Proceedings of the 2003 International Radon Symposium – Volume II
American Association of Radon Scientists and Technologists, Inc.
October 5 – 8, 2003

# RADON-RESISTANT NEW CONSTRUCTION (RRNC) EFFICIENCY TESTING IN MANHATTAN, KANSAS

Snead, Bruce and Hanson, Brian

Bruce Snead, Kansas State University, Manhattan Kansas, USA
Brian Hanson, Kansas State University, Manhattan Kansas, USA

**November 2002 to March 2003**

Funding provided by the National Environmental Health Association (NEHA) and the Environmental Protection Agency (EPA) through the State Indoor Radon Grant (SIRG) program. Work performed by the Kansas Industrial Extension Service at Kansas State University and the Manhattan Municipal Code Department at the City of Manhattan.

## Abstract

The Kansas Radon Program assisted the city of Manhattan with conducting a survey of homes built with radon-resistant new construction (RRNC) techniques. The project was part of an EPA initiative to build a database of RRNC homes across the country. Twenty-four homes were initially tested with 13 homes (54%) exhibiting elevated radon levels (average radon value of 4.0 pCi/L or higher). Seven homes were then tested using the EPA RRNC efficiency testing protocol. The average observed reduction in radon was approximately 31%. Multiple construction errors were noted during physical examination of the homes including 1) either uncovered or unsealed sump pit foundation penetrations, 2) excessive horizontal pipe runs, 3) failure to run the vent pipe through the roof, and 4) placement of the vent pipe in non-conditioned spaces such as garages.

## Introduction

Radon gas is a radioactive element that can collect in homes, sometimes in fairly high airborne concentrations. Studies have shown that radon gas is the second leading cause of lung cancer, behind tobacco smoke. As such, exposure to elevated levels of radon in the home can increase the risk for individuals regarding the development of lung cancer.

As of February 2001, all new single-family and two-family homes in Manhattan, Kansas, have been required to be built with radon-resistant new construction (RRNC) building techniques, due to the adoption of the RRNC appendix to the International Building Code (IBC). The goal of RRNC construction is to control indoor radon concentrations, with the stated concentrations to be maintained below 4.0 pCi/L, which is the EPA's recommended action level.

Three primary elements exist with RRNC construction. First, a porous fill is used to level the future foundation of the house. Gravel fill is ideal, as it provides the least resistance to airflow. Sand fill can be used as long as corrugated drain tile is looped through the fill. Second, a polyvinyl sheet is used to separate the fill from the concrete. The polyvinyl sheet acts as a barrier to radon gas, which aids in keeping the radon from penetrating the concrete foundation. Third, a polyvinyl vent stack is run from the fill, through the foundation, and up through the roof of the house. The vent stack provides a means of escape for the radon from under the foundation and the polyvinyl sheet and acts to vent the radon into the atmosphere. However, since RRNC techniques are designed to be inherently passive means of radon control, there is no guarantee that indoor radon levels will be maintained below the 4.0 pCi/L action level.

In order to examine the efficiency of RRNC construction, NEHA and the EPA partnered to provide funds to municipalities to test homes built to RRNC specifications. The city of Manhattan, Kansas, in conjunction with the Kansas State University Research and Extension Service, was one of the award grantees.

## Results

At the time that the Kansas Industrial Extension Service became involved with the project, approximately 60 homes had been built using RRNC construction techniques. Letters explaining the project were sent to all RRNC houses occupied by October 2002. Twenty-four homes responded to the initial letter and were tested to determine existent radon levels.

Results for the initial radon tests are listed in Table 1. All homes were tested with simultaneously deployed electret ion chamber test devices using short-term electret plates, with an average testing period of 163 hours. Homes were kept in closed-house conditions throughout the testing period. Test results for each home were averaged. Of the 24 homes, 13 exhibited average radon values above 4.0 pCi/L.

Following conclusion of the initial testing, volunteers were requested from the 24 homes to conduct further testing using the EPA RRNC testing protocol. This protocol consists of three periods: 1) a five-day simultaneous test with the RRNC passive system uncapped and functional, 2) a seven-day period through which the RRNC passive system vent is capped (making the system temporarily non-operational) and followed by 3) a second five day simultaneous test with the system capped and non-functional.

Nine homes agreed to the additional testing procedure. One of the nine homes was eliminated from testing due to construction features of the roof, which would have made the capping/uncapping process unnecessarily dangerous. A second of the nine homes was disqualified when additional examination of the RRNC vent stack revealed that it had been exited through the side of the house at ground level rather than vented through the roof as required by the RRNC protocol. Seven homes were successfully tested using the EPA RRNC efficiency protocol, results of which are listed in Table 2.

Five of the seven homes tested exhibited a drop in radon levels when the RRNC system was operational, with the average radon reduction being approximately 31%. House #1 indicated that a window in an upstairs bedroom had inadvertently been opened. House #7 indicated that the HVAC system for the house had been turned off and that there was one evening during the testing period where two windows were inadvertently opened on the upper floor but not in the basement where the test kits were located.

A statistical examination of the results (see Table 3) indicated an average radon value of 5.4 pCi/L with RRNC systems operational and 6.6 pCi/L with the systems non-operational. A Student's T-Test indicates that there is no significant difference between the operational and non-operational sample sets ($t=0.4$, $p<0.05$). This result indicates that the absolute radon values between the two sample sets are not statistically different. However, the observed average percent reduction of 31% in radon between the sample sets is a better indicator of system efficiency, due to the low n-value of homes used in the statistical evaluation.

## Discussion

The current study examined the efficiency of RRNC construction techniques for the control of indoor radon concentrations, with the state goal being to maintain radon concentrations below the EPA's action level of 4.0 pCi/L. Homes were tested in Manhattan, Kansas. The homes tested were all approximately two years of age or less.

An examination of the initial test results showed 54% of the 24 homes tested exhibited an average indoor radon value of 4.0 pCi/L or higher during winter testing (November-December 2002). Seven homes were subsequently tested using the EPA's protocol for RRNC efficiency testing. Statistical evaluation of the samples during operational and non-operational phases indicated no significant difference in radon reduction. However, an examination of the percent reduction indicated an average 31% radon reduction across the houses between operational and non-operation phases. This observed reduction indicates that while the RRNC passive systems are not meeting the 4.0 pCi/L goal, the systems are reducing indoor radon concentrations.

Bruce Snead, mitigation specialist and radon program trainer for the Kansas Industrial Extension Service, identified several construction flaws or mistakes during the examination of the houses. In homes containing basement sump pump pits, only one home examined had the pit covered with an airtight seal. Horizontal runs of the vent pipe were excessive in two homes examined when compared to the vertical heights required to reach the roof exit point. One house examined had the vertical exit run piped through the unheated garage. One house had the exit run piped horizontally through the side of the home at ground level, rather than vertically through the home's roof.

These construction flaws contribute to the loss of radon reduction value from the RRNC construction. Long horizontal runs reduce the vent stack's ability to draw radon through it by increasing airflow resistance. Garage-mounted vent stacks also lose pulling ability by losing the heat provided to the vent stack when embedded in interior walls. Non-sealed sump pits provide areas of escape for radon gas from the vent stack itself. The failure to provide for a roof exit point in the case of the sidewall-exited system severely incapacitates the passive movement of radon through the system.

Two items need to be noted concerning results of this study. One, RRNC construction techniques do reduce the amount of indoor radon gas. As noted above, the average percent reduction across the seven houses was slightly more than 31%. Given the possible lung cancer risk factors associated with long-term radon exposure, any reduction in the radon concentration is desirable. Two, errors in following the protocols for installation of RRNC passive control systems deteriorate the overall efficiency of those systems.

However, there is no blame to be given in the observed construction faults. There is a learning curve associated with any new technique, and it is the purpose of this type of research to identify flaws and offer recommendations on corrective measures. Once identified, a design fault can be corrected, and the information gained here will assist in correcting those faults in the future.

**References:**

U. S. Environmental Protection Agency. 1999. Design for a program to measure the effectiveness of passive RADON RESISTANT new construction. Indoor Environments Division, Washington, DC.

## Appendix A. Tables and Figures

Table 1. Preliminary Home Testing

| # | Zip Code | Kit 1 | Kit 2 | Kit Average |
|---|---|---|---|---|
| 1 | 66502 | 1.0 | 0.2 | 0.6 |
| 2 | 66503 | 1.1 | 1.1 | 1.1 |
| 3 | 66502 | 1.3 | 1.3 | 1.3 |
| 4 | 66503 | 1.7 | 1.7 | 1.7 |
| 5 | 66502 | 2.2 | 1.2 | 1.7 |
| 6 | 66502 | 1.9 | 1.8 | 1.9 |
| 7 | 66502 | 2.4 | 1.8 | 2.1 |
| 8 | 66502 | 2.0 | 2.4 | 2.2 |
| 9 | 66502 | 2.6 | 2.4 | 2.5 |
| 10 | 66502 | 2.6 | 2.4 | 2.5 |
| 11 | 66502 | 3.5 | 3.7 | 3.6 |
| 12 | 66502 | **4.4** | 3.8 | |
| 13 | 66502 | **4.4** | **4.1** | |
| 14 | 66502 | **4.4** | **4.3** | |
| 15 | 66502 | **5.4** | **4.9** | |
| 16 | 66502 | **4.9** | **5.4** | |
| 17 | 66502 | **5.4** | **5.0** | |
| 18 | 66502 | **6.1** | **6.0** | |
| 19 | 66502 | **6.0** | **6.2** | |
| 20 | 66502 | **5.5** | **6.7** | |
| 21 | 66502 | **6.0** | **6.7** | |
| 22 | 66502 | **8.7** | **8.7** | |
| 23 | 66502 | **10.1** | **9.5** | |
| 24 | 66502 | **10.3** | **10.4** | 10.4 |

Table 2. EPA RRNC Test Protocol Houses

| # | Zip Code | Preliminary Test | House Operational | House Non-operational | Percent Reduction |
|---|---|---|---|---|---|
| 1 | 66502 | 2.3 | 2.4 | 1.9 | N/A |
| 2 | 66502 | | 3.8 | | **17.4%** |
| 3 | 66502 | | | | **41.4%** |
| 4 | 66502 | | | | **15.8%** |
| 5 | 66502 | | | | **39.2%** |
| 6 | 66502 | | | 11.1 | **45.0%** |
| 7 | 66502 | 10.1 | 12.1 | | N/A |

## Appendix B. Statistical Results from the RRNC Efficiency Testing

Table 3. Statistical Results

| | **House Operational** | House Non-operational |
|---|---|---|
| Mean | **5.4** | **6.6** |
| Standard Deviation | **3.1** | **2.9** |
| Student's T-Test | | 0.4 |