Radon and Radon Decay Product Measurement Protocols" and "Interim Protocols for Screening and Follow-up Radon and Radon Decay product Measurements". They must be accepted by, and on file with, EPA by the end of the follow-up test.

Once enrolled, a company must meet EPA's minimum screening-measurement requirements for each method. A company must meet all detector and analysis result deadlines as listed on the program schedule. Applications, detectors, and analyses reporting forms received after a scheduled deadline will not be considered in the performance evaluation process. A company's detector(s) must be tested every round to maintain its proficiency listing.

EXPLANATION OF ACRONYMS

Methods	Units
AT - Alpha-track Detection	(pCi/l)
CC - Activated Charcoal Adsorption	(pCi/l)
CR - Continuous Radon Monitoring	(pCi/l)
CW - Continuous Working-Level Monitoring	(WL)
GR - Grab Radon Sampling	(pCi/l)
GW - Grab Working-Level Sampling	(WL)
RP - Radon Progeny Integrated Sampling/RPISU	(WL)

Measurement Units

pCi/l - Picocuries per liter air, radon gas measurement units.

WL - Working-level, radon progeny measurement units.

Definition of Performance Indicators

L1 - Signifies a company's ability to meet all program requirements with the given measurement method in the performance test.

LA - Signifies a company's ability to pass all program requirements with the given method only after the follow-up test.

NL - Signifies a method's omission from the CPR because of unsuccessful participation. This indicator is only used when a method has passed a round, then failed, resulting in its performance record being omitted from a previous report, and has now passed again. "NL" is used in the method's reinstated performance record.

Others

QA - Quality Assurance.

DT - Detector(s) damaged or lost through no fault of the participant.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
NATIONAL	
ABE Radiation Measurements Lab	CC
ARIX Sciences, Inc.	GR,GW
Accu-Test	AT,CC
Accurate Air Testing	CC
Advanced Radiation Monitoring Serv.	CC
Affiliated Building Inspectors, Inc	AT
Air Chek, Inc.	CC
Air Sciences, Inc/Overman Assoc.	CC
Air-N-Sol Corporation	GR,GW,CW
Alpha Control, Inc.	AT,CC
Alpha Spectra	CC
Amersham Corporation	AT,CC
Appalachian Envir. Testing Inc	AT
Applied Energy Company	CC
Applied Health Physics Inc.	AT,CC,CR,GR,GW,CW
Applied Radon Test. & Reduct'n	CC
Barcon, Inc.	AT,CC
Barringer Laboratories, Inc.	CC
Battelle	AT,CC,CR
Bowling Green Radon Laboratory	CC
CDS Technologies, Inc.	AT,CC
CMT Inc.	CC
Camp Dresser & McKee Inc.	CC,CR,GR,GW,CW
Camroden Associates	AT,CC,CR,GR
Canberra Industries Inc.	CC
Capital Materials Testing Inc.	CC
Centarus Corporation	CC
+ Chemical Engineering Unit, RTI	CR
Clean Air Engineering, Inc.	CC
Con-Test, Inc.	GW
Core Laboratories Inc	GR
EKS RadTech	CC
ENV Services, Inc.	GW
Eberline Instrument Corp.	CR
Electro Mechanical Concepts	CC
EnRad, Inc./Rad. T. & Eng. Inc	AT,CC
Envirohazards Management, Inc.	CC
Environmental Chemistry	CC
Enviroserv	CC
Envirotest	CC
Futura Medical Systems, Inc.	CC
GEOMET Technologies, Inc.	AT,CC
Garden St. Home Inspection Svc	CC
General Health Physics Inc.	CC
Health Physics Associates, Inc.	CC
Health Physics Associates, Ltd.	CC
Health and Safety Associates	AT,CC
Home Inspection Service, Inc.	CC
Home Sentry Inc.	CC
Home Testing Service	CC
Hudson Valley Radon Testing Corp.	CC
Infiltec	CC,GR
Inspex of Boulder, Inc.	CC
JRW Industries, Inc.	CC
K & J Solar Service	CC
KSE, Inc.	CC
Key Technology, Inc.	CC
Lapteff Associates	CC
+ MIT/MIT Radon Project	CC,GR
+ Maine Public Health Laboratory	CC
NODAR, Inc.	GW
National Radon Control, Inc.	RP
Niton Corporation	CC,GR
Northeast Radon Testing Svc., Inc.	CC
Northeastern PA Envir. Council	CC
Nuclear Sources & Services Inc.	CC
Nucleon Lectern Associates, Inc.	AT,CC,GR,CW
O. K. Rema Corp.	CC
+ Oak Ridge Assoc. Universities	CC
Phoenix Labs	CC
Princeton Testing Laboratory	AT,CC
Pylon Electronic Development	GW,CW
Pyramid Environmental Systems, Inc.	CW
R.A.D. Service & Instruments Ltd.	RP
RAD Environmental Services	AT,CC,CR,GR,GW,CW
RAF Engineering	AT,CC
RISE	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Rad-Elec, Inc.	AT,CC
Radiation Data	CC
Radiation Protection Services	CC
Radiation Safety Engineering	CC
Radiation Safety Services, Inc.	AT,GW
Radon Alert Detection Center	AT,CC
Radon Analists, Inc.	CC
Radon Analysis Incorporated	CC
Radon Consultants, Inc., VA	AT,CC
Radon Detection Services, Inc., GA	AT,CC
Radon Detection Services, Inc., MD	AT,CC,GR,GW,CW
Radon Detection Services, Inc., NJ	AT,CC,GW,CW
Radon Detection Services, Inc., PA	AT,CC,GW,CW
Radon Detection Systems, CO	AT,CC,GW
Radon Detection and Control	CC
Radon Engineering Services Inc	CC
Radon Engr, a Unit of PSI Engr, Inc	AT,CC
Radon Environ. Monitoring, Inc	AT
Radon Measurement and Services	AT,CC,GR,GW
Radon Measurements Inc.	AT,CC
Radon Project, The	CC
Radon Research Group	AT
Radon Safety Services, Inc.	CC,RP
Radon Surveys, Div. Cope Tech Svcs	CC
Radon Testing Corp. of America RTCA	CC
Radon Testing Svc, Pittsburgh, PA	CC
Radon Testing Svcs, Baltimore, MD	CC
Radonics, Inc.	CC
Radonix	CC
Real Estate Support Services	CC
Recon Systems, Inc.	AT,CC
Rogers & Assoc. Engineering Corp.	AT,CC,GR
Ross Systems, Inc.	AT,CC
Roy F. Weston, Inc.	GR,GW
Ryan Nuclear Laboratories	CC
Scientific Testing Associates	CC
SepTech	CC,GR
Southern Radon Services, Inc.	CC,CW
Standor Radon Detection	AT,CC
TCS Industries, Inc.	CC

• Company	Measurement Methods
TEQ Corporation	AT,CC,CR,CW
TMA/Eberline, Health Physics	CC,GR
Teledyne Isotopes	CC
Terradex Corporation	AT
Testing 1. 2. 3	AT,CC
+ US Army Envir. Hygiene Agency	CC
+ US E.P.A., Las Vegas, NV	GR
US Radon Testing Service	CC
Univ of Texas School of Pub. Health	CC
Univ. of Pittsburgh Radon Project	AT,CC
+ University of Lowell	CC
Virginia Radon Service, Inc.	CC
W. S. Fleming and Associates	AT,CC,CR,GR,CW
+ Wilkes College	AT,CC,CR,GR,CW
Wright Lab Services, Inc.	CC
ALABAMA	
Advanced Materials Enterprises, Inc	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Energy Systems, Inc	AT,CC,CR,GR
Environmental Radon Measurements	AT
Enviroserv-Radon Detect. of AL	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
ALASKA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Columbia Radiological Test Lab	AT
Madrona Divirsified, Inc.	CC
Radon Testing Svc, Englewood, CO	CC,GW
West Coast Environmental Services	CC
ARIZONA	
AAAirscan Engineering Corp.	AT,CC
Cavin Analytical Consultants	CC,GR,GW

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
Radon Measurement and Control	AT
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
ARKANSAS	
ACI Chemical Co. In. d/b/a ACI Insu	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
CALIFORNIA	
AAAirscan Engineering Corp.	AT,CC
ABMS, Inc.	GW
+ CA State Dept. of Health Serv.	CC,GR
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
COLORADO	
AAAirscan Engineering Corp.	AT,CC
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Colorado Radon Engineering Inc	CC
Environmental Engineering & Testing	CC
Ero Resources Corporation	CC
Faytek Incorporated	AT,CC
Geo-Chek, Inc.	CC,CW
Hazen Research, Inc.	CC
Madrona Divirsified, Inc.	CC
Natural Resource Technologies	CC
Radon Consultants, CO	AT,CC
Radon Env. Test Experts, Inc.	CC
Radon Measurement & Control	CC
Radon Measurement and Control	AT
Radon Screening Service, Inc.	AT,CC
Radon TNT	CC,GW
Radon Testing Svc, Englewood, CO	CC,GW
Rocky Mountain Radon Testing	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
Timberline Radon Service	CW
Univ. of Colorado-Colorado Springs	CC
West Coast Environmental Services	CC
CONNECTICUT	
A-1 Sherlock Home Inspectors	CW
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Ecological Interactions, Inc.	AT,CC
Environmental Control Technologies	CW
Environmental Radioactivity Measure	CR,GR
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Enviroserv	CW
Faytek Incorporated	AT,CC
Federal Nuclide Monitors	CC
Gesell Institute, The	AT,CC
MRC Home Inspections	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Protect-A-Home	CC
Radiation Safety Associates, Inc.	CC
Radon Detection, Inc.	CR
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	AT,CC,CR,GR,GW
Radon Management Laboratories	CC,GW,RP
Radon Safety Services, Inc.	CW
Radon Technologies Inc.	AT,CC,GR
Radonics, Inc.	GW,CW
Res-I-Tec	CC
Residential Radon Test Service	CC
Ross Systems, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Shotwell Associates	GW,CW
Sorensen Enterprises, Inc.	CC

DELAWARE

• Company	Measurement Methods
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Alpha-Ban	AT,CC
Biomedical Toxicology Assoc.	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Ecological Interactions, Inc.	AT,CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Health Physics Associates, Inc.	GR,GW,CW
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
R.J. Moore & Associates, Inc.	AT,CC
Radiation Service Organization	CC
Radon Testing Svcs, Princeton, NJ	CC
Radonics, Inc.	GW,CW
Safe Shelter Environmental	CW
Scientific Analysis, Inc.	CC
Shotwell Associates	GW,CW
Sorensen Enterprises, Inc.	CC
U.S. Toxic Substance Testing Bureau	CW

DISTRICT OF COLUMBIA

• Company	Measurement Methods
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Abionics, Ltd.	AT,CC
Alpha Control, Inc.	GW
Alpha-Ban	AT,CC
Appalachian Envir. Testing Inc	CW
Biomedical Toxicology Assoc.	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Federal Nuclide Monitors	CC
Foresight Engineering, Inc., VA	CC
Health Physics Associates, Inc.	GR,GW,CW

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Home Sure Inspections, Inc.	GR
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
R.J. Moore & Associates, Inc.	AT,CC
RADON Home Inspection Service	GW
Radiation Service Organization	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Management Company	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
Terradynamics Corporation	AT
West Coast Environmental Services	CC
FLORIDA	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Ecological Interactions, Inc.	AT,CC
Environ. Detection Associates	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of AL	CC
Faytek Incorporated	AT,CC
Federal Nuclide Monitors	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC

• Company	Measurement Methods
Microbac Labs, Seaway Div	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Mitigators, Inc.	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
GEORGIA	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Advanced Materials Enterprises, Inc	CC
Carolina Radon Consultants	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environ. Detection Associates	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of AL	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radon Measurement & Control	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
HAWAII	
AAAirscan Engineering Corp.	AT,CC
Chem-Safe Inc.	CC
IDAHO	
Cavalier Corporation	CC
Chem-Safe Inc.	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Faytek Incorporated	AT,CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
+ Nuclear Radiation Center	CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
ILLINOIS	
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Columbia Radiological Test Lab	AT
Commonwealth Eng. & Technology	CC
Energy Marketing Midwest, Inc	CC
Environmental Engineering & Testing	CC
Environmental Risk Consultants, Inc	CC,GW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of OH	CC
Home Buyers Inspection Service	CC
Hoosier Environmental	CC
+ IL Dept. of Nuclear Safety	AT,CC,GR,GW,CW
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radon Consultants, CO	AT,CC
Radon Detection Specialists	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Surveys, Div. Alpha Tech Corp	GW
Residential Radon Measurements	AT,CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
INDIANA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Environmental Engineering & Testing	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of OH	CC
Home Buyers Inspection Service	CC
Hoosier Environmental	CC
Insul-Tech, Inc.	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Rad-Test, Inc.	CC
Radon Detection Specialists	CC
Radon Surveys, Div. Alpha Tech Corp	GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
IOWA	
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Columbia Radiological Test Lab	AT
Commonwealth Eng. & Technology	CC
Energy Marketing Midwest, Inc	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Frazier Co., The	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC

• For addresses, phone numbers, and performance records see Table 2.
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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

* Company	Measurement Methods
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
KANSAS	
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Colorado Radon Engineering Inc	CC
Columbia Radiological Test Lab	AT
Environmental Engineering & Testing	CC
+ KS Dept. of Health & Environ.	CC
Radon & Environ. Professionals	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
KENTUCKY	
AIDCO Maine Corp	CC
Advanced Materials Enterprises, Inc	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Energy Systems, Inc	AT,CC,CR,GR
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of OH	CC
Hoosier Environmental	CC
Insul-Tech, Inc.	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC

* Company	Measurement Methods
Rad-Test, Inc.	CC
Radiation Service Organization	CC
Radon Measurement & Control	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
LOUISIANA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Environmental Radon Measurements	AT
Enviroserv-Radon Detect. of AL	CC
Microbac Labs, Erie Testing Lab Div	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MAINE	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Control Technologies	CW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Federal Nuclide Monitors	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Radon Detection, Inc.	CR
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	GR,GW
Radon Registry	CC

* For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Radonics, Inc.	GW,CW
Residential Radon Test Service	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MARYLAND	
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Abionics, Ltd.	AT,CC
Alpha Control, Inc.	GW
Alpha-Ban	AT,CC
Appalachian Envir. Testing Inc	CW
Biomedical Toxicology Assoc.	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Ecological Interactions, Inc.	AT,CC
Environmental Engineering & Testing	CC
Environmental Radioactivity Measure	CR,GR
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Federal Nuclide Monitors	CC
Foresight Engineering, Inc., VA	CC
Garco Research Company	CC
Health Physics Associates, Inc.	GR,GW,CW
Home Sure Inspections, Inc.	GR
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
R.J. Moore & Associates, Inc.	AT,CC
RADON Home Inspection Service	GW
Radiation Service Organization	CC

• Company	Measurement Methods
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Management Company	CC
Radon Mitigators, Inc.	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Shotwell Associates	CW
Sorensen Enterprises, Inc.	CC
Terradynamics Corporation	AT
West Coast Environmental Services	CC
MASSACHUSETTS	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Control Technologies	CW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Federal Nuclide Monitors	CC
Foresight Engineering, Inc., VA	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Radiation Safety Associates, Inc.	CC
Radon Detection, Inc.	CR
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	AT,CR,GR,GW
Radon Registry	CC
Radon Safety Services, Inc.	CW
Radon Technologies Inc.	AT,CC,GR
Radon X Company, Inc., The	GW

• For addresses, phone numbers, and performance records see Table 2.
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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Radonics, Inc.	GW,CW
Residential Radon Test Service	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MICHIGAN	
AIDCO Maine Corp	CC
Air-Tight of Genesee	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of OH	CC
Hoosier Environmental	CC
Insul-Tech, Inc.	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radon Surveys, Div. Alpha Tech Corp	GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MINNESOTA	
AAAirscan Engineering Corp.	AT,CC
Cavin Analytical Consultants	CC,GW
Chem-Safe Inc.	CC
Energy Marketing Midwest, Inc	CC
Enviroserv-Radon Detect. of OH	CC
Madrona Divirsified, Inc.	CC
Radon Measurement & Control	CC
Scientific Analysis, Inc.	CC
Shotwell Associates	GW
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC

• Company	Measurement Methods
MISSISSIPPI	
Advanced Materials Enterprises, Inc	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Environmental Radon Measurements	AT
Enviroserv-Radon Detect. of AL	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MISSOURI	
ACI Chemical Co. In. d/b/a ACI Insu	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Columbia Radiological Test Lab	AT
Environmental Engineering & Testing	CC
Radon & Environ. Professionals	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Residential Radon Measurements	AT,CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
MONTANA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
Radon Consultants, CO	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
NEBRASKA	

• For addresses, phone numbers, and performance records see Table 2.
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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
AAAirscan Engineering Corp.	AT,CC
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Colorado Radon Engineering Inc	CC
Columbia Radiological Test Lab	AT
Energy Marketing Midwest, Inc	CC
Frazier Co., The	CC
Radon & Environ. Professionals	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC

NEVADA

• Company	Measurement Methods
AAAirscan Engineering Corp.	AT,CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC

NEW HAMPSHIRE

• Company	Measurement Methods
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Boxford Radon Lab (B.R.L.)	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Environmental Control Technologies	CW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Federal Nuclide Monitors	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Radon Detection, Inc.	CR
Radon Inspection Service	GW
Radon Registry	CC
Radon X Company, Inc., The	GW
Radonics, Inc.	GW,CW
Residential Radon Test Service	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC

NEW JERSEY

• Company	Measurement Methods
A-1 Sherlock Home Inspectors	CW
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Air-N-Sol Corporation	AT
All Eastern Home Inspection Co.	CC
BCT	CC
Biomedical Toxicology Assoc.	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Chief Construction Specialists	CC
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Dittmar Inspection Co. Inc.	CC
ECO Testing Corporation	CC
Eastern Integrated Services	CC
Ecological Interactions, Inc.	AT,CC
Environmental Engineering & Testing	CC
Environmental Radioactivity Measure	CR,GR

• For addresses, phone numbers, and performance records see Table 2.
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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Envr. Testing & Consulting Corp.	CC,CW
Excel Inspection Service Inc.	CC
Faytek Incorporated	AT,CC
Federal Nuclide Monitors	CC
Foresight Engineering, Inc., NJ	CC,CW
Garco Research Company	CC
Health Physics Associates, Inc.	GR,GW,CW
Home-Tech Engineering	CC
JBK Inspection Service, Inc.	CC
Lamson Home Inspections	CC
MRC Home Inspections	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
+ NJ Dept of Environmental Protection	CC
O. K. Rems Corp.	GW
Princeton Home Inspection Svc.	CC
R.J. Moore & Associates, Inc.	AT,CC
Radiation Service Organization	CC
Radiation Surveys Incorporated	CC,GR
Radon Diagnostics	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Gasbusters	CW
Radon Inspection Service	AT,CC,CR,GR,GW
Radon Management Laboratories	CC,GW,RP
Radon Mitigators, Inc.	CC
Radon Safety Services, Inc.	CW
Radon Technologies Inc.	AT,CC,GR
Radon Testing Svcs, Princeton, NJ	CC
Radonics, Inc.	GW,CW
Ram Exterminators	CC
Ross Systems, Inc.	GW,CW
Safe & Sound Home Inspect. Con	CC

• Company	Measurement Methods
Safe Shelter Environmental	CW
Scientific Analysis, Inc.	CC
Shelterworks Inc.	CC
Shotwell Associates	GW,CW
Silver Springs Home Inspection	GW
Sorensen Enterprises, Inc.	CC
Thorough Check, Inc.	CC
U.S. Toxic Substance Testing Bureau	CW
Union Cnty. Bld. Inspection Svc	CC
NEW MEXICO	
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Madrona Diviraified, Inc.	CC
Natural Resource Technologies	CC
Radon Measurement and Control	AT
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
NEW YORK	
A-1 Sherlock Home Inspectors	CW
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Air-N-Sol Corporation	AT
All Eastern Home Inspection Co.	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Chief Construction Specialists	CC
Commonwealth Eng. & Technology	CC

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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Continental Environment Company	AT,CC
ECO Testing Corporation	CC
Ecological Interactions, Inc.	AT,CC
Environmental Radioactivity Measure	CR,GR
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Faytek Incorporated	AT,CC
Federal Nuclide Monitors	CC
Garco Research Company	CC
Health Physics Associates, Inc.	GR,GW,CW
Home-Tech Engineering	CC
MRC Home Inspections	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
+ New York State Dept. of Health	CC
O. K. Rems Corp.	GW
Radiation Safety Associates, Inc.	CC
Radiation Service Organization	CC
Radiation Surveys Incorporated	CC,GR
Radon Diagnostics	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	AT,CC,CR,GR,GW
Radon Management Laboratories	CC,GW,RP
Radon Measurement & Control	CC
Radon Mitigators, Inc.	CC
Radon Safety Services, Inc.	CW
Radon Technologies Inc.	AT,CC,GR
Radon X Company, Inc., The	GW
Radonics, Inc.	GW,CW
Res-I-Tec	CC
Ronald Stein Construction Inc.	AT,CC
Ross Systems, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Shotwell Associates	GW,CW

• Company	Measurement Methods
Sorensen Enterprises, Inc.	CC
NORTH CAROLINA	
AAAirscan Engineering Corp.	AT
AIDCO Maine Corp	CC
Appalachian Envir. Testing Inc	CW
Carolina Radon Consultants	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Enviradon, Inc.	AT,CC
Environ. Detection Associates	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
+ NC Dept. of Human Resources	GR
Radiation Service Organization	CC
Radiological Physics Services	CC
Radon Management Company	CC
Radonics, Inc.	GW,CW
Roberts Environmental Services	AT,CC,CR,GR,GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
+ University of North Carolina	CC
NORTH DAKOTA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Radon Consultants, CO	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW

• For addresses, phone numbers, and performance records see Table 2.
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TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
OHIO	
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of OH	CC
Hoosier Environmental	CC
Insul-Tech, Inc.	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radiation Service Organization	CC
Radon Detection Systems Inc., OH	CC
Radon Measurement & Control	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
Terradon Exploration Tech. Inc.	AT,CC
Triple Seal, Inc.	CC
OKLAHOMA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Columbia Radiological Test Lab	AT
Radon & Environ. Professionals	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC

• Company	Measurement Methods
Sorensen Enterprises, Inc.	CC
OREGON	
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Madrona Diversified, Inc.	CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
PENNSYLVANIA	
A-1 Sherlock Home Inspectors	CW
AAAirscan Engineering Corp.	AT,CC
ABE Radiation Measurements Lab	GR,GW,CW
AIDCO Maine Corp	CC
Air-N-Sol Corporation	AT
All Eastern Home Inspection Co.	CC
Alpha-Ban	AT,CC
Biomedical Toxicology Assoc.	CC
CDS Technologies, Inc.	CW
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Chief Construction Specialists	CC
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Ecological Interactions, Inc.	AT,CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Enviroserv-Radon Detect. of OH	CC
Faytek Incorporated	AT,CC
Foresight Engineering, Inc., NJ	CC
Garco Research Company	CC
Health Physics Associates, Inc.	GR,GW,CW
Home-Tech Engineering	CC
Insul-Tech, Inc.	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
O. K. Rems Corp.	GW
Princeton Home Inspection Svc.	CC
R.J. Moore & Associates, Inc.	AT,CC
Radiation Service Organization	CC
Radioactivity Alert Detection Serv.	AT,CC
Radon Diagnostics	CC
Radon Inspection Service	AT,CC,CR,GR,GW
Radon Management Company	CC
Radon Management Laboratories	CC,GW,RP
Radon Mitigators, Inc.	CC
Radon Safety Services, Inc.	CW
Radon Technologies Inc.	AT,CC,GR
Radon Testing Svcs, Princeton, NJ	CC
Radonics, Inc.	GW,CW
Reynolds Radiological Services, Inc	CW
Ross Systems, Inc.	GW,CW
Safe Shelter Environmental	CW
Science Management Services, Ltd.	GW
Scientific Analysis, Inc.	CC
Shotwell Associates	GW,CW
Sorensen Enterprises, Inc.	CC
U.S. Toxic Substance Testing Bureau	CW
RHODE ISLAND	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Control Technologies	CW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Foresight Engineering, Inc., VA	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Radiation Safety Associates, Inc.	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	GR,GW
Radonics, Inc.	GW,CW
Residential Radon Test Service	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
SOUTH CAROLINA	
AAAirscan Engineering Corp.	AT,CC
Carolina Radon Consultants	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Enviradon, Inc.	AT,CC
Environ. Detection Associates	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of AL	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radiation Service Organization	CC
+ S. C. Dept of Health & Env Control	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
SOUTH DAKOTA	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Energy Marketing Midwest, Inc	CC
Radon Consultants, CO	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
TENNESSEE	
ACI Chemical Co. In. d/b/a ACI Insu	CC
AIDCO Maine Corp	CC
Advanced Materials Enterprises, Inc	CC
CDS Technologies, Inc.	CW
Carolina Radon Consultants	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Energy Systems, Inc	AT,CC,CR,GR
Environ. Detection Associates	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv-Radon Detect. of AL	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radiation Service Organization	CC
Radiation Services Inc.	GR

• Company	Measurement Methods
Radon Air Pollution Testing Co, Inc	AT,CC
Radon Detection Systems of TN	CC,GW
Radon Measurement & Control	CC
Safe Air	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
TEXAS	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Continental Environment Company	AT,CC
Environmental Engineering & Testing	CC
Madrona Divirsified, Inc.	CC
Radon Measurement and Control	AT
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
UTAH	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Madrona Divirsified, Inc.	CC
Radiation Surveys Incorporated	CC,GR
Radon Consultants, CO	AT,CC
Radon Measurement and Control	AT
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
VERMONT	

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
AAAIrscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Biomedical Toxicology Assoc.	CC
Boxford Radon Lab (B.R.L.)	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Control Technologies	CW
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
New England Radon, LTD.	CC
Radon Detection, Inc.	CR
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Inspection Service	GR,GW
Radon Registry	CC
Radon Technologies Inc.	AT,CC,GR
Radon X Company, Inc., The	GW
Residential Radon Test Service	CC
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC

VIRGINIA

• Company	Measurement Methods
AAAIrscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Abionics, Ltd.	AT,CC
Alpha Control, Inc.	GW
Appalachian Envir. Testing Inc	CW
Biomedical Toxicology Assoc.	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Commonwealth Eng. & Technology	CC
Continental Environment Company	AT,CC
Environ. Detection Associates	CC
Environmental Engineering & Testing	CC
Environmental Radon Measurements	AT
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Federal Nuclide Monitors	CC
Foresight Engineering, Inc., NJ	CC,CW
Foresight Engineering, Inc., VA	CC
Garco Research Company	CC
Home Sure Inspections, Inc.	GR
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
R.J. Moore & Associates, Inc.	AT,CC
RADON Home Inspection Service	GW
Radiation Service Organization	CC
Radiological Physics Services	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Management Company	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
Terradynamics Corporation	AT

WASHINGTON

• Company	Measurement Methods
Cavalier Corporation	CC
Chem-Safe Inc.	CC
Faytek Incorporated	AT,CC
Insul-Tech, Inc.	CC
Madrona Divirsified, Inc.	CC
+ Nuclear Radiation Center	CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC

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+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
WEST VIRGINIA	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Foresight Engineering, Inc., VA	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radiation Service Organization	CC
Radiological Physics Services	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Management Company	CC
Radon Measurement & Control	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
WISCONSIN	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Enviroserv-Radon Detect. of OH	CC
Home Buyers Inspection Service	CC
Radon Detection Specialists	CC
Radon Surveys, Div. Alpha Tech Corp	GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
WYOMING	
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Colorado Radon Engineering Inc	CC
Environmental Engineering & Testing	CC
Fsytek Incorporated	AT,CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Natural Resource Technologies	CC
Radon Consultants, CO	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
PUERTO RICO	
Cavin Analytical Consultants	CC,GR,GW
New England Radon, LTD.	CC
Sorensen Enterprises, Inc.	CC
VIRGIN ISLANDS	
AAAirscan Engineering Corp.	AT,CC
Cavin Analytical Consultants	CC,GR,GW
Sorensen Enterprises, Inc.	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
A-1 Sherlock Home Inspectors 6-01 Fairlawn Avenue, Fairlawn, NJ 07410 Steven J. Luxton (201) 796-4942	5/87							L1	
AAAirscan Engineering Corp. 8 Eric Drive Granby, CT 06035 Kevin O'Rourke (203) 653-5639 (203) 653-4787	11/86 5/87	L1 L1	L1 L1						
ABE Radiation Measurements Lab Box 214 Lenhartsville, PA 19534 Anthony LaMastra (215) 756-4153	5/87		L1		L1	L1		L1	X
ABMS, Inc. 5508 San Pablo Ave Oakland, CA 94608 Tim Hussler (415) 547-7144	5/87					L1			
ACI Chemical Co. In. d/b/a ACI Insu P. O. Box 306 Walnut Ridge, AR 72476 Charles E. Snapp (501) 886-6625	5/87		L1						
AIDCO Maine Corp Grassy Pond House Rindge, NH 03461 Robert K. Multer (603) 899-5166	5/87		L1						X
ARIX Sciences, Inc. 1200 E. High St. Pottstown, PA 19464 William F. McKelvey (215) 327-1140	5/87				L1	L1			
Abionics, Ltd. 12509 Kings Lake Dr. Reston, VA 22091 Dr. William R. Hancuff (703) 620-3767	11/86 5/87	L1 L1	L1 L1						
Accu-Test Suite 115-343, 1350 Beverly Rd McLean, VA 22101 Bruce Johnson (703) 448-8068	5/87	L1	L1						
Accurate Air Testing 1209 Piney Woods Drive Friendswood, TX 77546 Charles T. Gallagher (713) 482-5097	11/86 5/87		L1 L1						
Advanced Materials Enterprises, Inc P. O. Box 121174 Nashville, TN 37212 Ron Quarles (615) 377-0624	5/87		L1						
Advanced Radiation Monitoring Serv. 2219 Prosperity Portage, MI 49081 Philip B. Noack (616) 323-9483	5/87		L1						

• See TABLE 1 for the States each company serves.

Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

TABLE 1
MEASUREMENT COMPANIES BY SERVICE AREAS

• Company	Measurement Methods
WEST VIRGINIA	
AAAirscan Engineering Corp.	AT,CC
AIDCO Maine Corp	CC
Cavin Analytical Consultants	CC,GR,GW
Commonwealth Eng. & Technology	CC
Environmental Sys. Service Ltd	CC
Environmental Systems Service	CC
Enviroserv	CW
Foresight Engineering, Inc., VA	CC
Microbac Labs, Erie Testing Lab Div	CC
Microbac Labs, Hanover, PA	CC
Microbac Labs, MA Testing Division	CC
Microbac Labs, New Castle, PA	CC
Microbac Labs, Pittsburgh, PA	CC
Microbac Labs, Schiller Div.	CC
Microbac Labs, Seaway Div	CC
Radiation Service Organization	CC
Radiological Physics Services	CC
Radon Engr, a Unit of PSI Engr, Inc	CW
Radon Management Company	CC
Radon Measurement & Control	CC
Radonics, Inc.	GW,CW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
WISCONSIN	
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Enviroserv-Radon Detect. of OH	CC
Home Buyers Inspection Service	CC
Radon Detection Specialists	CC
Radon Surveys, Div. Alpha Tech Corp	GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
WYOMING	
Alpha Radon Screening & Home	CC
Cavin Analytical Consultants	CC,GR,GW
Chem-Safe Inc.	CC
Colorado Radon Engineering Inc	CC
Environmental Engineering & Testing	CC
Faytek Incorporated	AT,CC
Hazen Research, Inc.	CC
Integral Resources, Inc.	AT
Natural Resource Technologies	CC
Radon Consultants, CO	AT,CC
Radon Screening Service, Inc.	AT,CC
Radon Testing Svc, Englewood, CO	CC,GW
Scientific Analysis, Inc.	CC
Sorensen Enterprises, Inc.	CC
West Coast Environmental Services	CC
PUERTO RICO	
Cavin Analytical Consultants	CC,GR,GW
New England Radon, LTD.	CC
Sorensen Enterprises, Inc.	CC
VIRGIN ISLANDS	
AAAirscan Engineering Corp.	AT,CC
Cavin Analytical Consultants	CC,GR,GW
Sorensen Enterprises, Inc.	CC

• For addresses, phone numbers, and performance records see Table 2.
+ Non-commercial laboratory for research purposes or State agencies' assistance only.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
A-1 Sherlock Home Inspectors 8-01 Fairlawn Avenue, Fairlawn, NJ 07410 Steven J. Luxton (201) 796-4942	5/87							<u>L1</u>	
AAAircan Engineering Corp. 8 Eric Drive Granby, CT 06035 Kevin O'Rourke (203) 653-5639 (203) 653-4787	11/86 5/87	L1 L1	L1 L1						
ABE Radiation Measurements Lab Box 214 Lenhartsville, PA 19534 Anthony LaMastra (215) 756-4153	5/87		<u>L1</u>		<u>L1</u>	<u>L1</u>		<u>L1</u>	X
ABMS, Inc. 5508 San Pablo Ave Oakland, CA 94608 Tim Hussler (415) 547-7144	5/87					<u>L1</u>			
ACI Chemical Co. In. d/b/a ACI Insu P. O. Box 308 Walnut Ridge, AR 72476 Charles E. Snapp (501) 886-6625	5/87		L1						
AIDCO Maine Corp Grassy Pond House Rindge, NH 03461 Robert K. Multer (603) 899-5166	5/87		L1						X
ARIX Sciences, Inc. 1200 E. High St. Pottstown, PA 19464 William F. McKelvey (215) 327-1140	5/87				<u>L1</u>	<u>L1</u>			
Abionics, Ltd. 12509 Kings Lake Dr. Reston, VA 22091 Dr. William R. Hancuff (703) 620-3767	11/86 5/87	L1 L1	L1 L1						
Accu-Test Suite 115-343, 1350 Beverly Rd McLean, VA 22101 Bruce Johnson (703) 448-8088	5/87	L1	L1						
Accurate Air Testing 1209 Piney Woods Drive Friendswood, TX 77546 Charles T. Gallagher (713) 482-5097	11/86 5/87		<u>L1</u> <u>L1</u>						
Advanced Materials Enterprises, Inc P. O. Box 121174 Nashville, TN 37212 Ron Quarles (615) 377-0624	5/87		<u>L1</u>						
Advanced Radiation Monitoring Serv. 2219 Prosperity Portage, MI 49081 Philip B. Noack (616) 323-9483	5/87		L1						

• See TABLE 1 for the States each company serves.

Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Affiliated Building Inspectors, Inc 7223 Delfield Street Chevy Chase, MD 20815 Larry Wasson (301) 986-8866	5/87	L1	L1						
Air Chek, Inc. Box 2000 Arden, NC 28704 B. V. Alvarez (704) 684-0893	4/86 7/86 11/86 5/87		L1 L1 L1 L1						
Air Sciences, Inc/Overman Assoc. P.O. Box 376 Bonne Terre, MO 63628 Ralph T. Overman, Ph.D. (314) 358-4011	4/86 7/86 11/86 5/87		L1 L1 L1 L1						
Air-N-Sol Corporation P.O. Box 437 Frenchtown, NJ 08825 Dale L. Johnson (201) 996-2028	4/86	L1							X
	7/86	LA			L1	L1			
	11/86	L1			L1	LA			
	5/87	L1			L1	L1		L1	
Air-Tight of Genesee 2429 N. Dort Hwy Flint, MI 48506 David Neblock (313) 235-5010	5/87		L1						
All Eastern Home Inspection Co. 309 Bloomfield Ave Caldwell, NJ 07006 Peter Kras / William Rodgers (201) 228-5548	5/87		L1						
Alpha Control, Inc. 6407 Good Luck Road Riverdale, MD 20737 Scott Parry (301) 474-0071	11/86		L1			L1			
	5/87	L1	L1			L1			
Alpha Radon Screening & Home Inspection Inc. 1216 Chinook Way Boulder, CO 80303 Bill Jewell (303) 494-9533	5/87		L1						
Alpha Spectra P. O. Box 6772 Denver, CO 80206 Frank Wilkinson III, M. S. (303) 377-2118	5/87		L1						
Alpha-Ban 5330 Long Corner Road White Hall, MD 21161 Kirk Nevin (301) 692-2700	11/86 5/87	 L1	L1 L1						
Amersham Corporation 2636 South Clearbrook Drive Arlington Heights, IL 60005 Mark A. Doruff (315) 593-6300	7/86 11/86 5/87	 L1	L1 L1 LA						
Appalachian Envir. Testing Inc 105 South Union St. Suite 326 Danville, VA 24541 Christopher R. Halladay (804) 792-1300	7/86 11/86 5/87	L1 L1 L1						DT L1 L1	

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• See TABLE 1 for the States each company serves.
Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Applied Energy Company 3316 Augusta Avenue Omaha, NE 68144 Jon Traudt (402) 334-5881	5/87		L1						
Applied Health Physics Inc. 2986 Industrial Boulevard Box 197 Bethel Park, PA 15102 Nathaniel L. Burden, Jr. (412) 563-2242	11/86 5/87	 L1	L1 L1	L1 L1	L1 L1	L1 LA		 L1	
Applied Radon Test. & Reduct'n 52205 Warehime Rd. Cumberland, OH 43732-9804 Frank J. Donia (614) 638-2078	5/87		L1						
Argonne National Laboratory 9700 South Cass Avenue Argonne, IL 60439 Henry Lucas (312) 972-4172	5/87				L1				
BCT 12 Magnolia Ave. Denville, NJ 07834 Kevin Scollans (201) 627-2802	11/86 5/87		L1 LA						X
Barcon, Inc. 599 Waldron Road LaVergne, TN 37086 Randall Q. Smith (615) 793-7993	5/87	L1	L1						
Barringer Laboratories, Inc. 15000 West Sixth Avenue, Suite 300 Golden, CO 80401 David Lasher (303) 277-1687	7/86 11/86 5/87		L1 L1 L1						X
Battelle 505 King Avenue Columbus, OH 43201 V. Pasupathi (614) 879-5163	11/86 5/87	 L1	L1 L1	 L1					
Biomedical Toxicology Assoc. P. O. Box 3588 Frederick, MD 21701 Winifred G. Palmer, Ph.D. (301) 662-0783	7/86 11/86 5/87		L1 L1 L1						
Bowling Green Radon Laboratory P. O. Box 83 Bowling Green, KY 42101 David W. Williams (502) 842-6200	5/87		L1						
Boxford Radon Lab (B.R.L.) 52 Wildmeadow Rd Boxford, MA 01921 John Fisher (617) 887-9641	5/87		L1						
CA State Dept. of Health Serv. Sanitation and Radiation Lab 2151 Berkeley Way, Room 465 Berkeley, CA 94704 George S. Uyesugi (415) 540-2201 (415) 540-2515	5/87		L1		L1				

• See TABLE 1 for the States each company serves.
Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
CDS Technologies, Inc. 5050 Tilghman Street Allentown, PA 18104 Richard D. Martin (215) 398-7125	5/87	L1	L1					<u>L1</u>	
CMT Inc. 2813 Rio Vista Emporia, KS 66801 Michael M. Nichols (316) 342-2760	11/86 5/87		<u>L1</u> <u>L1</u>						
Camp Dresser & McKee Inc. Raritan Plaza 1, Raritan Ctr. Edison, NJ 08818 Jay W. Davis (201) 225-7000	5/87		L1	<u>L1</u>	<u>L1</u>	<u>L1</u>		<u>L1</u>	X
Camroden Associates RD #4 Box 82 Rome, NY 13440 Terry Brennan (315) 865-4289	5/87	L1	L1	<u>L1</u>	<u>L1</u>				
Canberra Industries Inc. One State Street Meriden, CT 06450 Bruce M. Gillespie (203) 238-2351	5/87		<u>L1</u>						
Capital Materials Testing Inc. P. O. Box 81 Latham, NY 12110 Thomas H. Attridge (518) 783-3160	5/87		<u>L1</u>						
Carolina Radon Consultants Box 2000 Etowah, NC 28729 Ned Doyle (704) 891-9559	5/87		L1						
Cavalier Corporation 11516 E. Sprague Spokane, WA 99206 Warren Riddle (509) 926-6217	5/87		L1						X
Cavin Analytical Consultants P. O. Box 464 Snellville, GA 30278 Donald K. Cavin (800) 533-1224	5/87		<u>L1</u>		<u>L1</u>	<u>L1</u>			X
Centarus Corporation P. O. Box 513 Glasgow, KY 42141 Q. Wayne Calvert (502) 651-2390	5/87		L1						
Chem-Safe Inc. 1345 Research & Technology Pk. Pullman, WA 99163 Cliff Cooper (509) 335-0922	5/87		L1						X
Chemical Engineering Unit, RTI Research Triangle Institute P. O. Box 12194 Research Triangle Park, NC 27709 Linda Michaels / Andy Viner (919) 541-6261 (919) 541-6747	5/87			L1					

• See TABLE 1 for the States each company serves.
Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Chief Construction Specialists and Inspectors, Inc. Box 284 Towaco, NJ 07082 Richard D. Conklin (201) 299-9087	11/86 5/87		L1 L1						
Clean Air Engineering, Inc. 207 North Woodwork Lane Palatine, IL 60067 Ann Marie Ramsden (312) 991-3300	5/87		L1						
Colorado Radon Engineering Inc 5104 Greenview Ct. Ft. Collins, CO 80525 Bill Alexander (303) 223-9755	5/87		L1						
Columbia Radiological Test Lab 4064 Victoria Court Columbia, MO 65201 William E. Becker / M Milewski (314) 443-3538	5/87	L1							
Commonwealth Eng. & Technology 3113 North Front Street Harrisburg, PA 17110 Judy F. Musselman (717) 232-2288	5/87		L1						X
Con-Test, Inc. 126 Shaker Road East Longmeadow, MA 01028 David A. MacLean (413) 525-1198	7/86 11/86 5/87					<u>L1</u> <u>L1</u> <u>L1</u>			
Continental Environment Company 34 Maple Street Summit, NJ 07901 Alvin M. Natkin (201) 277-2256	4/86 7/86 11/86 5/87	 L1 L1	L1 L1 L1 L1						
Core Laboratories Inc 420 West First St Casper, Wy 82601 David L. Demorest (303) 236-5741	5/87				<u>L1</u>				X
Dittmar Inspection Co. Inc. 20 Redding Place Towaco, NJ 07082 Willy C. Dittmar (201) 263-4746	5/87		L1						
ECO Testing Corporation RD. 1 Box 266 B Annandale, NJ 08801 Peter W. Georges (201) 735-2770	5/87		L1						
EKS RadTech 1000 Herald Square Aston, PA 19014 John T. Hoback (215) 358-9425 (215) 358-9426	5/87		<u>L1</u>						
ENV Services, Inc. 216 Goddard Blvd., Suite 117 King of Prussia, PA 19406 Scott Berger (800) 345-6094 (215) 337-8222	5/87					<u>L1</u>			

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

* Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Eastern Integrated Services P. O. Box 784 Princeton Jct., NJ 08550 Bill Thompson / Rick Pettit (609) 799-8574	5/87		L1						X
Eberline Instrument Corp. P. O. Box 2108 Santa Fe, NM 87504-2108 Eric L. Geiger (505) 471-3232	4/85						L1	L1	X
	7/86						NL	L1	
	11/85						L1	L1	
	5/87			L1			L1	L1	
Ecological Interactions, Inc. 96 East Main Street Rockaway, NJ 07866 F. Michael Fitzpatrick (201) 625-7700	11/86	L1	L1						
	5/87	L1	L1						
Electro Mechanical Concepts 130 Mountaineer Lane West Mifflin, PA 15122 Matt Kovac (412) 276-2272	4/86		L1						X
	7/86		L1						
	11/86		L1						
	5/87		L1						
EnRad, Inc./Rad. T. & Eng. Inc 18705 B. North Frederick Road Gaithersburg, MD 20879 Charles Osterberg, Ph.D. (301) 948-8040	7/86		L1						
	11/86		L1						
	5/87	L1	L1						
Energy Marketing Midwest, Inc E-57 Rd, Box 93 Kelley, IA 50134 Kenneth D. Wiggers (515) 769-2400	5/87		L1						
Energy Systems, Inc 134 Carr avenue Cookeville, TN 38501 Dwight G Moore, Jr (615) 528-7247	5/87	L1	L1	L1	L1				
Enviradon, Inc. 914 Rollingwood Drive Mt. Holly, NC 28120 William Brad McRee (704) 827-1293	7/86	L1							X
	11/86	L1	L1						
	5/87	L1	L1						
Envirohazards Management, Inc. P. O. Box 1064 So. Orange, NJ 07079 Diane Trainor (201) 761-7226	5/87		L1						
Environ. Detection Associates P. O. Box 1006 Pisgah Forest, NC 28768-1006 Wolfgang Selle or Harry Hill (704) 877-4300	5/87		L1						
Environmental Chemistry 1233 Ogden Street, Suite 504 Denver, Colorado 80218 John B. Taylor (303) 831-0437	5/87		L1						
Environmental Control Technologies 400 Amherst Street Nashua, NH 03063 Harold W. Eriksen (603) 881-7133	5/87							L1	

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Environmental Engineering & Testing	11/86		L1						
9186 East Kenyon Ave., Suite 190	5/87		LA						
Denver, CO 80237									
G. P. Logan									
(303) 722-2112									
Environmental Radioactivity Measure	7/86			L1	L1				X
P. O. Box 226	11/86			L1	L1				
Piermont, NY 10968	5/87			L1	L1				
Katherine Ellins									
(914) 353-3513, (914) 353-0208									
Environmental Radon Measurements	5/87	L1							X
49 N. Orange Ave.									
Orlando, FL 32801									
Catherine Hershey									
(305) 648-1969									
Environmental Risk Consultants, Inc	5/87		L1			L1			X
800 Cluster									
Evanston, IL 60202									
David Slutzky									
(312) 864-1255									
Environmental Sys. Service Ltd	5/87		L1						X
P. O. Box 220									
College Park, MD 20740									
G. D. Fleming									
(301) 779-0606									
Environmental Systems Service	5/87		L1						X
P. O. Box 512									
Culpeper, VA 22701									
Cheryl B. Ludy									
(703) 825-6660									

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Enviroserv	7/86		L1					L1	X
15 Buckley Hill Road	11/86		L1					L1	
Morristown, NJ 07960	5/87		L1					LA	
Donald M. Ulbrich									
(2010 285-1065									
Enviroserv-Radon Detect. of AL	11/86		L1						
325-D Poplar Place	5/87		L1						
Birmingham, AL 35209									
Douglas T. Ulbrich									
(205) 871-6715									
Enviroserv-Radon Detect. of OH	11/86		L1						
781 Mount Vernon Ave.	5/87		L1						
Marion, OH 43302									
D. Todd Ulbrich									
(614) 382-2354									
Envirotest	11/86		L1						
P.O. Box 223	5/87		L1						
North Ridgeville, OH 44039-0223									
Vincent A. Gargaro									
(216) 327-9432									
Envr. Testing & Consulting Corp.	4/86		L1					L1	
1316 Gross Street	7/86		L1					L1	
Manville, NJ 08835	11/86		L1					L1	
	5/87		L1					L1	
Thomas R. Reilly									
(201) 722-5293									
Ero Resources Corporation	5/87		L1						
2801 Youngfield, Suite #121									
Golden, CO 80401									
Mark DeHaven									
(303) 231-9022									

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Excel Inspection Service Inc. 438 Windmill Way Somerville, NJ 08876 Daniel R. Loreti (201) 526-7277	5/87		L1						
Faytek Incorporated P. O. Box 2229 Coeur D'Alene, ID 83814 Jan Elizabeth Fay (208) 667-3283	5/87	L1	L1						
Federal Nuclide Monitors 2023 Park Road, N.W. Washington, DC 20010 Paul A. Danckwerth (202) 265-0429	11/86		L1						
	5/87		LA						
Foresight Engineering, Inc., NJ Box 621 Madison, NJ 07940 Theresa Kaufmann (201) 377-0602	4/86		L1						
	7/86		L1						
	11/86		L1						
	5/87		L1					L1	
Foresight Engineering, Inc., VA P. O. Box 7333 Arlington, VA 22207-0333 Steven Duarte (703) 525-4790	5/87		L1						X
Frazier Co., The 15105 Industrial Rd. Omaha, NE 68144 Dean Frazier (402) 330-3400	5/87		L1						
Futura Medical Systems, Inc. 387 Regency Ridge Centerville, OH 45459 E. Theodore Agard, Ph. D. (513) 436-2215	5/87		L1						
GEOMET Technologies, Inc. 20251 Century Boulevard Germantown, MD 20874 Dr. Niren L. Nagda (301) 428-9898	4/86		L1						X
	7/86		L1						
	11/86	L1	L1						
	5/87	L1	LA						
Garco Research Company 144A Sutton Road Lebanon, NJ 08833 Gary J. Gilbert (201) 832-7895	5/87		L1						X
Garden St. Home Inspection Svc 475 Valley Rd. West Orange, NJ 07052 Thomas Pasquariello (201) 678-3333	5/87		L1						
General Health Physics Inc. 7217 Lockport Pl Lorton, VA 22079 John B. Davis (703) 550-7525	5/87		L1						
Geo-Chek, Inc. 2270 Stony Hill Road Boulder, CO 80303 Phil Herrington (303) 494-0576	5/87		L1					L1	

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PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Gesell Institute, The Env. & Occupational Health Div 310 Prospect St. New Haven, CT 06511 Robert McLellan, MD/MPH (203) 789-1911	5/87	L1	L1						X
Hazen Research, Inc. 4601 Indiana St. Golden, CO 80203 John C. Jarvis (303) 279-4501 Ex. 218	5/87		L1						
Health Physics Associates, Inc. RDI Box 796 Lenhartsville, PA 19534 Anthony La Mastra (215) 756-4153	7/86		L1		L1	L1			X
	11/86		L1		L1	L1			
	5/87		L1		L1	L1		L1	
Health Physics Associates, Ltd. 3304 Commercial Avenue Northbrook, Illinois 60062 William B. Rivkin (312) 564-3330	4/86		L1						X
	7/86		L1						
	11/86		L1						
	5/87		LA						
Health and Safety Associates 35 Grove Street Medford, MA 02155 Neil A. Gaeta (617) 488-7081	5/87	L1	L1						
Home Buyers Inspection Service 320 Elmwood Drive Naperville, IL 60540 John R. Ball P.E. (312) 357-0903	5/87		L1						
Home Inspection Service, Inc. 1916 Southland Ave. Highland Park, IL 60035 Jerry Comer (312) 432-8861 (312) 831-4545	5/87		L1						
Home Sentry Inc. P. O. Box 555 Midland Park, NJ 07432 Christopher Pedersen (201) 652-2497	5/87		L1						X
Home Sure Inspections, Inc. 444 N. Frederick Ave. STE L348 Gaithersburg, MD 20877 James Schelble (301) 428-7672	5/87				L1				
Home Testing Service 70 Wabasso St. Waltham, MA 02154 Steven D. Wightman (617) 862-3440	5/87		L1						X
Home-Tech Engineering P. O. Box 43129 51 Upper Montclair Plaza Upper Montclair, NJ 07043 David A. Osage (201) 744-6674	5/87		L1						
Hoosier Environmental 11116 Wood Court Carmel, IN 46032 Richard Jordan (317) 846-0227	5/87		L1						

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Hudson Valley Radon Testing Corp. P.O. Box 790 Poughkeepsie, NY 12601 Paul Costello, Robert Hare (914) 431-6424 (914) 485-5581	11/86		L1						
	5/87		L1						
IL Dept. of Nuclear Safety 1035 Outer Park Drive Springfield, IL 62704 Melanie Anne Hamel (217) 546-8100	7/86		L1						
	11/86	L1	L1		<u>L1</u>	<u>L1</u>			
	5/87	L1	L1		<u>L1</u>	<u>L1</u>		<u>L1</u>	
Infiltec P.O. Box 1533 Falls Church, VA 22041 David W. Saum (703) 820-7696	7/86		L1						
	11/86		L1		<u>L1</u>				
	5/87		L1		<u>L1</u>				
Inspex of Boulder, Inc. 2955 Valmont Street, Suite 300 Boulder, CO 80301 Kevin M. O'Hornett (303) 442-8995	5/87		L1						
Insul-Tech, Inc. 5559 Westerville Road Westeville, OH 43081 Danny R. West (614) 891-9555	11/86		L1						
	5/87		L1						
Integral Resources, Inc. 1916 East El Parque Tempe, AZ 85282 James W. Krueger (602) 967-8029	5/87	L1							
JBK Inspection Service, Inc. (The Bld. Inspector of America 225B Cottrell Road Matawan, NJ 07747 Barry Benevento (201) 525-9140	5/87		L1						
JRW Industries, Inc. 2312 North Second Street Harrisburg, PA 17110 James Williams (717) 236-1418	5/87		L1						
K & J Solar Service 1142 Fillmore St. Denver, CO 80206 James Valastro (303) 393-8372	5/87		L1						
KS Dept. of Health & Environ. Radiation Laboratory Forbes Bldg. 740 Topeka, KS 66620 Dr. Dominic To (913) 862-9360 ext 408	5/87		<u>L1</u>						X
KSE, Inc. P. O. Box 368 Amherst, MA 01004 Dr. Charles W. Quinlan (413) 549-5506	11/86		<u>L1</u>						X
	5/87		<u>L1</u>						
Key Technology, Inc. P.O. Box 562 Jonestown, PA 17038 Claude Wiblin (717) 274-8310	4/86		<u>L1</u>						X
	7/86		<u>L1</u>						
	11/86		<u>L1</u>						
	5/87		<u>L1</u>						

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Lamson Home Inspections 9 Lougheed Avenue West Caldwell, NJ 07006 William M. Lamson (201) 228-1862	5/87		L1						X
Lapteff Associates P.O. Box 4150 Woodbridge, VA 22194 Dr. Alexander Lapteff (703) 491-6700	11/86 5/87		L1 L1						
M.V.E., Inc. 1911 Lelaray Street Colorado Springs, CO 80909 Mr. Kent Rockwell (303) 635-5736	5/87	L1	L1						
MIT/MIT Radon Project Building 26, Rm # 421 Cambridge, MA 02139 Professor Lee Grodzins (617) 253-4151	5/87		L1		L1				
MRC Home Inspections P. O. Box 157 Wyckoff, NJ 07481 Henry H. Doron (201) 891-7067	5/87		L1						
Madrona Divirsified, Inc. 1938 Fairview Ave. East Seattle, WA 98102 Dr. Samuel E. Kelly (206) 324-0920	5/87		L1						
Maine Public Health Laboratory Statehouse Station #12 Augusta, ME 04333 Cheryl L. Baker (207) 289-2727	5/87		L1						
Microbac Labs, Erie Testing Lab Div 2411 W. 26th St. Erie, PA 16506 Jeffrey Ports (814) 833-4790	11/86 5/87		L1 LA						X
Microbac Labs, Hanover, PA 701 3rd. Street Hanover, PA 17331 Ronald M. Barber Not Installed Yet	5/87		L1						X
Microbac Labs, MA Testing Division 202 Bussey Street Dedham, MA 02021 Andrew W. Niemann (617) 326-7117	5/87		L1						X
Microbac Labs, New Castle, PA R. D. #3, Pulaski Road New Castle, PA 16105 Mary V. Wolford (412) 654-4212	5/87		L1						X
Microbac Labs, Pittsburgh, PA 4580 McKnight Road Pittsburgh, PA 15237 William A. Larid (412) 931-5851	5/87		L1						X

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Microbac Labs, Schiller Div. 449 Rochester Road Pittsburgh, PA 15237-1733 David J. Danis, Lab Director (412) 369-4830	5/87		L1						X
Microbac Labs, Seaway Div 542-544 Conkey Street Hammond, IN 46324 Karen A. Erny (219) 932-1770	5/87		L1						X
NC Dept. of Human Resources Radiation Protection Section 701 Barbour Drive Raleigh, NC 27603-2008 Harry J. Newman 35 (919) 733-4283	11/86 5/87				L1 L1				
NJ DEP - Bureau of Env. Radiation 380 Scotch Road Trenton, NJ 08625 Duncan White (609) 530-4051	4/86 7/86 11/86 5/87		L1 L1 L1 L1			 L1		L1 L1 L1 L1	
NJ Dept of Environmental Protection Environmental Laboratory 380 Scotch Road Trenton, NJ 08628 Ms. Patricia Gardner (609) 530-4116	4/86 7/86 11/86 5/87		L1 L1 L1 L1						
NODAR, Inc. Route 5 Box 333R Athens, AL 35611 William Young (205) 729-1900	11/86 5/87					L1 LA			
National Radon Control, Inc. P.O. Box 5342 North Branch, NJ 08876 David T. deNeufville (201) 231-0844	4/86 7/86 11/86 5/87						L1 L1 L1 LA		
Natural Resource Technologies 32131 Steven Way Conifer, CO 80433 George H. Sylvester (303) 850-9335	5/87		L1						
New England Radon, LTD. 373 Main St. Salem, NH 03079 Daniel Espinal (603) 893-4260, (800) 637-2366	11/86 5/87		L1 LA						X
New York State Dept. of Health Radiological Sciences Lab Empire State Plaza, Room D-366-B Albany, NY 12201 Robert J. Mahoney (518) 474-2134, (518) 474-6649	5/87		L1						
Niton Corporation P. O. Box 9153 Lexington, MA 02173 James Williams (617) 229-4929	5/87		L1		L1				
Northeast Radon Testing Svc., Inc. P. O. Box 94 Stormville, NY 12582 Karen A. Bard (914) 221-0236	5/87		L1						

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Northeastern PA Envir. Council P. O. Box 3113 Scranton, PA 18505 Edward Dructor (717) 961-1150	5/87		L1						
Nuclear Radiation Center Washington State University Pullman, WA 99164-1300 Roy Filby (509) 335-8917 (509) 335-8641	5/87		L1						
Nuclear Sources & Services Inc. P. O. Box 34042 Houston, TX 77234 Charles T. Gallagher (713) 641-0391	11/86		L1						
	5/87		LA						
Nucleon Lectern Associates, Inc. 2919 Olney-Sandy Spring Road Suite D Olney, MD 20832 Michael S. Terpilak (301) 774-3301	4/86		L1						
	7/86		L1						
	11/86		L1						
	5/87	L1	L1		L1			L1	
O. K. Rems Corp. 174 Flock Rd. Mercerville, NJ 08619 Jeffrey C. Olcott (609) 588-9627	7/86		L1			L1			
	11/86		L1			L1			
	5/87		L1			L1			
Oak Ridge Assoc. Universities Professional Training Progress P. O. Box 117 Oak Ridge, TN 37831-0117 Elbert Carlton (615) 576-5517	5/87		L1						
Phoenix Labs L. Rorbes Road Route 1, Box 247 Colebrook, NH 03576 Gilbert McCarthy (603) 237-5773	5/87		L1						X
Princeton Home Inspection Svc. 380 Nassau Street Princeton, NJ 08540 Clive Usiskin (609) 921-3775	5/87		L1						
Princeton Testing Laboratory Princeton Service Center 3490 US Route 1 Princeton, NJ 08540 Mr. Anthony Damato (609) 452-2037	11/86		L1						X
	5/87	L1	LA						
Protect-A-Home P. O. Box 584 Newtown, CT 06470 B. Michael MeeHan (203) 426-3000	5/87		L1						
Pylon Electronic Development 147 Colonnade Rd. Nepean, Ont., Canada K2E7L9 Dave Hanneson (613) 226-7920	5/87					L1		L1	X
Pyramid Environmental Systems, Inc. P. O. Box 548 Sparta, NJ 07871 Jeffrey R. DeChacon (201) 729-9375	7/86							L1	
	11/86							L1	
	5/87							L1	

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• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
R.A.D. Service & Instruments Ltd. 50 Silver Star Blvd., Unit 208 Scarborough, Ontario M1V2W4 Canada Dr. H. L. Pai (416) 298-9200	7/86 11/86 5/87						L1 L1 L1		
R.J. Moore & Associates, Inc. 1010 West Street Annapolis, MD 21401 Roderic E. Ordway (301) 269-5950	11/86 5/87	L1 L1	L1 L1						
RAD Environmental Services 2308 Rodeo Drive Durham, NC 27704 Dr. Marc Y. Menetrez 37 (919) 688-9226	5/87	L1	L1	L1	L1	L1		L1	X
RADON Home Inspection Service P.O. Box 65 Damascus, MD 20872 Richard K. Jeck (301) 253-0029	11/86 5/87					L1 L1			
RAF Engineering Hillside Road Rockaway, NJ 07866 Ralph Favale (201) 983-9041	5/87	L1	L1						X
RISE 280 Broadway Providence, RI 02903 John Masiello (401) 272-1040	5/87		L1						
Rad-Elec, Inc. 124 North Barry Street Olean, NY 14760 John C. Dempsey (716) 945-5012	5/87	L1	L1						
Rad-Test, Inc. P. O. Box 22576 Louisville, KY 40222 Jeffrey L. Tallent (502) 368-5996	5/87		L1						
Radiation Data Div. Princeton Geophysical Svc 1200 State Road Princeton, NJ 08540 Thomas Van Leeuwen (609) 921-6712	5/87		L1						
Radiation Protection Services P. O. Box 2395 Darien, CT 06820-1295 Michael L. Caprio Jr. (203) 324-7967	11/86 5/87		L1 L1						
Radiation Safety Associates, Inc. P. O. Box 107 Hebron, CT 06248 Paul Steinmeyer (203) 228-0487	5/87		L1						
Radiation Safety Engineering 6106 South Ash, Suite 1 Tempe, AZ 85283 Robert Metzger (602) 897-9459	11/86 5/87		L1 L1						X

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Radiation Safety Services, Inc.	7/86					L1			
1564 Ashland Avenue	11/86					L1			
Evanston, IL 60201-4070	5/87	L1				LA			
Radon Coordinator									
(312) 866-7744									
Radiation Service Organization	4/86		L1						
P.O. Box 1526	7/86		L1						
Laurel, MD 20707-7444	11/86		L1						
	5/87		L1						
Gregory D. Smith									
(301) 953-2482 (301) 792-7444									
Radiation Services Inc.	5/87				L1				
3412 Dorlswood Ct.									
Antioch, TN 37013									
Michael C. Bradshaw									
(615) 361-6492									
Radiation Surveys Incorporated	7/86				L1				X
63 Kingwood Ave.	11/86				L1				
Frenchtown, NJ 08825	5/87		L1		L1				
Carolyn Davis									
(201) 996-3855									
Radioactivity Alert Detection Serv.	5/87	L1	L1						
1313 Roberts Ave.									
Feasterville, PA 19047									
Garry Stklovsky									
(215) 357-0574									
Radiological Physics Services	5/87		L1						
Health East, Inc.									
P. O. Box 13367									
Roanoke, VA 24033									
Joseph . Surace									
(703) 981-7379									
Radon & Environ. Professionals	11/86		L1						X
1902A Kentucky St.	5/87	L1	L1						
Lawrence, KS 66044									
Linda Guinn									
(913) 749-7920 (316) 265-2006									
Radon Air Pollution Testing Co, Inc	5/87	L1	L1						
1499 Lakeview Drive									
Mt. Juliet, TN 27122									
Carlotta Bogart									
(615) 758-9392									
Radon Alert Detection Center	7/86		L1						
204 W. Chestnut Hill Ave.	11/86		L1						
Philadelphia, PA 19118	5/87	L1	L1						
Ulrich W. Hiesinger, Ph.D.									
(800) 345-6348 (215) 247-9197									
Radon Analists, Inc.	7/86		L1						
P. O. Box 509	11/86		L1						
Livingston Manor, NY 12758	5/87		L1						
Vincent J. A. Santoro									
(914) 439-5111 (914) 292-2277									
Radon Analysis Incorporated	7/86		L1						X
RR#1 Box 561M Fox Run Road	11/86		L1						
Stewartsville, NJ 08886	5/87	L1	L1						
David Chippendale									
(201) 479-6086									
Radon Consultants, CO	5/87	L1	L1						
P. O. Box 789									
Golden, CO 8402									
Dennis N. Poffenroth									
(303) 279-1358									

• See TABLE 1 for the States each company serves.

Note: Underscored performance indicators denote a primary company capable of performing measurement analyses in house or making measurements using operators and instruments belonging to the company.
See Definitions of Performance Indicators on pages 5 and 6.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Radon Consultants, Inc., VA 4012 N. 35th Street Arlington, VA 22207 Dr. Jacquelyn Q. Black (703) 522-8669 (301) 736-7040	11/86 5/87	L1 L1	L1 L1						
Radon Detection Services, Inc., GA P. O. Box 768172 Roswell, GA 30076 Chester Micek (404) 993-1471	11/86 5/87	L1 L1	L1 LA						X
Radon Detection Services, Inc., MD P. O. Box 1196 Laurel, MD 20707 Tom Hoy (301) 725-2901	11/86 5/87	L1 L1	L1 LA		L1 L1	L1 L1		L1 L1	X
Radon Detection Services, Inc., NJ P.O. Box 419 Ringoes, NJ 08551 Gene Fisher (201) 788-3080	4/86 7/86 11/86 5/87	L1 L1 L1 LA	L1 L1 L1 LA			L1 L1 L1 L1		L1 L1 L1 L1	X
Radon Detection Services, Inc., PA P. O. Box 3309 Allentown, PA 18106 Deborah Fuggazotto (215) 481-9555	11/86 5/87	L1 L1	L1 L1			L1 L1		L1 L1	X
Radon Detection Specialists 7966 South Madison Street Burr Ridge, IL 60521 Karl Weber (312) 325-4443	11/86 5/87		L1 L1						X
Radon Detection Systems Inc., OH P. O. Box 473 Aurora, OH 44202 Sandra Sawyer (216) 562-4647	5/87		L1						
Radon Detection Systems of TN 3102 Bellwood Ave. Suite B Nashville, TN 37203 Walter Perkins / Odom Clark (615) 269-4616	5/87	L1	L1			L1			
Radon Detection Systems, CO 2300 Central Avenue Suite B-1 Boulder, CO 80301 Tim Smith (303) 444-5253	7/86 11/86 5/87	L1 L1 L1	L1 L1 L1			 L1 L1			
Radon Detection and Control P. O. Box 222 Georgetown, PA 15043 John B. Mallon Jr. (412) 573-0202	5/87		L1						
Radon Detection, Inc. 131 Amherst Street P. O. Box 900 Amherst, NH 03031-0900 Lucian Borduz (603) 882-7340	5/87			L1					
Radon Diagnostics Box 761 Andover, NJ 07821 Charles R. Wayne, Jr. (201) 729-1251	5/87		L1						

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See Definitions of Performance Indicators on pages 5 and 6.

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Radon Engineering Services Inc 3129 Overton Rd. Birmingham, AL 35223 Dr. F. Milton Jessup, P.E. (205) 967-2665	6/87		L1						
Radon Engr, a Unit of PSI Engr, Inc One Lethbridge Plaza Mahwah, NJ 07430 Harvey Greenberg, P.E. (201) 529-8300	4/86 7/86 11/86 6/87	L1 L1 L1 L1	L1 L1 L1 L1					L1 L1 L1 L1	X
Radon Env. Test Experts, Inc. 5271 Holmes Pl. Boulder, CO 80303 David Oppenheimer (303) 442-2344	6/87		L1						
Radon Environ. Monitoring, Inc Box 5306 Evanston, IL 60204 Robert Pollock (312) 328-6628	6/87	L1							
Radon Gasbusters 513 Lyons Avenue Irvington, NJ 07111 Michael Kellison (201) 375-3710	11/86 6/87							L1 L1	
Radon Inspection Service 789 East Glen Avenue Ridgewood, NJ 07450 Robert D. Shumeyko (201) 670-8821	4/86 7/86 11/86 6/87	 L1 L1 L1	L1 L1 L1 L1	 L1	 L1 L1 L1	L1 L1 L1 L1			
Radon Management Company 4332 Gingham Court Alexandria, VA 22310 Gordon M. Davidson (202) 547-1006 (703) 960-4407	11/86 6/87		L1 L1						
Radon Management Laboratories 2 Riverdale Road Pompton Lakes, NJ 07442 James Matonti, Joseph Fastiggi (201) 835-6721	6/87		L1			L1	L1		
Radon Measurement & Control 7935 Kilbourne Rd. Sunbury, OH 43074 John R. Hunt (614) 866-1197	11/86 6/87		L1 LA						
Radon Measurement and Control of New Mexico 1527 Granite St. NW Albuquerque, NM 87104 Dr. William M. Turner (505) 843-7306	6/87	L1							X
Radon Measurement and Services 13131 West Cedar Drive Lakewood, CO 80228 R. Stanley Thompson (303) 980-5086	4/86 7/86 11/86 6/87	L1 L1 L1 L1	 L1 LA		 L1	 L1			
Radon Measurements Inc. 2916 West T. C. Jester Houston, TX 77018 John H. Cohen (713) 683-8227	6/87	L1	L1						

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See Definitions of Performance Indicators on pages 5 and 6.

[Transcriber's note, not printed on the page: underlining cannot be shown in this table. The underlined entries are all CW and GW entries, all GR entries of Radon Inspection Service, the CR entry of Radon Inspection Service, the AT entry of Radon Environ. Monitoring, both CC entries of Radon Measurement & Control, and the GW entry of Radon Management Laboratories. For Radon Measurement and Services, the GR and GW entries of 6/87 are underlined.]

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Radon Mitigators, Inc. 16 Hillside Drive Clinton, NJ 08809 Lawrence H. Kaplan (201) 730-6596	5/87		L1						X
Radon Project, The P. O. Box 90069 Pittsburgh, PA 15224 Bernard L. Cohen (412) 687-3393	5/87		L1						X
Radon Registry 819 Second St. B-178 Manchester, NH 03102 Tom Roller (603) 645-6780	5/87		L1						
Radon Research Group P.O. Box 1143 Germantown, MD 20874 Michael J. Myers 800/445-8436, MD 800/544-8436	7/86	L1							X
	11/86	L1							
	5/87	L1							
Radon Safety Services, Inc. Box 441 New Providence, NJ 07974 Guy J. Agrati (201) 825-8287 (201) 665-1188	7/86						L1	L1	X
	11/86						L1	L1	
	5/87		L1				L1	L1	
Radon Screening Service, Inc. P. O. Box 27007 Denver, CO 80237 Thomas Staley (303) 741-3207	5/87	L1	L1						
Radon Surveys, Div. Alpha Tech Corp 2205 13th Street Winthrop Harbor, IL 60096 Steven P. Ray (312) 872-3883	11/86					L1			X
	5/87					L1			
Radon Surveys, Div. Cope Tech Svcs 3506 87th Pl. Kenosha, WI 53142 James L. Cope (414) 694-3730	5/87		L1						
Radon TNT 1015 Beta Loop Colorado Springs, CO 80906 Richard Cole (303) 520-5893	11/86					L1			X
	5/87		L1			L1			
Radon Technologies Inc. 39 Woodrow Court Troy, NY 12180 Robert J. Mahoney (518) 447-5834	5/87	L1	L1		L1				
Radon Testing Corp. of America RTCA 12 W. Main Street Elmsford, NY 10523 Nancy A. Bredhoff 800/457-2366, 800/537-7822 -NY	7/86		L1						X
	11/86		L1						
	5/87		L1						
Radon Testing Svc, Englewood, CO P. O. Box 1130 Englewood, CO 80110 David L. Egleston, Jr. (303) 762-8598	5/87		L1			L1			

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See Definitions of Performance Indicators on pages 5 and 6.

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Radon Testing Svc, Pittsburgh, PA P. O. Box 19425 Pittsburgh, PA 15213 Mark Johnson (412) 687-1533	11/86		L1						
	5/87		L1						
Radon Testing Svcs, Baltimore, MD P. O. Box 7999 Baltimore, MD 21221-0999 Laurence V. Kolego (301) 321-8008	5/87		L1						
Radon Testing Svcs, Princeton, NJ P. O. Box 3311 Princeton, NJ 08543 Rodney T. Miller (609) 737-8818	5/87		L1						
Radon X Company, Inc., The 217 Roxbury Street Keene, NH 03431 David P. Tkatch (603) 352-5319	5/87					L1			
Radonics, Inc. (Div. of Gemini Research) 5101-D Backlick Road Annandale, VA 22003 Brian P. Fimian (703) 941-0070	11/86	L1	L1			L1		L1	X
	5/87	L1	L1			LA		LA	
Radonix 34 Dogwood Lane Middletown, PA 17057 Edward V. Kellogg (717) 944-5520	5/87		L1						
Ram Exterminators 97 Frank St. Somerset, NJ 08873 James R. Savage (201) 937-6900	5/87		L1						
Real Estate Support Services 7901 Flying Cloud Drive, #132 Eden Prairie, MN 55344 Julie Steen (612) 941-7558	11/86		L1						
	5/87		L1						
Recon Systems, Inc. P.O. Box 460 Three Bridges, NJ 08887 Peter L. Rosen (201) 782-5900	7/86	L1							
	11/86	L1	L1						
	5/87	L1	L1						
Res-I-Tec 94 Limekiln Road Redding, CT 06896 Ron Passaro (203) 938-9611	5/87		L1						
Residential Radon Measurements P. O. Box 3061 Fairview Heights, IL 62208 Todd A. Jokerst (618) 397-0099	5/87	L1	L1						
Residential Radon Test Service 126 Old Oaken Bucket Raod Scituate, MA 02066 Jim Wood (617) 545-9160	5/87		L1						

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See Definitions of Performance Indicators on pages 5 and 6.

TABLE 2
PERFORMANCE RESULTS OF COMPANIES

* Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Reynolds Radiological Services, Inc RD 1 Box 271-5 Bainbridge, PA 17502 H. W. Reynolds (717) 653-9366 (717) 367-7829	7/86							L1	
	11/86							L1	
	6/87							L1	
Roberts Environmental Services 4110 Old Wake Forest Road Suite 109 Raleigh, NC 27609 Glenn David Osmond (919) 790-9378	11/86				L1			L1	X
	6/87	L1	L1	L1	L1	L1		L1	
Rocky Mountain Radon Testing 6820 S. Brook Forest Dr. Evergreen, CO 80439 Duane A. Riggenbach (303) 674-7029	6/87		L1						
Rogers & Assoc. Engineering Corp. 515 East 4500 South, Suite G-200 Salt Lake City, UT 84107 Dr. Kirk K. Nielson (801) 263-1600	7/86		L1						
	11/86	L1	NL		L1				
	6/87	L1	L1		L1				
Ronald Stein Construction Inc. 21 Davis Ave. Poughkeepsie, NY 12603 Ronald Stein (914) 473-0064	6/87	L1	L1						X
Ross Systems, Inc. 174 Route 94 Blairstown, NJ 07825 Richard Ross (201) 364-5571	4/86	L1	L1			L1			
	7/86	L1	L1			L1			
	11/86	L1	L1			L1			
	6/87	L1	L1			L1		L1	
Roy F. Weston, Inc. One Weston Way (Bldg. 4-2) West Chester, PA 19380 Jean-Claude F. Dehmel (215) 692-3030 ext 2746	11/86				L1	L1			X
	6/87				L1	L1			
Ryan Nuclear Laboratories 7030 D Huntley Rd Columbus, OH 43229 Wayne Ballantyne (614) 848-4414	6/87		L1						
S. C. Dept of Health & Env Control Bureau of Radiological Health J. Marion Sims Bldg. Columbia, SC 29201 Nolan Bivens (803) 734-4700	6/87		L1						
Safe & Sound Home Inspect. Con P. O. Box 196 Cedar Knolls, NJ 07927 Steven W. Freedman (201) 515-0013	6/87		L1						
Safe Air P. O. Box 120064 Nashville, TN 37115 Carolyn Tompkins (615) 865-5325	6/87		L1						
Safe Shelter Environmental 527 W. Lancaster Ave. Frazer, PA 19355 Richard Haag / Joe Batten (215) 436-3632	6/87							L1	

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Science Management Services, Ltd. 25 Eshelman Road Lancaster, PA 17601 D. Dwight Browning (717) 392-1425	7/86					L1			
	11/86					L1			
	5/87					L1			
Scientific Analysis, Inc. 6012 East Shirley Lane Montgomery, AL 36117 John Allen Gunn 800/345-2575 800/638-8348+724	4/86		L1						X
	7/86		L1						
	11/86		L1						
	5/87		LA						
Scientific Testing Associates Star Route Box 124 Topping, VA 23169 Dr. John D. Reynolds (804) 758-5728	11/86		L1						
	5/87		L1						
SepTech N. 7625 Howard Spokane, WA 99208 John L. Cox (509) 467-6274	5/87		L1		L1				X
Shelterworks Inc. 53 New St. Dover, NJ 07801 Joseph F. Corsetto (201) 328-2912	5/87		L1						
Shotwell Associates Box 83 Budd Lake, NJ 07828 HP Shotwell (201) 691-9037	7/86					L1			
	11/86					L1			
	5/87					L1		L1	
Silver Springs Home Inspection P. O. Box 182 Landing, NJ 07850 Glenn A. Bredder P.E. (201) 770-0026	5/87					L1			X
Sorensen Enterprises, Inc. 886 W. Hunt Rd. Alcoa, TN 37701 Peter F. Sorensen (615) 984-1376	11/86		L1						
	5/87		L1						
Southern Radon Services, Inc. 1000 Johnson Ferry Rd. Suite B-145 Marietta, GA 30068 Mr. Fred Stafford (404) 565-3886	11/86		L1						X
	5/87		L1					L1	
Standor Radon Detection 598 S. Edgewood Drive Jacksonville, FL 32206 Stanley J. Szczepanski (904) 388-0284	11/86	L1							
	5/87	L1	L1						
TCS Industries, Inc. 4326 Crestview Road Harrisburg, PA 17112 Jacquelyn S. Distenfeld (717) 657 7032	4/86		L1						X
	7/86		L1						
	11/86		L1						
	5/87		L1						
TEQ Corporation 93 Main Street Duryea, PA 18642 Russell Hendershot (717) 457-0233	5/87	L1	L1	L1				L1	

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

* Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
TMA/Eberline, Health Physics 5635 Kircher Blvd. NE Albuquerque, NM 87109 Jeff Brown / Ernie Sanchez (505) 345-9931	5/87		L1		<u>L1</u>				
Teledyne Isotopes 50 Van Buren Avenue Westwood, NJ 07675 J. David Martin (201) 664-7070	4/86 7/86 11/86 5/87		<u>L1</u> <u>L1</u> <u>L1</u> <u>L1</u>						X
Terradex Corporation 3 Science Road Glenwood, IL 60425 R. Craig Yoder (312) 755-7911	4/86 7/86 11/86 5/87	<u>L1</u> <u>L1</u> <u>L1</u> <u>L1</u>							X
Terradon Exploration Tech. Inc. Radon Survey Systems P. O. Box 22288 Cleveland, OH 44122 Dr. Darioush T. Ghahremani (216) 464-2002	5/87	L1	L1						
Terradynamics Corporation Route 1 Aldie, VA 22001 Ned Mamula (703) 327-6500 (703) 435-3033	7/86 11/86 5/87	L1 L1 L1							
Testing 1. 2. 3 50 Freeway Drive Cranston, RI 02920 Nicholas H. Kondon (401) 461-0530	5/87	L1	L1						
Thomson & Nielsen Electronics 4019 Carling Ave. Phase 1, Suite 202 Kanata, Ontario, CAN, K2K 2A3 Torben K. Nielsen (613) 592-3019	5/87							<u>L1</u>	
Thorough Check, Inc. 315 E. Lacey Rd. Unit B Forked River, NJ 08731 William A. DeMarsico (609) 971-1810	11/86 5/87		L1 L1						X
Timberline Radon Service 1780 Copper Lane Evergreen, CO 80439 David Snyder (303) 674-2828	5/87							<u>L1</u>	
Triple Seal, Inc. 2425 Patterson Rd. Kettering, OH 45420 A. Brown Dillard (513) 258-8255	5/87		L1						
U.S. Toxic Substance Testing Bureau 1024 Cottman Avenue Philadelphia, PA 19111 Harold Steele (215) 342-5100	7/86 11/86 5/87							<u>L1</u> <u>LA</u> <u>L1</u>	
US Army Envir. Hygiene Agency Radiological & Inorganic Chem. Div. Aberdeen Proving Ground, MD 21010-5422 Ronald J. Swatski (301) 671-2619/2637	5/87		<u>L1</u>						X

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
US E.P.A., Las Vegas, NV	4/86				L1				
4220 S. Maryland Parkway	7/86				L1				
LaPlaza Bldg.C, Room 532	11/86				NL				
Las Vegas, NV 89109	5/87				L1				
Richard D. Hopper									
(702) 798-2447									
US Radon Testing Service	5/87		L1						
1200 S. Arlington Ridge Road									
Suite 709									
Arlington, VA 22202									
Robert T. Grow									
(703) 892-8952									
Union Cnty. Bld. Inspection Svc	5/87		L1						
502 Twin Oaks Rd.									
Union, NJ 07083									
Michael L. Jupa									
(201) 687-6110									
Univ of Texas School of Pub. Health	4/86		L1						
P. O. Box 20186	7/86		L1						
Houston, TX 77225	11/86		L1						
	5/87		LA						
Howard M. Prichard									
(713) 792-4431									
Univ. of Colorado-Colorado Springs	5/87		L1						
Dept. of Physics									
P. O. Box 7150									
Colorado Springs, CO 80933-7150									
Dr. James F. Burkhart									
(303) 593-3214									
Univ. of Pittsburgh Radon Project	4/86		L1						X
Physics Deptartment	7/86		NL						
Pittsburgh, PA 15260	11/86		L1						
	5/87	L1	L1						
Bernard L. Cohen									
(412) 624-9245									
University of Lowell	5/87		L1						
1 University Avenue									
Lowell, MA 01854									
Kenneth W. Skrable									
(617) 453-1045									
University of North Carolina	7/86		L1						
Dept. of Envr. Sciences & Engr.201H	11/86		L1						
Chapel Hill, NC 27514	5/87		L1						
James E. Watson, Jr.									
(919) 966-3840									
Virginia Radon Service, Inc.	5/87		L1						
Box 332 B Route 1									
Roseland, VA 22967									
Thomas Eick									
(804) 277-5491									
W. S. Fleming and Associates	5/87	L1	L1	L1	L1			L1	
6310 Fly Road									
E. Syracuse, NY 13057									
Dr I. Nitschke/Michael Clarkin									
(315) 437-1869									
West Coast Environmental Services	5/87		L1						
P. O. Box 18182									
Seattle, WA 98118									
John Gilmore									
(206) 324-0920									
Wilkes College	5/87	L1	L1	L1	L1			L1	
Physics Dept.									
Wilkes-Barre, PA 18766									
Roger Maxwell									
(717) 824-4651 ext 481									

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TABLE 2
PERFORMANCE RESULTS OF COMPANIES

• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan	• Company	Date of Round	Radon Measurement AT	CC	CR	GR	Working Level Measurement GW	RP	CW	QA Plan
Wright Lab Services, Inc. 3240 Schoolhouse Road Middletown, PA 17067 Ian Milnes (717) 944-5541	5/87		<u>L1</u>																

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Appendix C
House Inspection Form

Date [ ] Name [ ]
Address [ ]
State [ ] ZIP [ ]
Investigator [ ]

Water

- [ ] Public
- [ ] Individual Well

Radon Measurement History

Location	Date Tested	Results
Water Concentration		
Toilet Bowl Gamma		

Mechanical Equipment and Stack Effect Bypasses (Number of Each)

Exhaust Appliances

- [ ] Range Hood
- [ ] Cooktop Range
- [ ] Bath Fan
- [ ] Dryer to Outside
- [ ] Large Exhaust Fan
- [ ] Attic Fan
- [ ] Heat Recovery Ventilator

Bypasses

- [ ] Around Chimney
- [ ] Balloon Walls
- [ ] Soffits
- [ ] Plumbing Chase
- [ ] Recessed Lights
- [ ] Attic Entry

Heating and Cooling

	Gas	Oil	Electric	Wood	Kerosene	Stack Damper	Air Cleaner	Return Supply	Dedicated Combustion Air(Y,N)
Furnace									
Boiler									
Space									
DHW									
Fireplaces									
Air Conditioning									
Dryer									

- [ ] Rock Bed Storage

Foundation Types

Foundation #1

☐ Crawlspace
☐ Space Vented
☐ Full Basement
☐ Slab on Grade

☐ PerCent Below Grade
☐ # Walkout Sides
☐ Water Present
☐ Water Damage Present

Walls
☐ Block
☐ Concrete
☐ Stone
☐ Perm. Wood

Wall Finish (%)
☐ None
☐ Paint
☐ Furring
☐ Stud Wall
☐ Sheetrock
☐ Paneling

Floor (%)
☐ Earth
☐ Slab
☐ Poly

Floor Finish (%)
☐ None
☐ Tile
☐ Carpet

SubSlab Material
☐ Stone
☐ Sand
☐ Clay
☐ Bedrock
☐ Can't Tell
☐ Poly Sheet

Penetrations (S,M,L)
☐ Water Entry
☐ Sewer Exit
☐ Pipes Thru Wall
☐ Wall Cracks
☐ Floor Cracks
☐ Gas Entry
☐ Pipes Thru Floor
☐ Main House Trap
☐ Beam Pocket
☐ Floor-Wall Crack

(Y/N)
☐ Open Block Tops
☐ Solid Block Tops
☐ Bathtub
☐ Shower
☐ Toilet
☐ Interior Block Walls
☐ Floor Drains
☐ Ducts Under Slab

Drainage(Y/N)
☐ Sump Hole
☐ Int. Pipe
☐ Ext.Pipe
☐ Pump
☐ Water Present
☐ Int. Footer Drain
☐ Ext. Footer Drain
☐ French Drain

Foundation Types

Foundation #2

☐ Crawlspace
☐ Space Vented
☐ Full Basement
☐ Slab on Grade

☐ PerCent Below Grade
☐ # Walkout Sides
☐ Water Present
☐ Water Damage Present

Walls
☐ Block
☐ Concrete
☐ Stone
☐ Perm. Wood

Wall Finish (%)
☐ None
☐ Paint
☐ Furring
☐ Stud Wall
☐ Sheetrock
☐ Paneling

Floor (%)
☐ Earth
☐ Slab
☐ Poly

Floor Finish (%)
☐ None
☐ Tile
☐ Carpet

SubSlab Material
☐ Stone
☐ Sand
☐ Clay
☐ Bedrock
☐ Can't Tell
☐ Poly Sheet

Penetrations (S,M,L)
☐ Water Entry
☐ Sewer Exit
☐ Pipes Thru Wall
☐ Wall Cracks
☐ Floor Cracks
☐ Gas Entry
☐ Pipes Thru Floor
☐ Main House Trap
☐ Beam Pocket
☐ Floor-Wall Crack

(Y/N)
☐ Open Block Tops
☐ Solid Block Tops
☐ Bathtub
☐ Shower
☐ Toilet
☐ Interior Block Walls
☐ Floor Drains
☐ Ducts Under Slab

Drainage(Y/N)
☐ Sump Hole
☐ Int. Pipe
☐ Ext.Pipe
☐ Pump
☐ Water Present
☐ Int. Footer Drain
☐ Ext. Footer Drain
☐ French Drain

Foundation Types
Foundation #3

☐ Crawlspace
☐ Space Vented
☐ Full Basement
☐ Slab on Grade

☐ PerCent Below Grade
☐ # Walkout Sides
☐ Water Present
☐ Water Damage Present

Walls
☐ Block
☐ Concrete
☐ Stone
☐ Perm. Wood

Wall Finish (%)
☐ None
☐ Paint
☐ Furring
☐ Stud Wall
☐ Sheetrock
☐ Paneling

Floor (%)
☐ Earth
☐ Slab
☐ Poly

Floor Finish (%)
☐ None
☐ Tile
☐ Carpet

SubSlab Material
☐ Stone
☐ Sand
☐ Clay
☐ Bedrock
☐ Can't Tell
☐ Poly Sheet

Penetrations (S,M,L)
☐ Water Entry
☐ Sewer Exit
☐ Pipes Thru Wall
☐ Wall Cracks
☐ Floor Cracks
☐ Gas Entry
☐ Pipes Thru Floor
☐ Main House Trap
☐ Beam Pocket
☐ Floor-Wall Crack

(Y/N)
☐ Open Block Tops
☐ Solid Block Tops
☐ Bathtub
☐ Shower
☐ Toilet
☐ Interior Block Walls
☐ Floor Drains
☐ Ducts Under Slab

Drainage(Y/N)
☐ Sump Hole
☐ Int. Pipe
☐ Ext.Pipe
☐ Pump
☐ Water Present
☐ Int. Footer Drain
☐ Ext. Footer Drain
☐ French Drain

Foundation Types
Foundation #4

☐ Crawlspace
☐ Space Vented
☐ Full Basement
☐ Slab on Grade

☐ PerCent Below Grade
☐ # Walkout Sides
☐ Water Present
☐ Water Damage Present

Walls
☐ Block
☐ Concrete
☐ Stone
☐ Perm. Wood

Wall Finish (%)
☐ None
☐ Paint
☐ Furring
☐ Stud Wall
☐ Sheetrock
☐ Paneling

Floor (%)
☐ Earth
☐ Slab
☐ Poly

Floor Finish (%)
☐ None
☐ Tile
☐ Carpet

SubSlab Material
☐ Stone
☐ Sand
☐ Clay
☐ Bedrock
☐ Can't Tell
☐ Poly Sheet

Penetrations (S,M,L)
☐ Water Entry
☐ Sewer Exit
☐ Pipes Thru Wall
☐ Wall Cracks
☐ Floor Cracks
☐ Gas Entry
☐ Pipes Thru Floor
☐ Main House Trap
☐ Beam Pocket
☐ Floor-Wall Crack

(Y/N)
☐ Open Block Tops
☐ Solid Block Tops
☐ Bathtub
☐ Shower
☐ Toilet
☐ Interior Block Walls
☐ Floor Drains
☐ Ducts Under Slab

Drainage(Y/N)
☐ Sump Hole
☐ Int. Pipe
☐ Ext.Pipe
☐ Pump
☐ Water Present
☐ Int. Footer Drain
☐ Ext. Footer Drain
☐ French Drain

Test Results

Sub-slab Vacuum Test

Location	Smoke	ΔP (" WC)	Freon	Radon Conc.	Feet From Suction (Point A)
FA					

Overall Rating of Sub-slab Communication (X)

- ☐ Good
- ☐ Spotty
- ☐ Some
- ☐ None
- ☐ Freon Only

Floor Area ☐ Volume - Whole house ☐
- Basement ☐

Basement Fan Door Test

Airflow Reversal
- ☐ CFM
- ☐ Pascals.

Whole House Fan Door Test

- ☐ Shielding Class
- ☐ Terrain Class
- ☐ Wind Speed

- ☐ ACH at 50 Pascals
- ☐ ELA at 4 Pascals

FLOOR PLAN

HOUSE IDENTIFICATION

NOTES

LOCATION

TECHNICIAN

DATE

HOUSE IDENTIFICATION

FLOOR PLAN

Appendix D
Hard to Find Materials and Tools

Materials

Obar Systems, Inc.
R.R.I., Box 759
Highland Lakes, NJ 07422
(201)607-1009

Fans

R.B. Kannalflakt, Inc.
1121 Lewis Avenue
Sarasota, FL 33577
(813)366-7505

RDS "Remediator"
Radon Detection Services
P.O. Box 419
Ringoes, NJ 08551
(201)788-3080

Sealants

Instafoam Electrical Services, Inc.
1500 Cedarwood Drive
Joliet, IL 60435
(800)435-9359/(800)741-6800

Mameco
Sika Sealant Division
P.O. Box 297
Lyndhurst, NJ 07071
(201)933-8800

Sealing Devices

Dranjer Corporation
1441 Pembina Highway
Winnipeg, Manitoba R3T 2C4
Canada
(204)474-0451

Pressure Differential Gauges

Dwyer Instruments
P.O. Box 373
Michigan City, IN 46360
219/872-9141

Neotronics N.A. Inc.
P.O. Box 370, 411 Bradford St., N.W.
Gainesville, GA 30503
(404)535-0600

Smoke Sticks

E. Vernon Hill, Inc.
P.O. Box 7053
Corte Madera, CA 94925
(415)924-6837

Miscellaneous

Reese Wynant — a supplier who represents various manufacturers
Auburn, NY
(315)252-1911

Freon detectors

TIF Instruments, Inc.
9101 N.W. 7th Street
Miami, FL 33150

Radon detectors

Ludlum Measurements, Inc.
501 Oak St., P.O. Box 810
Sweetwater, TX 79556
(915)235-5494

Pylon Electronic Development Co., Ltd.
147 Colonnade Road
Nepean, Ottawa K2E 7L9
Canada
(613)226-7920

Working level monitors

Alphanuclear
1125 Derry Road East
Mississauga, Ontario L5T 1P3
Canada
(416)676-1364

Eberline
P.O. Box 2108
Santa Fe, NM 87501
(505)471-3232

Appendix E
Further Information

Health Risks

A Citizen's Guide to Radon: What it is and What to Do About It, U.S. Environmental Protection Agency/U.S. Centers for Disease Control, August 1986, Publication #EPA-86-004.

New Construction

Brennan, Terry and William Turner "Radon's Threat Can Be Subdued," Solar Age, May 1985, pp. 19-22.

A Guide to Radon Reduction in New Construction, U.S. Environmental Protection Agency — Office of Radiation Programs, Washington, DC 20460.

For further information, contact: John Spears, National Association of Homebuilders, NAHB National Research Center, 400 Prince George's Center Blvd., Upper Marlboro, MD 20772-8731.

Measurement

Interim Protocols for Screening and Follow-up Radon and Radon Decay Product Measurements, 1986, U.S. Environmental Protection Agency, Washington, DC 20460.

Proceedings: EML Indoor Radon Workshop, 1982 (published June 1983), U.S. Department of Energy, Environmental Measurements Laboratory, New York, NY 10014.

Mitigation

Brennan, Terry and William Turner, "Radon's Threat Can Be Subdued," Solar Age, May 1985, pp. 19-22.

Brennan, Terry and William Turner, "Defeating Radon," Solar Age, March 1986, pp. 33-37.

Henschel, D. Bruce and Arthur G. Scott, "Testing of Indoor Radon Reduction Techniques in Eastern Pennsylvania: An Update," presented at the Second International Specialty Conference on Indoor Radon, sponsored by the Air Pollution Control Association, Cherry Hill, New Jersey, April 6-10, 1987.

Turk, B.H., R.J. Prill, et. al., "Radon and Remedial Action in Spokane River Valley Residences: An Interim Report," Indoor Air Program, Lawrence Berkeley Laboratory, University of California, 1986.

Radon Reduction Methods: A Homeowner's Guide, U.S. Environmental Protection Agency, 1986. Publication #EPA-86-005.

Radon Reduction Techniques for Detached Houses: Technical Guidance, U.S. Environmental Protection Agency, June 1986. Publication #EPA/5-86/019.

The Authors

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