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Project Summary

Preliminary Diagnostic Procedures for Radon Control

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Analytical procedures for diagnosing radon entry mechanisms into buildings are described. These diagnostic methods are generally based on the premise that pressure-driven flow of radon-bearing soil gas into buildings is the most significant source of radon in houses with elevated concentrations, although procedures to determine the contributions of other potential sources (e.g., building materials and potable water) to indoor airborne concentrations are also included. Flowcharts are presented that develop a logical sequence of events in the diagnostic process, including problem diagnosis, selection and implementation of mitigation systems, and post-mitigation evaluation. The initial problem assessment procedures rely on an organized set of measurements to characterize the structure, the surrounding soil, and the likely entry pathways from the soil into the building. The measurement procedures, described in detail, include radon grab sampling under both naturally and mechanically depressurized conditions, visual and instrumental analyses of air movement at various substructure locations, building leakage area tests, and soil characterization methods. Post-mitigation evaluation procedures are also described. Samples of various data forms and test logs are provided.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

With the discovery of high indoor radon (Rn-222) concentrations in a significant number of houses since the late 1970s, it has become important to develop a better understanding of the mechanisms of radon movement into and accumulation in buildings and suitable methods for controlling or eliminating the accumulations. In general, earlier research has found that the most significant source of indoor radon is the soil surrounding the building shell from which radon migrates into the building, transported by the pressure-driven flow of soil gas. Factors influencing the radon entry rate include indoor-outdoor air temperature differences, wind loading, soil characteristics, construction details of the building superstructure and substructure, and the coupling between the soil and the substructure.

To further investigate radon control techniques, the U. S. Environmental Protection Agency (EPA), the Department of Energy (DOE), and the New Jersey Department of Environmental Protection (NJDEP) funded an intensive study in 14 northern New Jersey houses. The research was conducted by the Lawrence Berkeley Laboratory (LBL) in seven houses and collaboratively by Oak Ridge National Laboratory and Princeton University in the remaining seven houses. The following overall objectives were established for the project:

- Extend the understanding of the fundamentals of soil gas flow and radon entry into buildings and improve the basic knowledge of factors that influence the entry rate.
- Refine and develop analysis procedures for diagnosing radon entry mechanisms and selecting appropriate control systems.
- Develop and demonstrate practical radon mitigation techniques for selected basement/crawl space houses.

The research plan to meet the above objectives had four main components: 1) house and site characterization measurements, 2) baseline and continuous monitoring of environmental and building parameters, 3) diagnostic procedure development, and 4) installation and operation of selected mitigation techniques.

Table 1. Project Measurements and Procedures

• *Visual Inspection of House*
• *Alpha Scintillation Cell Radon Grab Samples*
• *Sub-slab and Wall Air Flow Communication Tests*
• *Air Infiltration Leakage Tests*
• *Appliance Depressurization Effects*
• *Soil Characterization*
• *Radon in Water*
• *Radon Flux from Building Materials*

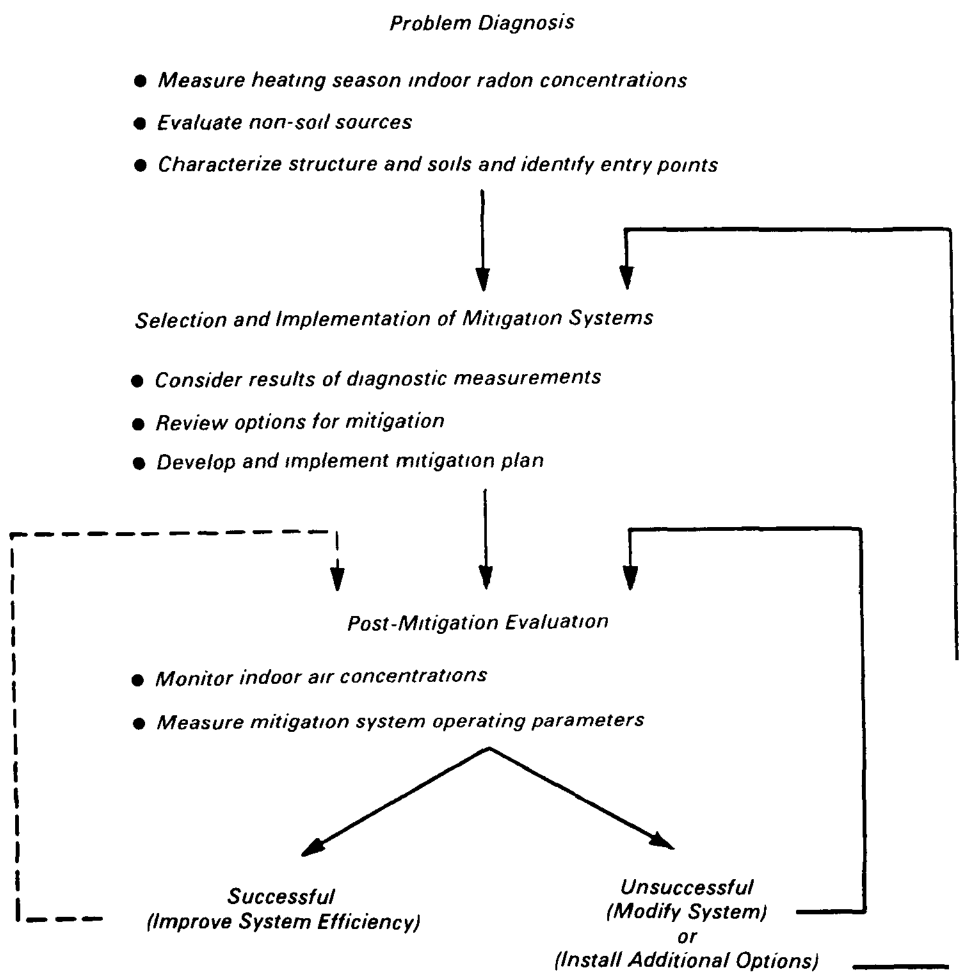

Figure 1. General plan for radon control

Diagnostic Procedures

This report focuses primarily on the second objective: i.e., the preliminary development of diagnostic procedures. Diagnostic procedures are defined here as organized and logical measurements, tests, and observations that are necessary for identifying the specific means by which radon enters and accumulates in a particular structure. These procedures should point the way to a suitable system or technique for controlling indoor radon levels. These procedures may also be applied as follow-up measurements, tests, and observations useful in optimizing mitigation system performance. This development effort builds on the previous, on-going, and generally unpublished work of others, including Scott, Tappan, Ericson, and Brennan, as well as on the basic scientific understanding developed by Nazaroff, Nero, Tanner, and others. This report provides a format for refinement, reduction and interpretation of the measurements and observations necessary for selecting an appropriately designed, effective, and economical system for controlling indoor radon concentrations in single-family detached houses. Table 1 lists the diagnostic research measurements and procedures discussed in this report.

The premise for many of the diagnostic procedures developed and discussed here is that the pressure-driven flow of radon bearing soil gas is the most significant source of radon in houses with elevated concentrations. However, other potential sources of radon, such as water and building materials are also included in the diagnostic procedures. Figure 1 outlines the mitigation process framework governing the use of diagnostic measurements.

The procedures described here rely on individual site-specific observations and short term measurements of air flow, pressure differentials, radon concentrations and near-building material characteristics. The measurements are then used to identify primary radon sources (water, building materials, soil) and most probable radon entry points and mechanisms. Tools and instruments listed in Table 2 are necessary to conduct the diagnostic procedures discussed in this report. The report assumes that the reader has prior experience with flow and pressure measuring devices, and alpha particle counting techniques. The full report describes the diagnostic procedures forms used for data recording and a sample application of diagnostics in a house studied as part of the aforementioned comprehensive study.

Table 2. Instruments and Equipment

Radon Grab Sampling:	*Alpha scintillation cells*
	Portable photomultiplier tube counting station
	Hand pump with sample tube and 0.8 cm filter
	Compressed air or nitrogen for cell flushing
	Vacuum pump for evacuating cells (70 cm, 27 in. Hg vacuum)
Air Leakage and Flow Measurements:	*Calibrated-flow blower door (6800 m^3h^{-1}, 4000 cfm @ 5 Pa)*
	Pitot tubes (electronic or liquid-filled manometers: 1-50 kPa)
	Hot wire anemometer (with temperature sensing element)
	Smoke tubes
	Industrial vacuum cleaner (170 m^3h^{-1}, 100 cfm @ 2 m H_2O pressure)
	1.5 m (5 ft) flow sections of: 7.6 cm (3 in.) PVC with coupler
	15 cm (6 in.) galvanized duct
	Non-toxic tracer gas (SF_6, Freon-12)
	Tracer gas detection instrument
Soils Characterization:	*Soil core and auger samplers*
	3/4 in. reversible electric drill
	Soil air permeability device
	Sliding hammers
	Various diameter drill bits, include some attached 1.5 m (5 ft) long extensions
	1.5 m (5 ft) long probe pipes
Inspection Equipment:	*Stiff wires*
	Telescoping mirrors
	Portable gamma spectrometer
	Fiber optics scope
Tools:	*3/8 in. variable-speed hand drill*
	Masonry bits
	1/2 in. hammer drill
	Impact bits
	Pocket flashlights
	Hand sledge
	Pry bar
	Pipe wrench
	Locking pliers
	Adjustable wrenches
	Portable lights
	Step ladders
	Long blade screwdriver
Miscellaneous:	*Forms*
	Inspection hole plugs
	Epoxy-based mortar patch or hydraulic cement
	Duct tape
	Duct seal
	0.3, 0.6, 1 cm (1/8, 1/4, 3/8 in.) diameter tubing
	Various-sized hypodermic needles
	Plastic film
	Thermometers: electronic and mercury-filled glass
	Silicone sealant

The report discusses details of the various diagnostic methods, techniques, and procedures currently under development, and provides in flowchart form a logical sequence of steps that will guide the reader through the measurement and evaluation mitigation process. The emphasis of this system of diagnosis is for research purposes and is intended to serve as the basis for development of approaches for general commercial applications.

The report provides a house-specific example of the above diagnostic procedures with the purpose of demonstrating and evaluating their utility in the mitigation process. Preliminary diagnostic procedures have been developed for identifying the sources of indoor radon problems and selecting systems for controlling radon. In houses where the recommended remedial measures have been installed, based on the diagnostic measurements, radon concentrations have fallen below the guideline of 4 pCi/L. However, a rigorous process for selecting successful, optimized systems has not yet been developed for widespread use by technicians and contractors.

Three new, and largely unvalidated techniques are presented that may assist in determining contributions to indoor radon levels from the domestic water supply and building materials and the approximate distribution of air infiltration leakage area in a structure. This document reports on progress in research still underway. Additional data and observations are being made that may support, augment, or in some cases invalidate, some of the conclusions discussed here.

Other diagnostic techniques and tools under invesitgation in this and other studies include: use of tracer gases to quantify entrainment of building air into subsurface ventilation systems; creating flow and pressure maps for hollow block foundation walls; quantifying and apportioning subsurface ventilation from below slabs and from within block walls; estimating outside air ventilation that enters along the soil/house interface; and development of a radon "sniffer" with faster recovery time between samples taken from test holes, entry points, and indoor air. Another new method will attempt to challenge an installed mitigation system by using a depressurization fan to gradually increase substructure depressurization and thereby determine the system failure point.

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***David C. Sanchez** is the EPA Project Officer (see below).*
The complete report, entitled "Preliminary Diagnostic Procedures for Radon Control," (Order No. PB 88-225 115/AS; Cost: $14.95, subject to change) will be available only from:
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The EPA Project Officer can be contacted at:
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