# Radon Resistant New Construction (RRNC) Efficiency Testing January 2005 through February 2005

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## Abstract

The Kansas Radon Program performed a follow-up round of efficiency testing of homes built with Radon Resistant New Construction (RRNC) techniques in Manhattan, Kansas. The project was designed to review performance and identify whether defects identified during the November 2002-January 2003 testing program (performed in conjunction with the National Environmental Health Association (NEHA), the EPA and the City of Manhattan), were being reduced or eliminated. Eleven homes volunteered to undergo efficiency testing as per the EPA RRNC efficiency testing protocol. Of the 11 homes, 4 homes (36%) exhibited elevated radon levels (average radon value of 4.0 pCi/L or higher) during the operational phase of the testing. The average observed percent reduction in the RRNC systems was 36.6%. Construction errors similar to those identified during the November 2002 testing period were found, including: 1) unsealed sump pit foundation penetrations, 2) excessive horizontal pipe runs, and 3) inadequate attic bracing on horizontal pipe runs.

## 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 2003). 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 polyethylene sheet is used to separate the fill from the concrete. The sheet acts as a barrier to radon gas, which aids in keeping the radon from penetrating the concrete foundation. Third, a minimum three inch diameter plastic vent stack is ran 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 polyethylene sheet and acts to vent the radon into the atmosphere. However, since RRNC techniques are designed to control radon passively, without the use of a fan to induce suction, 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, along with the Kansas State University Research and Extension Service, was one of the award grantees.

Nine homes agreed to participate in the first RRNC efficiency 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, the results of which are listed in Table 1.

Table 1. EPA RRNC Test Protocol Houses - First Round - November 2002

| # | Zip Code | Preliminary Test | House Operational | House Non-operational | Percent Reduction |
|---|---|---|---|---|---|
| 1 | 66502 | 2.3 | 2.4 | 1.9 | N/A |
| 2 | 66502 | **4.4** | 3.8 | **4.6** | **17.4%** |
| 3 | 66502 | **5.2** | **4.1** | **7.0** | **41.4%** |
| 4 | 66502 | **5.2** | **4.8** | **5.7** | **15.8%** |
| 5 | 66502 | **6.1** | **4.8** | **7.9** | **39.2%** |
| 6 | 66502 | **6.1** | **6.1** | **11.1** | **45.0%** |
| 7 | 66502 | **10.1** | **12.1** | **7.7** | N/A |

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 2) 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.

Table 2. Statistical Results – First Round – November 2002

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

A follow-up round of testing was proposed for the winter in the Kansas Radon Program's work plan for the State Indoor Radon Grant (SIRG) Year 15 funding period. A total of 149 homes constructed since the testing period began in November 2002 were contacted to participated in the new round of RRNC efficiency testing. Fifty-three letters were returned as undeliverable, indicating that those homes were as yet unoccupied or still under construction. Eleven homes volunteered to undergo the testing procedure.

Results

Eleven homes were tested during the operational phase of the efficiency testing protocol. The average exhibited radon value was **3.4 pCi/L** with a standard deviation of 2.4 (See Table 3). Four homes (36%) exhibited operational phase radon concentrations of 4.0 pCi/L or greater. Home number 2 was eliminated from the non-operational phase due to safety concerns related to roof design and the placement of the radon vent pipe. The average exhibited radon value during the non-operational phase was **4.8 pCi/L** with a standard deviation of 3.4. The average percent reduction across the 8 homes that exhibited differential radon values was **36.6%.**

Table 3. EPA RRNC Test Protocol Houses - Second Round - January 2005

| # | Zip Code | House Operational | House Non-operational | Percent Reduction |
|---|---|---|---|---|
| **1** | 66502 | 0.8 | 1.5 | 46.7% |
| **2** | 66502 | 3.7 | Not Tested | N/A |
| **3** | 66502 | 0.8 | 1.0 | 20% |
| **4** | 66502 | **6.9** | 11 | 37.3% |
| **5** | 66502 | 3.7 | **5.8** | 37.9% |
| **6** | 66502 | **5.4** | **7.6** | 28.9% |
| **7** | 66502 | 1.9 | **4.0** | 52.5% |
| **8** | 66502 | 1.3 | 2.0 | 35% |

| | | | | |
|---|---|---|---|---|
| **9** | 66502 | **7.4** | **6.9** | N/A |
| **10** | 66502 | 1.3 | 1.1 | N/A |
| **11** | 66502 | **4.4** | **6.7** | 34.3% |

As noted above, home number 2 was eliminated from the non-operational testing phase due to safety concerns. The vent pipe on home number 9 was found to have fallen into the home's attic when Kansas Radon Program personnel boarded the roof to place the cap on the vent pipe. When the pipe was reinserted through the roof and a proper drainage level for the pipe was achieved, it was noted that there was water trapped in the pipe, making it non-functional during the operational testing phase. The system in home number 10 was examined, but no identifiable flaws were located. The lack of significant change in radon values between the operational and non-operational phases indicates that the RRNC system is having little to no effect on the homes radon gas concentrations.

A Student's T-Test indicates that there is no significant difference between the operational and non-operational sample sets **(t=0.3, 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 **36.6**% 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. The statistical results are essentially unchanged from the November 2002 testing program results.

Table 4. Statistical Results - Second Round - January 2005

| | **House Operational** | **House Non-operational** |
|---|---|---|
| **Mean** | 3.4 | 4.8 |
| **Standard Deviation** | 2.4 | 3.4 |
| **Student's T-Test** | | **0.3** |

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 1 year of age or less. The testing regimen was used to identify whether or not previous construction errors identified during the November 2002 testing period had been corrected by area home builders.

An examination of the initial test results, 36% of the 11 homes tested exhibited an average indoor radon value of 4.0 pCi/L or higher during winter testing (January 2005). These results compare to 54% of the 24 homes screened in November 2002. As with the November 2002 testing period, 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 36.6% radon reduction across the houses between the operational and non-operation phases, compared

with an average 31% reduction in November 2002. This observed reduction indicates that while the RRNC passive systems are not always meeting the 4.0 pCi/L goal, the systems are reducing indoor radon concentrations.

As was the case with the group of homes tested during the November 2002 program, several construction errors were identified. Several homes had covered but unsealed/caulked sump pits. Multiple homes exhibited horizontal pipe runs, either in the level where the pipe entered the foundation or in the attics. One home was found to have the radon vent pipe fallen into the attic due the installation of upside-down J-hooks being used to support a horizontal run. Another home had the pipe exit through the attic portion over the garage, outside the heated envelope of the home.

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 reduce stack effect induced venting suction by placing the stack outside the heated area of the home. Non-sealed sump pits provide areas of escape for radon gas from the vent stack itself.

Two items need to be noted concerning the 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 eight houses was slightly more than **36%**. 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.