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MINI FAN FOR SSD RADON MITIGATION IN NEW CONSTRUCTION

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ABSTRACT

Subslab depressurization (SSD) systems in new houses constructed with well sealed slabs and good aggregate beds will probably achieve excellent radon mitigation performance with fans that are considerably smaller than the 80 Watt fans that are currently recommended. This paper describes the development, testing, and evaluation of a low power radon mitigation fan for installation in new houses. This "mini SSD fan" uses only 10 Watts of power, and its radon mitigation performance is shown to be almost as good as the larger fans. Since the EPA plans to recommend the installation of SSD systems in hundreds of thousands of houses that are constructed each year in high radon areas, the long term energy savings involved in reducing fan power could involve billions of dollars. In addition, the mini SSD fan lowers the installation cost of the radon mitigation system, and this might encourage more builders to follow with the EPA recommendations.

BACKGROUND

One strategy for radon mitigation in new construction is for builders in areas with high radon levels to install SSD systems in all the houses that they build. Experience with SSD in new construction suggests that when houses are constructed with SSD combined with a well sealed foundation and a porous aggregate layer, then the performance of SSD radon mitigation has been shown to be excellent. Although many houses with these systems would not have had a radon problem above the EPA action level of 4 pCi/L, even the lower level houses would probably experience some radon mitigation. Since most radon exposure occurs in these lower level houses (due to their large numbers), the net result of installing SSD in all houses in high radon areas is a substantial decrease in radon exposure for occupants of these houses.

A primary objection to installing SSD systems in all houses would be the costs, both for initial installation and for energy and eventual replacement. This objection could be reduced by using the lowest cost components consistent with good radon mitigation performance, long life, and low energy costs. This paper describes the development, test, and life cycle cost evaluation of a low power SSD radon mitigation fan for installation in new houses. This "mini SSD fan" uses 10 Watts of electric power compared to the 80 Watts of the standard fan, and its performance is shown to be almost as good as the larger fans. Since the EPA plans to recommend the installation of SSD systems in hundreds of thousands of houses that are constructed each year in high radon areas, the long term energy savings involved in reducing fan power could involve billions of dollars, and these energy savings might provide some assistance in solutions to problems such as global warming and U.S. energy independence. In addition, the mini SSD fan lowers the installation cost of the radon mitigation system, and this might encourage more builders to follow the EPA recommendations.

PREVIOUS EXPERIENCE

Although SSD is by far the most common radon mitigation technique, the details of its operation are not entirely clear and the size of the fan that is necessary for effective mitigation is not well understood. As a result, most mitigators use 80 Watt fans for most of their mitigation jobs, and most of the industry experience is based on the use of these fans. For new house construction, it seems that smaller fans might be successful if the builder provides a good site preparation by installing at least a 4" depth of large diameter aggregate under the slab, and by sealing all slab penetrations. Several documents have been written about construction details for radon resistant new construction, including: a new ASTM standard[1], a Bonneville Power Administration report[2], and the EPA new construction guide[3]. Unfortunately, these documents do not contain much discussion of fan performance versus size or of life cycle costs. The EPA will soon issue recommendations on model code language for radon resistant new construction, and there will be a technical support document with life cycle cost calculations.

However, there is one study that suggests that very small fans might provide good performance: the February 1990 EPA Symposium Paper

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Radon Mitigation Performance of Passive Stacks in Residential New Construction[4] by Saum and Osborne. This research showed that one builder's passive stacks (SSD systems without any fans) offered significant radon mitigation performance in both summer and winter. Table 1 shows a summary of the radon mitigation results for this study. The passive stacks reduced the radon levels by about 66%, and 45 Watt SSD fans reduced radon levels by an average of 98% of the pre mitigation levels. Most performance reductions in these passive stack houses are thought to be due poor installation of the stacks, or to depressurization of the basement by leaky forced air return ducts which reversed the passive stack pressures. This suggests that a small SSD fan would boost the passive stack pressures enough to overcome most of these residual mitigation problems.

MINI FAN DESIGN

The first step in this project was to design a low power and low cost fan that could be used in a conventional new home SSD system. It was assumed that the builder would install a 4 inches of coarse aggregate under the slab, seal all slab penetrations, and run a stack pipe (3" or 4" PVC) up through the slab and exiting though the roof. In order to take advantage of the passive stack effect, the stack should run through the heated part of the house. The desirable fan characteristics were considered to be low power, long life, and low cost. Conventional radon fans use about 80 Watts, have an estimated 100,000 hour life, require 2 pipe couplings to connect to the stack pipe, and the total cost of fan and couplings is about $150.

The final mini SSD fan design is shown in Figure 1. The conventional radon fan system consists of a fan motor, fan housing, and two pipe couplings. To reduce noise, the conventional 45 or 90 Watt radon fans use a backward inclined blade, but 10 Watt fans are so quiet that a conventional low-cost axial fan blade can be used. For simplicity and lower cost, the mini fan is built into one pipe coupling which serves as a combined fan housing and pipe coupling. The final mini fan design consists of a high quality 10 Watt, 3" diameter, axial fan mounted in a 3" diameter PVC ring, and enclosed in a 3" flexible pipe coupling. When a 3" stack pipe is used, the fan housing serves as the pipe coupling. If a 4" stack pipe is used, then two 4" to 3" pipe couplings can be used to couple the fan to the 4" stack. The use of 3" stacks would be recommended because of the low air flows, the reduced costs, and the consistency with the use of 3" plumbing stacks already installed in houses. To complete the radon control system, a pressure gauge capable of monitoring the low expected stack pressures was developed from the commercially available "Fancheck" type pressure indicator. The Fancheck is a modified Dwyer air flow meter that consists of a small ball in a tapered clear-plastic tube. The conventional Fancheck indicates pressures greater than about 0.2" wc, but this device was modified for use with the mini SSD fan by using a much lighter ball so that it indicates pressures of only a few hundredths " wc.

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COST ESTIMATES

FAN PARTS COSTS

The parts cost of the mini SSD fan is less than $20, and the modified pressure gauge is about the same cost (about $10) as the Fancheck gauge. Therefore the mini SSD fan could be sold to builders for considerably less than a standard radon mitigation fan system consists of an 80 Watt fan with 2 pipe couplings (about $150), and a pressure indicator ($10). It is anticipated that the mini SSD fan system could be sold to builders for about $75, half the cost of the standard 80 Watt fan system.

LIFE CYCLE COSTS

The largest cost savings are in the life-cycle costs, not the initial installation costs. Table 2 shows a comparison of life cycle costs between a 10 Watt SSD fan and a standard 80 Watt SSD fan. Three types of recurring costs are assumed: electric cost for running the fan continuously, wasted heat costs for warming house air that is exhausted through the fan, and fan replacement costs. These calculations show that the mini SSD fan would cost about $29 per average year, while the standard 80 Watt fan would cost about $135 per year to operate continuously.

If builders follow the forthcoming EPA recommendations that all houses in radon prone areas have radon resistant features built into them, then it is reasonable to assume that at least 100,000 of the 1,000,000 new home built every year will have SSD fans installed. Under these assumptions, the estimated savings for installing a 10 Watt fan, rather than an 80 Watt fan, are shown to be $11 million in the first year, $476 million in 10 years, and $4.6 billion in 30 years.

RADON MITIGATION PERFORMANCE

Ideally we would like to know the performance trade-off between fan power and radon mitigation performance under a wide variety of conditions: geology, climate zones, building practices, heating/cooling system variations, contractor variables, failure modes, etc. With this type of data, we could begin to make a calculation of the cost per life saved with different SSD fan systems. Unfortunately, this type of study is far beyond the scope of this project.

PASSIVE STACK PERFORMANCE

The passive stack experiment data shown in Table 1 suggests that the mini SSD fan radon reductions in new houses should be somewhere between the performance of the passive stack systems (about 66% reduction) and the performance of the 45 Watt fan systems (about 98% reductions). It seems likely that if the performance of the passive stacks is based on the extremely weak forces of stack effect, then the performance of 10 Watt fan systems will be much closer to the 45 Watt fan systems than to the passive stack systems. We believe that is not unreasonable to assume that the mini SSD fan will give at least a 90% average reduction of elevated radon levels in new construction, assuming the recommendation on the subslab aggregate layer and sealing is followed.

MINI FAN PERFORMANCE IN ONE HOUSE

Only one prototype fan was available for experiments until last month when an additional half dozen prototype units were received from the fan manufacturer. The original prototype has been tested for several months under worst case conditions: an older house with no slab sealing and a poor subslab aggregate bed. These conditions were expected to be much worse than would be found in new houses built for radon resistance. The data from these tests is shown in Figures 2-5. These Figures show that even in an older house with no sealing of cracks and an uneven subslab aggregate bed, the 10 Watt mini SSD fan lowers the radon level from 10 pCi/L to 2.1 pCi/L (a 79% reduction), versus a reduction to 0.8 pCi/L (a 92% reduction) for a 45 Watt fan. Figures 2 and 3 show the performance of the two fans over a month as the fans are being cycled off and on every 3.5 days. Figures 4 and 5 show the averages of 4 on/off cycles so that the variations are smoothed out. Note that both fans reduce radon levels within a few hours after the fans are turned on, but the larger fan seems to have depleted the radon under the slab more extensively than the smaller fan, and it takes longer for the radon levels to build up in the house after the larger fan is turned off.

PERFORMANCE LIMITATIONS

Some general limitations of SSD fans that may apply to the mini SSD fan have not been fully investigated yet: 1) problems with large slabs, 2) problems when sand or other low porosity aggregates are used below slabs, and 3) problems when the soil below the slab is very porous. These situations are not well understood for even the standard SSD radon mitigation systems. It seems likely that this type of problem could be addressed by written guidance that would be included with the mini SSD fan systems.

FUTURE DEVELOPMENT PLANS

The future plans for development of the mini SSD fan call for more field tests of the prototype, refinement of the design, field tests with cooperative builders, certification (UL or equivalent), volume purchase agreements, and eventual sale to builders and mitigators.

DISCLAIMER

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

REFERENCES

1. Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings, Standard Guide 1990, American Society for Testing and Materials, Philadelphia, PA, 1990.

2. Nuess, M., Northwest Residential Radon Standard Project Report, DOE/BP-1273, Bonneville Power Administration, Portland, OR, October 1989.

3. Osborne, M.C., Radon-Resistant Residential New Construction, EPA/600/8-88/087, July 1988.

4. Saum, D.W., Osborne, M.C., Radon Mitigation Performance of Passive Stacks In Residential New Construction, Presented at the 1990 International Symposium on Radon and Radon Reduction Technology, Atlanta, 1990.

Table 1 Radon Mitigation Performance Data from Passive Stack Study

HOUSES WITH PASSIVE STACKS, NO FANS

Test House No.	Stack Open (pCi/L)	Stack Sealed (pCi/L)	Radon Reduction (%)	Comment
126	0.3	6.1	95%	summer data
126	0.1	13.6	99%	winter data
162	4.7	8.5	45%	duct leaks, poor communication
40	8.8	12.8	31%	duct leaks, poor communication
53	1.1	2.7	59%	
209	1.2	6.5	82%	
105	0.6	1.8	67%	
42	1.9	9.4	80%	duct leakage
84	4.9	5.8	16%	duct leaks, poor communication
206	2.9	19.9	85%	winter - duct leakage
206	0.6	2.4	75%	summer - duct leakage fixed
AVERAGE:	2.5	8.1	70%	

HOUSES WITH FANS IN PASSIVE STACKS, FANS OFF

Test House No.	Stack Open (pCi/L)	Stack Sealed (pCi/L)	Radon Reduction (%)	Comment
383	1.8	13.0	86%	winter
308	4.5 na	na	na	summer, duct leakage
308	8.0	33.5	76%	winter, duct leakage
221	1.5	12.0	88%	winter, duct leakage
181	6.7	7.4	9%	stack in unheated garage
233	na	18 na	1.9 na	not used, fan inside basement
237	7.4	13.7	46%	stack in unheated garage
184	12.7	26.4	52%	duct leakage
AVERAGE:	6.3	17.7	64%	

HOUSES WITH FANS IN PASSIVE STACKS, FANS ON

Test House No.	Fan On (pCi/L)	Stack Sealed (pCi/L)	Radon Reduction (%)	Comment
383	0.1	13.0	99%	winter
308	0.4	na	na	summer, duct leakage
308	0.2	33.5	99%	winter, duct leakage
221	0.3	12.0	98%	winter, duct leakage
181	0.1	7.4	99%	stack in unheated garage
233	na	18 na	na	not used, fan inside basement
237	0.6	13.7	96%	stack in unheated garage
184	0.8	26.4	97%	duct leakage
AVERAGE:	0.4	15.1	98%	

COMMENTS AND CONCLUSIONS

1. This data was collected by an EPA Office of Research & Development funded study conducted in 1989-90 and performed by Infiltec and Ryan Homes.
2. All radon measurements are averages of one or more weeks of hourly continuous radon data collected with Pylon or Femtotech monitors.
3. Passive stacks lowered radon by about 1/3, fan systems by about 1/40
4. Passive stacks provided mitigation in summer as well as winter.
5. Passive stack performace appeared to be reduced by duct leaks and poor subslab communication causing blocked pipes.
6. Passive stacks provided some mitigation in all cases.
7. A low power fan to assist the passive stack might overcome many of the the problems caused by house pressures or poor communication.
8. Limitations of study: one builder (Ryan Homes), one region (D.C. Metro), small number of houses (16), one HVAC type (heat pump).
9. All radon control systems were installed by the builder without supervision by a radon mitigation expert.
10. Houses with summer and winter data are included twice in averages.

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Table 2 Life Cycle Costs of the Mini SSD Fan and Standard SSD Fan

CALCULATION ASSUMPTIONS:

GENERAL ASSUMPTIONS:	VALUE	COMMENT
Electric rate	$0.08 per kwh	approximate U.S. electric rate
Gas rate	$0.60 per therm	approximate U.S. gas rate
Oil rate	$1.00 per gallon	approximate U.S. oil rate
Fuel cost escalation	0.00%	to simplify long term calc.
Inflation rate	0.00%	to simplify long term calc.
New houses built	1 million/yr	approximate U.S. average
House lifetime	30 years	used as long term limit
New houses with SSD	10.00% of total	SSD = SubSlab Depres. system
New houses with SSD	0.1 million/yr	this is a guess

HEATING ASSUMPTIONS:	VALUE	COMMENT
Heating degree day	5000 deg F days	approximate U.S. degree days
Gas efficiency	70%	gas furnace and ducts
Gas heat for 1 cfm	$1.12 per year	gas cost/yr/cfm of exhaust
Oil efficiency	70%	oil furnace and distribution
Oil heat for 1 cfm	$1.36 per year	oil cost/yr/cfm of exhaust
Elec. efficiency	90%	elec. furnace & ducts
Elec. heat for 1 cfm	$4.60 per year	electric cost/yr/cfm exhaust
Heat pump efficiency	200%	heat pump and distribution
Heat pump for 1 cfm	$2.08 per year	heat pump cost/yr/cfm exhaust
Avg fuel for 1 cfm	$2.29 per yN /	average cost/yr/cfm exhaust

FAN ASSUMPTIONS:	STANDARD FAN	MINI FAN	COMMENT
Fan power	80 watts	10 watts	continuous electric
Exhausted house air	25 cfm	3.125 cfm	this is a guess
Exhaust heat cost	$57 /yr	$7	avg oil, gas & elec.
Fan life	11.42 yrs	11.42 yrs	rated @ 100,000 hrs
Fan & gauge cost	$150	$75	cost to builder
Fan replacement cost	$250	$175	fan plus install

ECONOMICS FOR SINGLE HOUSE:

	STANDARD FAN	MINI FAN	$ SAVING	% SAVING
electricity (/yr)	$56	$7	$49	88%
heat loss (/yr)	$57	$7	$50	88%
replacement (/yr)	$22	$15	$7	30%
Cost (/yr)	$135	$29	$106	78%
Cost (/house life)	$4,056	$885	$3,172	78%

ECONOMICS FOR U.S.:

	STANDARD FAN	MINI FAN	$ SAVING
Costs (1st year)	$14 million	$3 million	$11 million
Costs (10 years)	$608 million	$133 million	$476 million
Costs (30 years)	$5,882 million	$1,283 million	$4,599 million

NOTE:

1. Costs of pipe installation and slab sealing ignored since they are common to both SSD fan systems.
2. Exhaust air leakage of 25 cfm for 80 Watt fan is a guess.
3. The estimate of 10% of new home builders installing SSD systems assumes the EPA will recommend new home SSD in radon prone areas.

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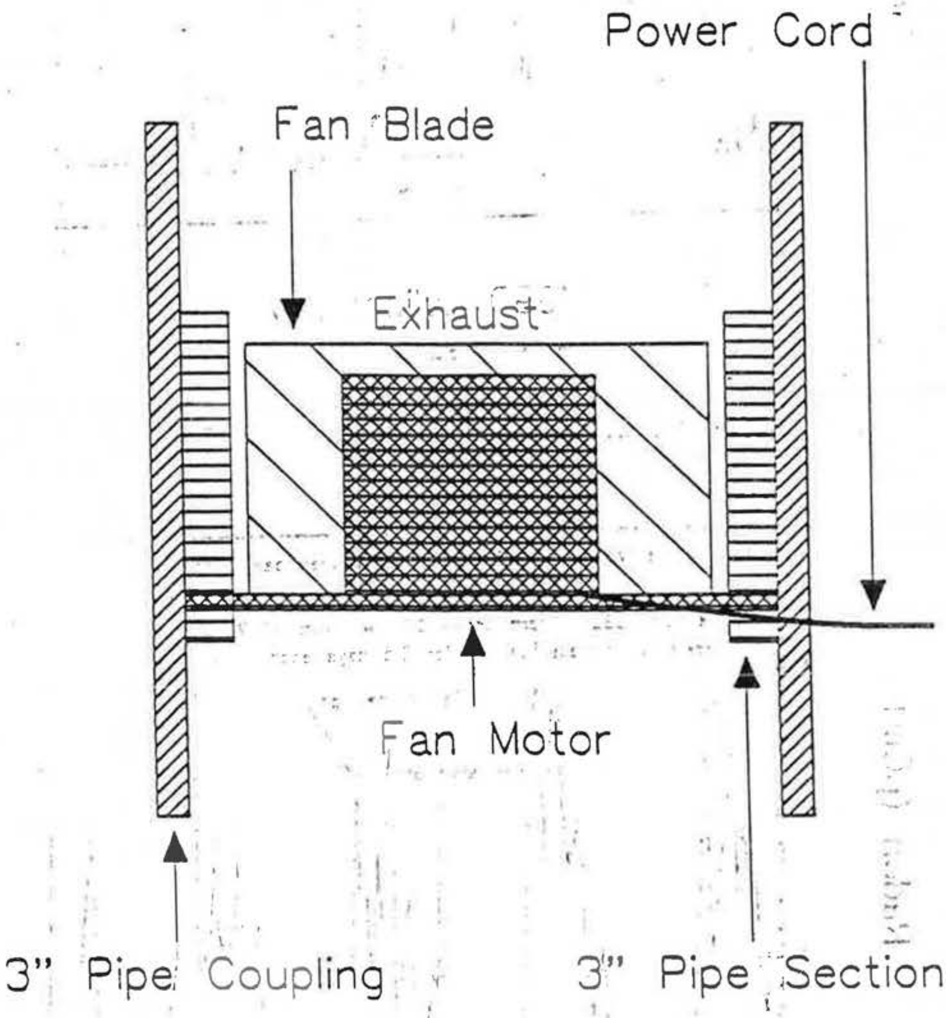

Figure 1 Vertical Cross-Section Schematic of Mini Fan

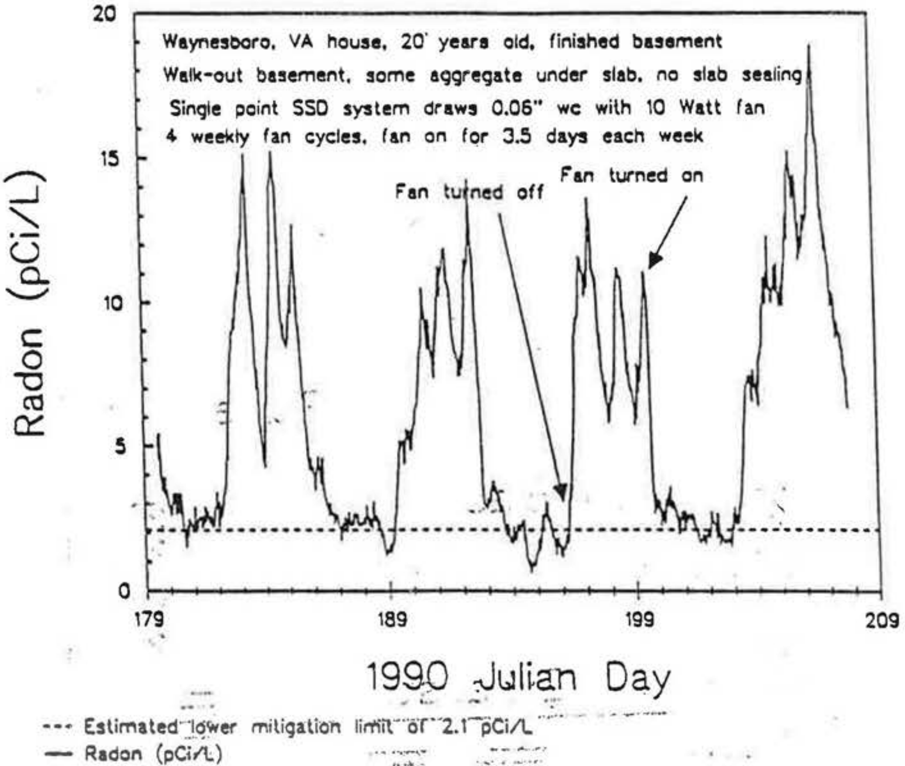

Figure 2 - Mitigation Performance of 10 Watt Fan

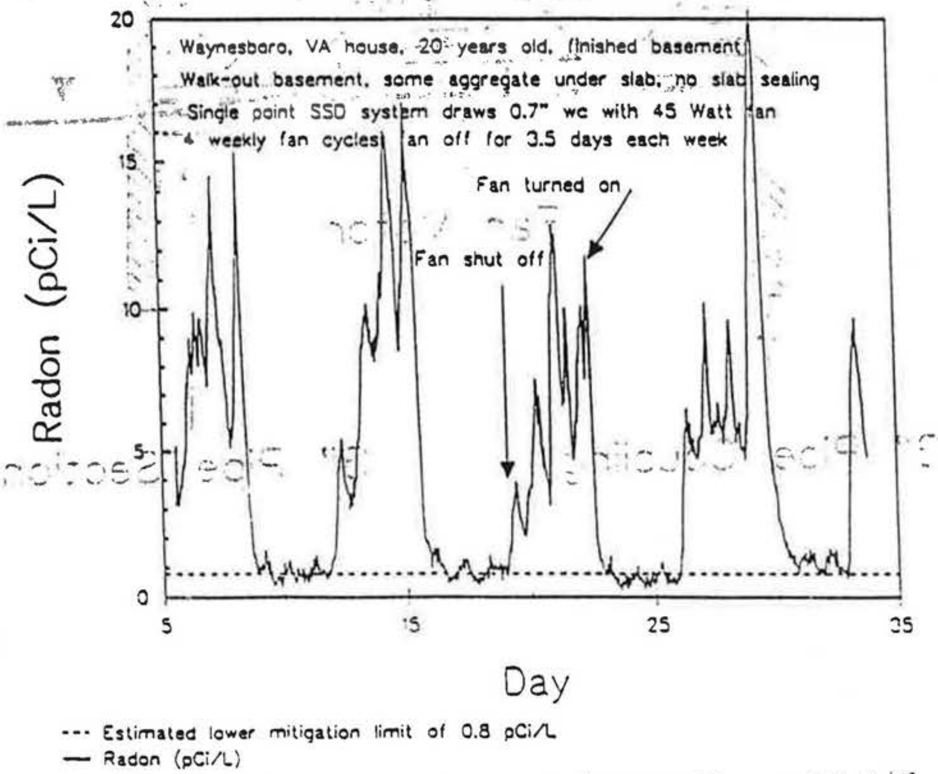

Figure 3 - Mitigation Performance of 45 Watt Fan

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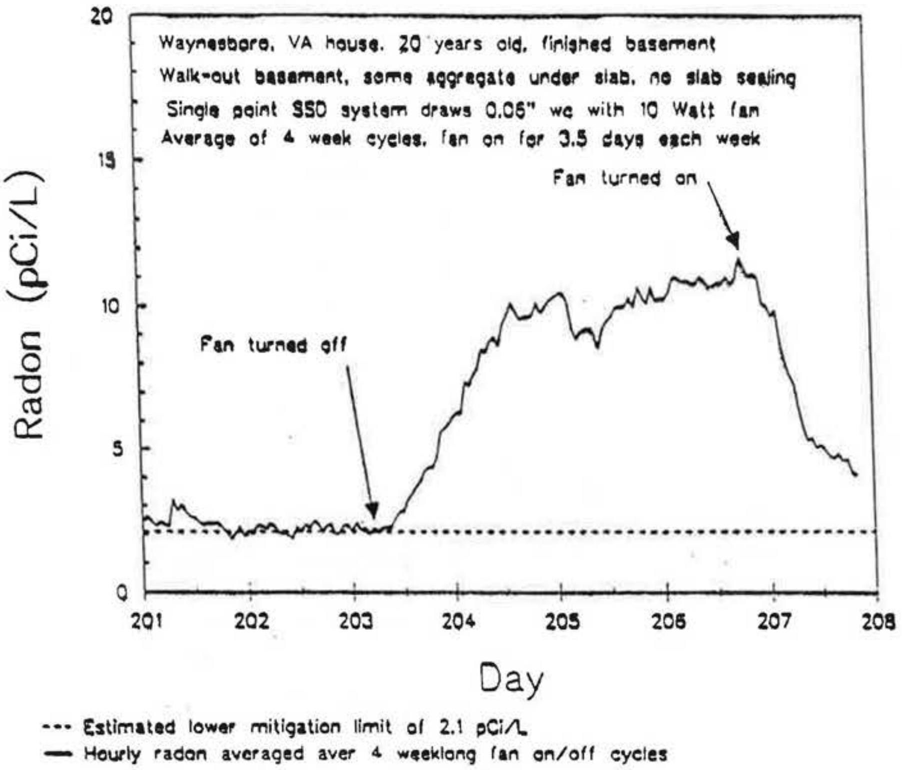

Figure 4 Average Mitigation Performance of 10 Watt Fan

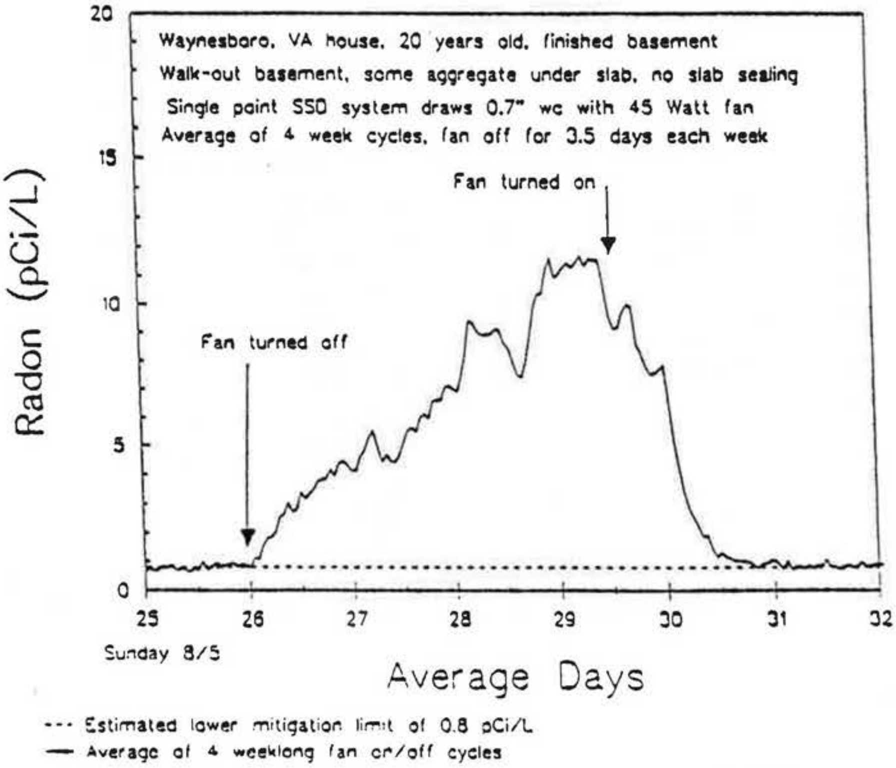

Figure 5 Average Mitigation Performance of 45 Watt Fan

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