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Richard Klein, James Olson

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SOLAR RADON REDUCTION SYSTEM DEMONSTRATION PROJECT

Richard J. Klein, II
James A Olson

Executive Summary

The Solar Radon Reduction System (SRRS) was installed in two test homes to evaluate the system's effectiveness in reducing indoor radon levels. Radon levels were reduced by 24% and 29% during operation of the system in a solar only mode (ventilation/pressurization during periods of solar insolation) over a 24 hour period. Extended operation of the system (solar only and during operation of the dwelling's heating system) accomplished a maximum radon level reduction of 56% as compared to background levels. Due to the introduction of solar heated air into the dwelling, radon reduction was accomplished at a net energy gain.

Introduction

Radon is a naturally occurring radioactive gas generated from the decay of uranium found in many soils. As a gas, radon can infiltrate into dwellings through walls, cracks and other soil/foundation interfaces. Human exposure to elevated levels of radon is a suspected cause of increased lung cancer occurrences. Common methods to reduce the infiltration and accumulation of radon in a dwelling include; sealing the foundation, sub-foundation ventilation, pressurization and/or increased ventilation of the dwelling.

The SRRS incorporates a variation of the pressurization/ventilation radon reduction method. The system operates by introducing forced draft, solar heated, outside air into the home. This introduction of air reduces radon concentration through simple dilution and reduced infiltration (due to pressurization of the structure).

Short term test data were collected operating the system in a solar only mode; heated air (80°F minimum) introduced into the test homes during periods of adequate solar insolation. Long term evaluations were conducted operating the system in the solar mode and also at times when home heating demands required operation of the furnace. Background radon data were collected at the onset of the demonstration and are used as the baseline from which system effectiveness is measured.

Objectives

The SRRS Demonstration Project was carried out to evaluate the SRRS's effectiveness in terms of

- Short term residential radon reduction.
- Long term residential radon reduction.
- Energy benefit/cost.

Methods and Materials

The demonstration was conducted in two (2) test homes. Test home #1 is a 900 ft^2, 1 and 1/2 story wood frame home equipped with a natural gas water heater, clothes dryer and forced draft furnace. Test home #2 is a single story, 1270 ft^2 wood frame home with all electric appliances including a resistant heat, forced draft furnace. Both homes have partial basements and crawl spaces under the living area. Other than installation of the SRRS, neither home had been modified for radon mitigation.

Two continuous radon monitors were initially operated, side-by-side in test home #2, to evaluate the precision of the instruments. Monitors were then installed in each of the two test homes for collection of background data. During the background collection period, both test homes were maintained in a "closed house condition" (USEPA, Document # 402-R-92-004, 1992) with the SRRS deactivated and sealed.

The short term evaluation of SRRS effectiveness was conducted with the SRRS operating in a "solar only" mode. Solar heated, outside air was introduced into the test homes during times when adequate solar energy was available to heat the outside air above the ambient temperature of the test home. Operation of the system in this mode typically occurred between the hours of 9:00 AM to 4:00 PM. Solar heated air entered the homes via an induced draft fan wired to a thermostat located on the surface of the solar collector. The thermostat limited operation of the fan to times when the temperature of the induced air exceeded the ambient temperature of the home; approximately 80°F minimum. Induced air temperatures as high as 120°F were recorded.

The project's long term evaluation, allowed operation of the SRRS in the solar only mode and also at times when home heating demands required operation of the furnace. Operation of the SRRS during periods of furnace operation was accomplished using an electrical relay circuit between the furnace fan and the SRRS fan. Both operations were independent of one another and allowed for longer SRRS operation than was observed by solar operation only. In addition to longer operation, the relay between the furnace and the SRRS fan allowed operation of the system at intervals throughout the day.

Radon data were collected in each test home using two continuous radon monitors/data loggers (Honeywell, Model 05-418) operated in accordance with EPA protocol (USEPA, Document # 402-R-92-004, 1992). Radon data were measured and recorded as the mean of 4 hour intervals. Dwelling pressure data was collected using manometers. The volume of air introduced into the test homes by the SRRS induced draft fans was calculated using manufacturer data and confirmed with pitot tube velocity and duct area measurements. The time of SRRS and furnace operation was measured and recorded daily using elapsed time hour meters.

Results

Both radon monitors were operated side-by-side in test home #2 to evaluate the precision of the instruments. Based on the ten day means of 8.4 and 8.3 picocuries per liter (pCi/l), both instruments recorded statistically similar results at a 99% confidence interval. The results of a carbon canister test, conducted during the precision test time interval, showed a radon concentration of 8.1 pCi/l.

Background data collected prior to operation of the SRRS showed mean radon concentrations of 4.3 and 8.0 pCi/l in test homes #1 and #2 respectively. (Test home #1 background data was collected over a 14 day period. The test home #2 value was obtained over a 10 day period.)

The SRRS in test home #1 produced an air flow of 65 to 130 cubic feet per minute (cfm) or 0.6 to 1.2 air changes per hour (ACH). The two flow rates were dependent on whether one or both SRRS solar panels were in operation. An air flow of 75 cfm or 0.4 ACH was measured in test home #2 as a result of the single SRRS panel operation.

Figures 1 and 2 show the short term (24 hour interval) effectiveness of the SRRS for test homes 1 and 2 respectively. The y-axis represents the mean of all data collected during the solar only operational mode, including days when solar insolation was insufficient to cause panel operation, and previously recorded background data. The x-axis represents the midpoint of the time interval during which the radon concentration was measured (i.e. 2:30 PM represents the time interval from 12:30 PM to 4:30 PM).

Figure 1. Average Radon Concentration vs. Time of Day - Test Home #1

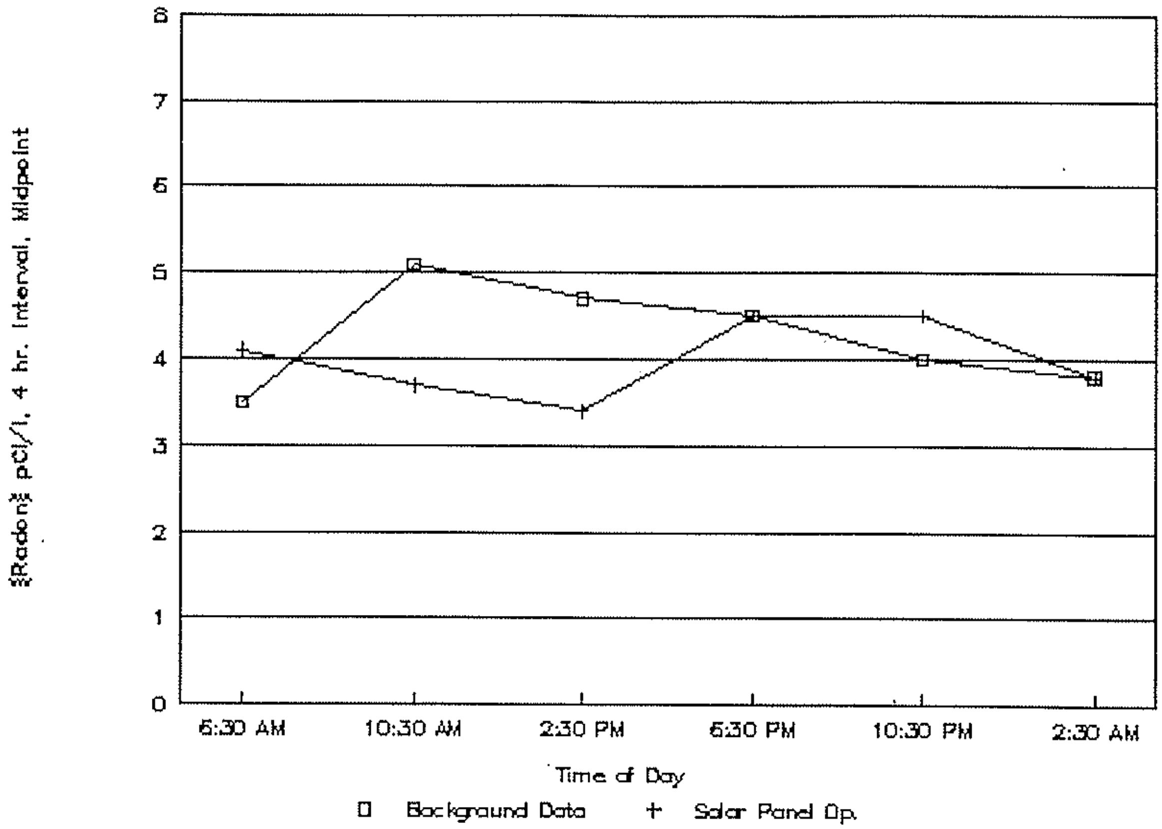
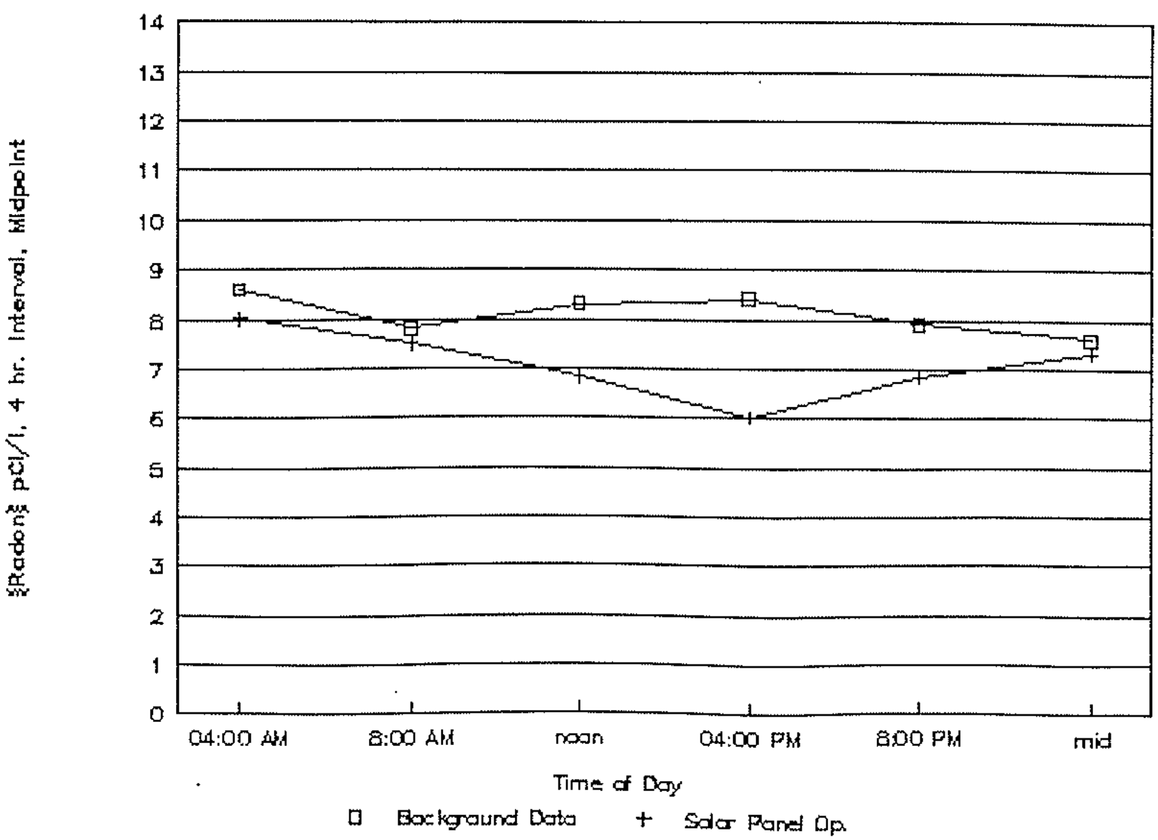


Figure 2. Average Radon Concentration vs. Time of Day - Test Home #2



As compared to background radon concentrations, both test homes showed a reduced radon concentration during the late morning and early afternoon hours. The general trend of reduced mid-day radon concentration directly correlates with the SRRS solar insolation operational time period (generally 10:00 AM and 4:00 PM). Increasing, and near background, radon levels were observed during periods of the day when the panel was not operating.

Figures 3 and 4 show the effect of the SRRS on a long term basis. These figures show average daily radon concentration versus the time of panel operation. Both solar only and solar/furnace operational mode data are presented and plotted using a simple linear regression. Figure 3 (test home #1) shows no correlation between radon concentration and the time of panel operation. Figure 4 (test home #2) show an obvious, direct relation between radon concentration and time of panel operation.

Figure 3. Average Radon Concentration vs. Hours of Panel Operation - Test Home #1

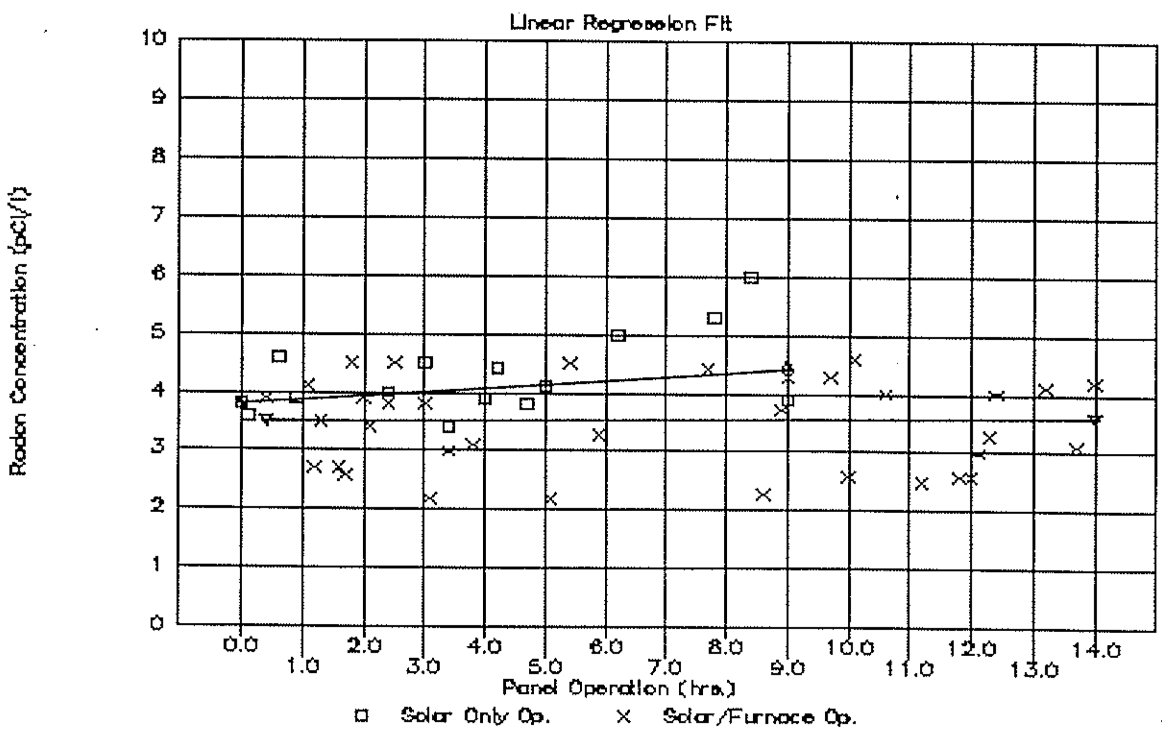


Figure 4. Average Radon Concentration vs. Hours of Panel Operation - Test Home #2

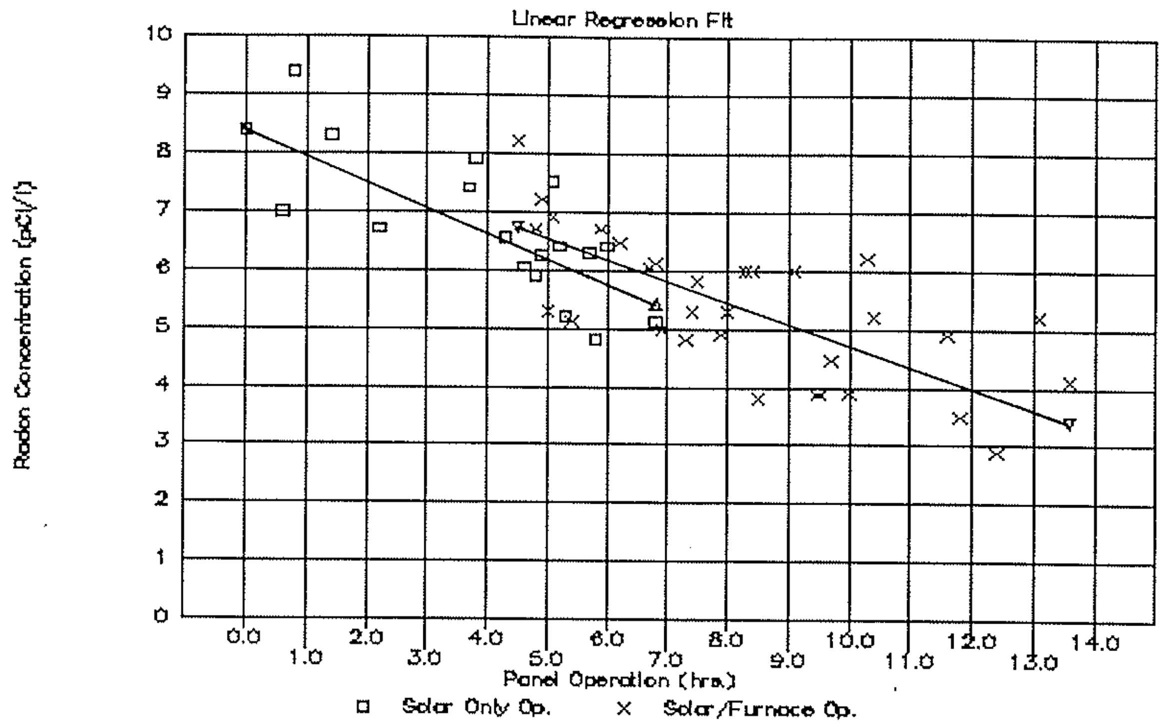


Table 1 shows the SRRS energy impact during the months of January, February and March. Total heat gain was calculated based on the cumulative volume of SRRS heated air introduced into the test homes (BTU = specific heat of air x mass x $(T_1 - T_0)$). During times when the SRRS was operating in response to furnace operation and when insufficient solar insolation was available to produce heated air (i.e. cold air introduced into the home) a heat loss was experienced. This heat loss was calculated using the modified infiltration heat loss equation shown below.

BTU = heat capacity of air x no. of air exchanges per hr. x (hr. of non-solar panel operation/24 hr.) x vol. of indoor air x 24 hr. x degree-day (Iowa Energy Policy Council, "Passive Solar Information Manual")

Net heat gain was calculated by subtracting the heat loss from the total heat gain. Dollars saved values were obtained by multiplying the net heat gain by an average electrical energy rate of $0.028/Kilowatt-hour ($8.10/MBTU). The operational costs of the 1 amp SRRS fan was assumed insignificant and therefore not included in the energy calculations.

TABLE 1

	Total Heat Gain	Net Heat Gain	$ Saved
Test Home #1	2.5 MBTU	1.1 MBTU	$9.17
Test Home #2	1.4 MBTU	0.2 MBTU	$1.21

As can been seen from Table 1, operation of the SRRS yielded a net, albeit small, energy savings in both test homes.

Discussion

SRRS solar only operation achieved a 29% and 24% average mid-day radon level reduction in test homes 1 and 2 respectively over a 1 1/2 month test period. As averages, these values include approximately 15 days when the system ran less than 1 hour. Due to continued radon infiltration, night-time and early morning radon levels returned to near background levels.

In order to evaluate the long term effect of SRRS operation on radon concentration, the system was modified to operate during times of adequate solar insolation and during periods of furnace operation. These data, plotted against hours of SRRS operation, showed mixed results. Test home #1 showed no correlation between radon concentration and hours of system operation. This may be attributed to the rate in which radon infiltrated the home during periods of non-SRRS operation. This assumption is supported by the relative steep slope of the Figure 1 curve between the time period of 2:30 PM and 6:30 PM. Test home #2 showed a direct correlation between radon concentration and hours of panel operation, as shown graphically in Figure 2. At maximum panel operation, a 56% radon reduction was achieved as a result of SRRS operation. In order to obtain EPA's recommended radon concentration level, 12 hours of solar operation at a 75 cfm flow was needed.

Commercially available ventilation/pressurization radon mitigation systems, including those with air-to-air heat exchangers, operate with a net energy loss due to the introduction of below ambient temperature air into the home. The solar aspect of the SRRS achieves a net conventional energy gain by introducing above ambient temperature solar heated air into the home. Long term energy savings are likely to be higher since the recorded solar insolation received during this test period was approximately half of the average value available to this part of the country during the period of January through March. Construction and installation of the SRRS was accomplished at approximately 10 percent of the cost of the commercially available systems.

Conclusion

Initial test results show the SRRS to be an effective radon reduction technique. Additional test data, either in a controlled environment or on a statistically valid number of test houses, is necessary to fully document the effectiveness of the system. While the radon reduction effectiveness of the system is expected to vary from installation to installation, improved indoor air quality and energy cost savings are expected in all cases.