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# Monitoring Radon Reduction in Clinton, New Jersey, Homes

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## INTRODUCTION

The discovery of high indoor concentrations of radon gas in the Reading Prong area of New Jersey, New York, and Pennsylvania, and in other locations in the United States, has raised serious concerns about a large number of people being exposed to this radioactive gas. In response, the U. S. Environmental Protection Agency (EPA), has issued a guidance booklet, "A Citizen's Guide to Radon: What it is and What to Do about It".[1] EPA guidelines recommend initiating corrective action in homes with radon concentrations in excess of 4 picocuries per liter (pCi/l) of air. At radon concentrations of 200 pCi/l temporary relocation is recommended.

In the early spring 1986, a preliminary survey of homes in Clinton, New Jersey, conducted by the New Jersey Department of Environmental Protection (DEP), identified more than 50 homes with indoor radon concentrations greater than 100 pCi/l in the subdivision of Clinton Knolls. Many of these homes had radon concentrations of 600 pCi/l or higher.

At the request of the New Jersey (DEP), EPA's Air and Energy Engineering Research Laboratory, AEERL, initiated a project to develop and demonstrate cost-effective radon reduction techniques in 10 representative Clinton Knolls homes. Radon reduction was to be completed before the beginning of the 1986-1987 heating season to keep the exposures of residents to a minimum. Additional data was collected to add to the general body of information on radon transport and its control in homes; however, the data collected in this study was secondary to the pressing need of demonstrating effective radon reduction techniques in Clinton, New Jersey, before the Fall of 1986.

The subdivision of Clinton Knolls is located near the center of the town of Clinton, New Jersey. The neighborhood is dominated by frame houses with approximately $140 m^2$ ($1500 ft^2$) of floor space. This uniformity is due to development of the subdivision predominantly by a single builder. Some custom-built homes, similar in style and size to the developer-built homes, are scattered among those built by the primary builder. Most of the houses are approximately 18 years old and many of the 103 DEP survey homes are still occupied by their original owners, making this neighborhood an unusually stable one.

The development is built on a dolomitic limestone hill that rises above Main Street and ends at the edge of an abandoned quarry. The hill crests at the interior streets of the subdivision with some rock rising near to the surface in the area. Several homeowners reported that the bedrock beneath their homes had to be blasted out before basements could be built or before sewer lines could be placed. Residents also reported the appearance of sinkholes throughout the neighborhood where the formation of underground caves had caused the earth to subside.

## SELECTION OF DEMONSTRATION HOMES

One hundred and three homeowners who had participated in the DEP radon survey in March and April of 1986 were asked to volunteer their homes for the radon reduction demonstration effort. Fifty-six of the homeowners who volunteered were selected for screening. Figure 1 demonstrates the proximity of the 56 homes participating in EPA's radon screening effort and Table I shows the range of radon concentrations among the 103 homes participating in the DEP radon survey.

The three basic floorplans repeated throughout the subdivision and a small number of diverse floorplans built by independent contractors were investigated. For the purposes of this paper, the floorplans have been assigned the following letter designations.

- Split-level with half basement (combination of slab-on-grade and block basement) - A
- Bi-level (slab-below-grade) - B
- Two story with no basement (slab-on-grade) - C
- Two story with basement (concrete-block basement) - D
- Independent builder floorplans (variety of substructures) - E

During a 1- week period, 56 homes were investigated by a diagnostic team of EPA and Research Triangle Institute personnel. The objective of the house screening effort was to characterize the pool of homes and select 10 homes as representative of the Clinton housing stock. These homes could then be used to demonstrate radon reduction measures.

Table I: Clinton Radon Levels

| Concentraction pCi/l | No. of Hosues | % of Sample |
|---|---|---|
| >2048 | 2 | 1.9 |
| 1024-2047 | 3 | 2.9 |
| 512-1023 | 13 | 12.6 |
| 256-511 | 17 | 16.5 |
| 128-255 | 17 | 16.5 |
| 64-127 | 12 | 11.7 |
| 32-63 | 12 | 11.7 |
| 16-31 | 14 | 13.6 |
| 8-15 | 5 | 4.9 |
| 4-7 | 6 | 5.8 |
| <4 | 2 | 1.9 |
| | 103 | |

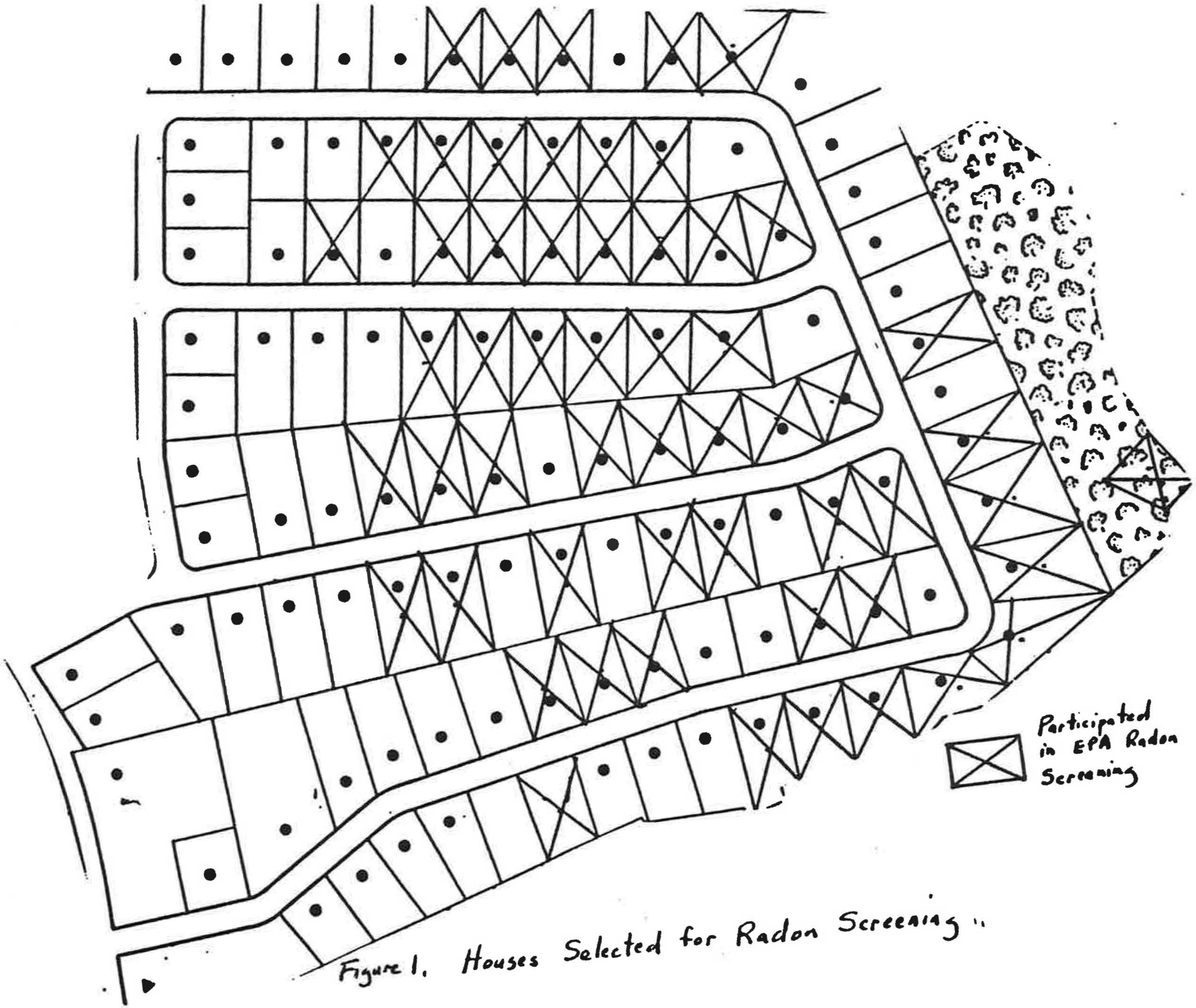


Figure 1. Houses Selected for Radon Screening.

Table II shows the distribution by floorplan of the homes selected for the demonstration study. All of these homes had radon concentrations in excess of 200 pCi/l in the DEP screening, and four of the houses had concentration in excess of 1000 pCi/l.

TABLE II DISTRIBUTION OF HOMES SELECTED FOR DEMONSTRATION

| Construction Design (substructure) | House Number |
|---|---|
| Split Level | C8A |
| (combination slab-on-grade | C30A |
| and block basement) | C39A |
| | C46A |
| Bi-level | C10B |
| (slab-below-grade) | C31B |
| | C48B |
| 2-Story | |
| (slab-on-grade) | C33C |
| (block basement) | C32D |
| Other | C24E |
| (combination slab-on-grade | |
| and dirt crawl space) | |

RADON MONITORING TECHNIQUES

Three radon monitoring techniques were used during this program: radon grab sampling using Pylon flow through scintillation cells, continuous radon monitoring using a Pylon AB-5 monitor together with a passive radon scintillation cell detector (PRD), and an integrating short-term technique using charcoal canisters. Protocols for the use of these techniques are detailed in the Quality Assurance Project Plan (QAPP)[2] and are not repeated in this paper.

Radon Grab Sample Measurements

Radon grab samples were obtained using a Pylon flowthrough scintillation cell attached to a Pylon AB-5 fitted with a Lucas cell adapter. Procedures as described in the EPA document "Interim Indoor Radon and Radon Decay Products Measurement Protocols[3] were followed. Grab samples were used to identify suspected soil gas entry routes. In all homes with sump holes, grab samples were taken in the stream of air exiting the footer drain pipe. Other common locations for effective grab sample collection were:

- Air space in unpaved crawlspaces
- Wall cavities
- Inside open cinder blocks
- Air exiting a hole drilled in a concrete block wall or slab floor
- Air in subslab heating ducts

Although grab sampling can be misleading, in conjunction with other measurements, it proved very useful in identifying major soil gas entry routes.

If the grab sample concentration can be combined with the measurement of soil gas flowrate from an opening to the soil, then a source strength can be calculated for the conditions under which the measurement was taken). The concentration and flowrate are dynamic and are affected by air pressure differentials, snow cover, precipitation, and even by time of day. An example source term calculation was made for house C30A. A soil gas flowrate of 90 $ft^3/h$ (2,500 l/h) was measured entering the building from the footer drains in the sump hole. The radon concentration in a grab sample of the air from the sump hole was 36,000 pCi/l. Under the measurement conditions (approximately 2 to 3 pascals of negative pressure due to both the furnace and clothes dryer operation), this measurement corresponded to a source term of over 91 million pCi/h and would account for an indoor concentraton of between 600 to 1,200 pCi/l given an air exchange rate from 0.5 to 1.0 air changes per hour (ACH). Because air concentrations of radon were from 1,400 to 2,700 pCi/l in this home, the sump hole was considered to be the largest but not the only source of soil gas infiltration to the house.

Efforts were made to measure the difference in pressure between the inside and outside of the house while grab samples were being taken. Because factors such as windspeed and furnace or fan operation can affect the flow of soil gas substantially, pressure difference information allows a reasonable interpretation of seemingly anomolous radon grab sample results and results form other techniques designed to determine the rate and location of radon entry. Pressure difference measurements were made using 0.005 to 0.25 in (.127 to 6.35mm) range magnahelic gauges.

## Continuous Radon Monitoring

Continous monitoring results were helpful in understanding the daily variations in radon concentration in a house and how this pattern, as well as overall radon levels, were affected by natural and powered ventilation, heating systems, and other factors that might influence radon levels.

The ability of the passive monitoring system to respond to temporal variations in radon concentration was tested in the Department of the Energy, Environmental Measurement Laboratory (EML) exposure chamber. In all cases, the field monitoring device was able to track the laboratory equipment response to concentration changes reliably.

The continuous monitoring system was set to count collected air samples at 30-minute intervals. Three 48-hour sampling periods were used to monitor pre- and post-radon reduction gas concentrations.

## Charcoal Canister Monitoring

Short-term integrating monitoring, using activated charcoal monitors, is the method most commonly used in radon screening and assessment studies. In addition, the simplicity and low cost of charcoal canister monitoring made it an attractive confirmatory measurement technique in the current work. The canisters and continuous monitoring devices were routinely deployed simultaneously in the same locations to allow comparison of monitoring results.

In the Clinton homes, radon concentrations varied by as much as a factor of 20 in a 24-hour period prior to the installation of radon reduction equipment. The ability of charcoal canisters to provide reliable measurement information under these conditions is uncertain. George[4] describes tests of the response by charcoal canisters to radon concentrations that varied by two times the lowest concentration during the monitoring period. Analyses of the canisters found radon concentrations to be representative of the average chamber concentration. Unfortunately, reports of tests at the larger concentration differences encountered in Clinton have not been located in a review of the literature.

# INVESTIGATION OF BASEMENT DEPRESURIZATION

In the majority of houses, differential air pressure measurements between basement air and outside air were made. Temperature-driven stack effects and mechanical equipment effects were isolated and the induced pressure differences measured. Pressure difference measurements for two houses are listed in Table III. It was found that:

- Dryers and bathroom fans resulted in a 1 pascal or less negative pressure on a basement.

- Furnaces in the 100,000 to 120,000 BTU/hr ($1.055 \times 10^8$ - $1.266 \times 10^8$ joules) range put 2 to 3 pascals negative pressure on a basement.

- Differential temperatures of 20 to 30 °F (11 to 17°C) resulted in 1 - 3 pascals of negative pressure on a basement.

During the pressure measurements described above with a furnace running, makeup air was drawn from the attic down the cavity around the chimney. In building C48B this amounted to approximately 50 CFM (1.4 $m^3$/min). Measurement of the airflow from the furnace exhaust at the chimney top showed airflow rates of between 100 and 200 CFM (2.8 -4.3 $m^3$/min). Figure 2 (a fan-flow curve for House C48B shows an induced negative pressure of 1 to 2 pascals at 200 CFM (4.3 $m^3$/min) reflecting the pressure difference actually measured in the house when neither the furnace nor the clothes dryer were in operation. Blower door generated fan-flow curves (as measured with blower door tests) were found to be useful in estimating the volume of make-up air required to compensate for basement negative pressures. The curves, when put to this use, were most accurate when generated from data collected with the blower door placed in a basement access door.

To reduce a negative pressure of 3 to 4 pascals to 0 pascals it was found that 7- 10 $ft^2$ (0.65 - 0.93 $m^2$) of window area must be opened to the outside.

It is difficult to make low pressure measurements in the field. Field instruments are only reliable to a lower limit of about 1 pascal. Even low windspeeds have a large impact on the pressure fields surrounding a house. Measurements were made when windspeeds were undetectable to avoid the confounding effects of wind. Toward the end of the diagnostic work, these measurements were made using a more sensitive electronic device assembled using components purchased form Modus Instruments (481 Gleason Rd., Stow, MA 01775). This system has a lower detection limit of 0.25 pascals.

Table III

Pressure Difference Measurements for Two Houses

| | |
|---|---|
| **House C46A** | |
| House closed, outside temp. = 62°F (16.6°C) inside temp. = 67°F (19.4°C) | 0 Pascals |
| Dryer + bath fan on | 1 Pascals |
| Furnace + dryer + bath fan on | 2 Pascals |
| Furnace + dryer + bath fan on inside temp. = 80°F (26.7°C) | 3 to 4 Pascals |
| **House C48B** | |
| House closed, outside temp. = 62°F(16.6°C) inside temp. = 64°F (17.8°C) | 0 Pascals |
| Furnace on | 3 Pascals |
| Furnace on, inside temp. = 93°F (33.8°C) | 4 Pascals |
| Furnace on, inside temp. = 93°F (33.8°C) | 5 to 6 Pascals |
| Furnace on, inside temp. = 93°F (33.8°C) + attic hatch closed | 4 Pascals |

A test was made to gain some insight into the potentially competing effects of increased soil gas entry versus added dilution air when a whole house fan was used to ventilate a building. The results are shown in Figure 3. Although the fan dramatically increased ventilation, 2,000 CFM (57 $m^3$/min), the large negative pressure differential ( 28 pascals) increased the rate of soil gas entry sufficiently to overwhelm the diluting effect. This test was made in only one house and the results depend upon factors that may be peculiar to the individual building, soil gas characteristics.