Effectiveness of Passive Radon-Reduction Systems in New Fort Collins Homes

Prepared by the City of Fort Collins
for the
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Indoor Radon Grant[1] Program

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Summary

The purpose of this project was to determine the effectiveness of radon-resistant new construction [RRNC] in a Colorado Front Range community. This is important because the US Environmental Protection Agency recommends RRNC for all new homes built within areas the Agency has designed as Radon Zone 1, which includes most of the State of Colorado. Homes in Zone 1 areas are likely to have radon levels above 4 picoCuries per liter of air [4 pCi/l]. USEPA and other health authorities recommend that homes with radon levels above 4 pCi/l be mitigated to reduce radon exposure. RRNC is an important tool to reduce population radon exposure, because RRNC is less expensive than mitigation after construction.

Using the USEPA protocol for "cap-on/cap-off" radon studies, we tested 65 new Fort Collins homes that were built in accordance with RRNC requirements adopted into the building code as of January 2005. We found that RRNC reduces radon by an average of 49%, which confirms the findings of similar studies in other part of the nation. We further found that the number of homes above 4 pCi/l dropped from 83% with the radon system disabled [capped] to 40% with the radon system enabled [uncapped]. Thus RRNC reduces radon by about half on average, and reduces the number of homes above 4 pCi/L by about half, as well. Because RRNC includes provision for later addition of a radon exhaust fan, it is easy for the owners of radon-resistant new homes to reduce radon levels even further.

These results will be useful to builders that are considering RRNC as a value-added feature for their product, and for local governments that are considering RRNC either as a guideline or a requirement for new homes.

Purpose

Fort Collins City Council amended the building code to require radon-resistant new construction [RRNC] in single-family homes and duplexes as of January 1, 2005. A passive radon-reduction system is required, consistent with Appendix F of the International Residential Code [2003]. The required system includes sub-slab aggregate or equivalent, a vent pipe ascending within the heated building envelope from the sub-slab through the roof, and sealing/caulking of all foundation penetrations and joints. When they decided to make RRNC

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mandatory, the City Council considered three previous studies cited by Kladder[2] that indicated the passive system would reduce radon by 47% on average. The purpose of this study was to determine the actual effectiveness of RRNC in Fort Collins homes, and to provide builders and construction inspectors with early warning of errors that may occur during RRNC installation and inspection.

Methodology

The effectiveness of radon-resistant new construction (RRNC) was determined in 65 new Fort Collins homes using the USEPA protocol[3] for "cap-on/cap-off" radon studies. The study methodology is called "cap-on/cap-off," because we temporarily disable the radon-reduction system by capping the vent pipe, in order to approximate the radon level that would occur with no radon system installed [cap-on test]. We also test with the passive system functioning normally for comparison [cap-off test]. All homes in this study were occupied during testing. Each volunteer homeowner was advised that closed-house conditions were required and each agreed to maintain closed-house conditions throughout the test period.

The City contracted with Radiation Technologies, LLC, to perform the testing, using electret ion chambers [E-PERMs]. The City and contractor had the following responsibilities.

City responsibilities:

- Recruit volunteer homeowners and provide their contact information to the contractor.
- Provide any written materials needed to communicate with customers.

Contractor responsibilities:

- Arrange with volunteers for access to interiors and roofs of homes.
- Inspect the radon system in each home.
- Test each home by the cap-on/cap-off methodology using E-PERMS. The work sequence for each home was as follows:
  - Visit 1 – inspect radon reduction system, place two devices for cap-off test
  - Visit 2 – retrieve test devices, place cap on vent pipe
  - Visit 3 – place two devices for cap-on test [seven days after Visit 2]
  - Visit 4 – retrieve test devices, remove cap from vent pipe
- Provide a report of test results to each volunteer homeowner.

Volunteer recruitment

The Neighborhood and Building Services Department provided the addresses of all homes constructed since January 1, 2005. Fort Collins Utilities provided contact information for the

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[2] Kladder, D.L.; Proposal for the Addition of Radon Resistant Construction Techniques to the Appendix Of the Uniform Building Code – Supplemental Information, submitted to the International Conference of Building Officials, 1996

[3] "Design for a Program to Measure the Effectiveness of Passive Radon-Resistant New Construction," USEPA 7/22/1999

residents of the new homes, subject to a privacy protocol to assure contact information would remain private. Residents were contacted by postcard and follow-up phone calls. We sent 777 postcards inviting homeowners to participate in the study, including brief information about radon, a pointer to more information on the City website, and a short survey.

The more-detailed information provided on the City web site included information on the health risk of participation in the study. In particular, we disclosed that the cap-on portion of the test would increase radon exposure for the few days the radon-reduction system was disabled.

Follow-up phone calls were successful in reaching only about 20% of invitees due to wrong numbers. About 16%, or 129 volunteers, responded to the postcards and calls. Most of these, 93%, had not yet tested their home for radon, and most were willing to have their home tested in the City Program.

Homeowners were provided with the radon test results, so they could make informed decisions about whether to activate their systems. Homeowners were also given the results of the radon system inspection. In cases where the inspection showed mistakes or omissions, homeowners could either ask their home builders to correct them, or could ask the Neighborhood and Building Services Department to work with the builder to get them corrected.

Results—Radon System Inspection

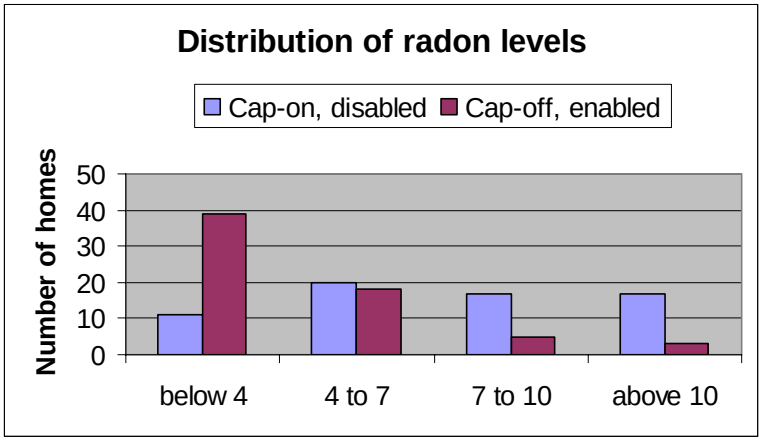
Radiation Technologies, LLC, inspected each passive radon-reduction system for compliance with building code requirements. Only the accessible portions of the system were checked, e.g., in unfinished areas, mechanical rooms, crawl spaces, attics, etc.

The three most frequent errors noted by the contractors were a lack of bird screen on the vent pipe (in almost all of the homes), the caulking/sealing of slab penetrations and joints was not done or done improperly, and omission of radon system labels.

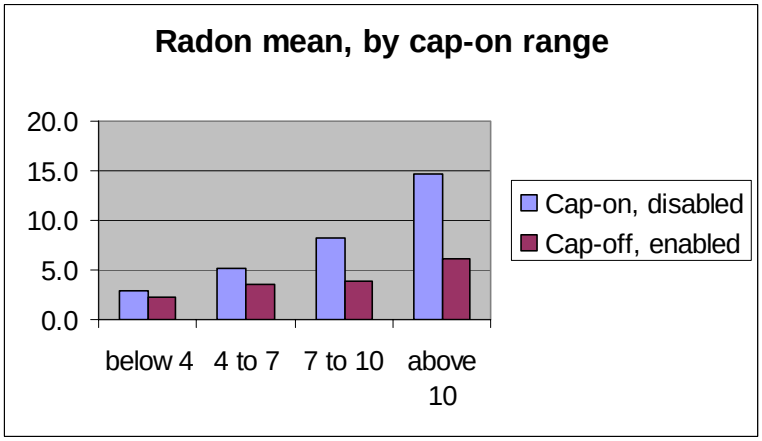
Neighborhood and Building Services Department is responsible for implementing the RRNC requirement as part of the building code. We expected that both home builders and building inspectors would go through a learning process following the adoption of new building codes, and the inspection data bears this out. After placing the houses in order by date of completion, more mistakes were noted in the earlier homes than the ones more recently built. With time is factored in, the results are encouraging – builders and inspectors appear to be getting better at building and evaluating the radon systems, as there are fewer problems noted on inspection forms in the more recent months as opposed to the first few months of inspections.

Results – Radon System Effectiveness

Sixty-five houses were tested from March through May 2006, and the table on the last page shows the data. The average radon change is -49% or -4.0 pCi/L [PicoCuries per Liter]. Radon change ranged from -19.1 to +3.1 pCi/L.



The graph above shows the distribution of cap-on and cap-off measurements. With radon systems disabled [cap-on], 54 houses [83%] are above four pCi/L. When the radon systems are enabled [cap-off], the number of houses above 4 drops to 26 [40%].



The graph above and the table below show that the higher-radon houses benefit from more radon reduction with the passive system. For example, houses in the above-ten range with the system disabled [cap-on] saw an average change of -8.5 [-58%] when the system was enabled [cap-off], while houses below 4 saw an average change of only –0.6 [-20%].

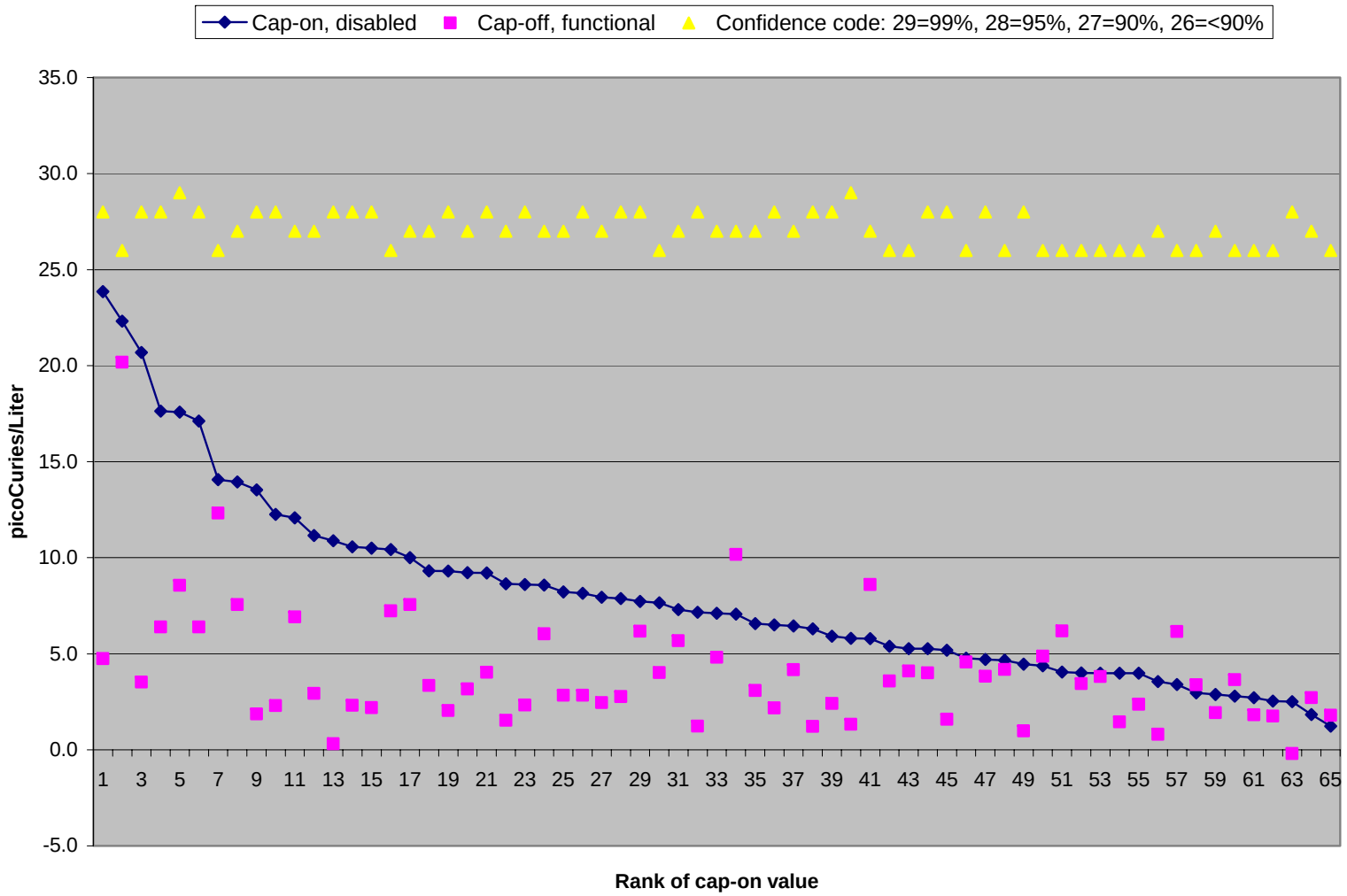
Range [cap-on]	Average with cap-on, pCi/L	Average with cap off, pCi/L	Change, pCi/L	Change, percent
Below 4	2.9	2.3	-0.6	-20%
4-7	5.2	3.6	-1.7	-32%
7-10	8.2	3.9	-4.3	-53%
Above 10	14.6	6.1	-8.5	-58%

The graph and table below provide a detailed look at the data. The line shows the cap-on radon level for each house in order from highest to lowest. Below the line are the uncapped radon levels for each house. Above the line are indicators of the statistical confidence that the cap-on and cap-off levels are different, using Student's t-test. All the houses that have increases are at the low end of the range, as are most of the lower-confidence measurements.

Conclusion

Testing of 65 new Fort Collins homes shows an average radon reduction of 49% attributable to the installation of passive radon-reduction systems. However, 40% of homes with a passive system have radon above 4 pCi/L, the USEPA-recommended action level. These 40% can easily activate their radon systems by adding an in-line fan.

Radon change and confidence level for individual homes



Radon change and confidence level for individual houses

Cap-on rank	Cap-on, pCi/L	Cap-off, pCi/L	Change, pCi/L	Change, percent	Confidence level
1	23.9	4.7	-19.1	-80%	95%
2	22.3	20.2	-2.1	-10%	<90%
3	20.7	3.5	-17.2	-83%	95%
4	17.6	6.4	-11.2	-64%	95%
5	17.6	8.6	-9.0	-51%	99%
6	17.1	6.4	-10.7	-63%	95%
7	14.1	12.3	-1.7	-12%	<90%
8	13.9	7.6	-6.4	-46%	90%
9	13.5	1.9	-11.7	-86%	95%
10	12.3	2.3	-10.0	-81%	95%
11	12.1	6.9	-5.2	-43%	90%
12	11.2	2.9	-8.2	-74%	90%
13	10.9	0.3	-10.6	-97%	95%
14	10.6	2.3	-8.2	-78%	95%
15	10.5	2.2	-8.3	-79%	95%
16	10.4	7.2	-3.2	-31%	<90%
17	10.0	7.6	-2.5	-24%	90%
18	9.3	3.4	-6.0	-64%	90%
19	9.3	2.0	-7.3	-78%	95%
20	9.2	3.2	-6.1	-66%	90%
21	9.2	4.0	-5.2	-56%	95%
22	8.6	1.5	-7.1	-82%	90%
23	8.6	2.3	-6.3	-73%	95%
24	8.6	6.0	-2.5	-30%	90%
25	8.2	2.8	-5.4	-65%	90%
26	8.2	2.8	-5.3	-65%	95%
27	7.9	2.4	-5.5	-69%	90%
28	7.9	2.8	-5.1	-65%	95%
29	7.7	6.2	-1.5	-20%	95%
30	7.7	4.0	-3.6	-47%	<90%
31	7.3	5.7	-1.6	-22%	90%
32	7.2	1.2	-5.9	-83%	95%
33	7.1	4.8	-2.3	-32%	90%
34	7.1	10.2	3.1	44%	90%
35	6.6	3.1	-3.5	-53%	90%
36	6.5	2.2	-4.3	-66%	95%
37	6.4	4.2	-2.3	-35%	90%
38	6.3	1.2	-5.1	-81%	95%
39	5.9	2.4	-3.5	-59%	95%
40	5.8	1.3	-4.5	-77%	99%
41	5.8	8.6	2.8	48%	90%

42	5.4	3.6	-1.8	-34%	<90%
43	5.3	4.1	-1.2	-22%	<90%
44	5.3	4.0	-1.3	-24%	95%
45	5.2	1.6	-3.6	-69%	95%
46	4.8	4.6	-0.2	-4%	<90%
47	4.7	3.8	-0.9	-19%	95%
48	4.7	4.2	-0.5	-10%	<90%
49	4.5	1.0	-3.5	-78%	95%
50	4.4	4.9	0.5	11%	<90%
51	4.1	6.2	2.1	53%	<90%
52	4.0	3.4	-0.6	-14%	<90%
53	4.0	3.8	-0.2	-5%	<90%
54	4.0	1.5	-2.5	-63%	<90%
55	4.0	2.4	-1.6	-41%	<90%
56	3.5	0.8	-2.7	-77%	90%
57	3.4	6.2	2.8	81%	<90%
58	3.0	3.4	0.4	14%	<90%
59	2.9	1.9	-1.0	-33%	90%
60	2.8	3.6	0.9	31%	<90%
61	2.7	1.8	-0.9	-33%	<90%
62	2.5	1.8	-0.8	-31%	<90%
63	2.5	-0.2	-2.7	-108%	95%
64	1.8	2.7	0.9	47%	90%
65	1.2	1.8	0.6	45%	<90%
Averages	8.0	4.1	-4.0	-49%	