1990_15

AARST ANNUAL RADON CONFERENCE
OCTOBER 4,5,6 1990

COMPARISON OF LONG TERM TESTING DEVICES INDOOR AND OUTDOOR

Bill Brodhead
WPB Enterprises, Inc.
2844 Slifer Valley Rd.
Riegelsville, Pa., 18077
610-346-8004, Fax 610-346-8575

ABSTRACT

The author exposed nine different long term radon detectors for two months in the basement of his own home. Included in the study were twenty-six alpha track detectors from four different companies, six Kodak film strips, six standard size ion-chambers and eight of the new smaller size LLT unit ion chambers and three At-Ease monitors. One of the At-Ease units included the upgraded with the new higher sensitivity.

Fifteen blank alpha track detectors and six film badges were left unexposed in their original bags during the test period to determine what background reading they might accumulate.

The actual radon levels were being determined by two AB-5 Pylons that had been first exposed in the Radon QC chamber in Easton, Pa., for calibration. The average daily radon levels fluctuated from five to sixty pCi/L in the basement. Radon decay product measurements were also made to determine the equilibrium ratio because of their effect on the film units. Thoron measurements were also made to determine if there was any significant amount in the basement that might influence the Pylon readings.

A comparison of all of the detectors except the At Ease units was also done outdoors. Two of each detector except the LST ion chambers were exposed outdoors. No continuous monitor was used outdoors. The outdoor units were exposed for 108 days.

A second exposure of detectors was begun outdoors and will be presented, but the levels were not available at the time of this printing.

INTRODUCTION

The EPA recommends that a screening radon measurement that falls between 4 pCi/l and 20 pCi/l be followed with a long term measurement in the lived in area of a dwelling for confirmation and determination of actual risk to the occupants. A long term measurement is defined as a measurement lasting more than three months although any measurement over one month is typically considered a long term measurement. There are a number of detectors that can be used for this purpose. These detectors fall into four groups; alpha track, film badge, ion chamber, and electronic silicone chip. The radon industry has, in the past, questioned the accuracy of these detectors. One of the problems associated with the accuracy of alpha track detectors is that if they are exposed to radon before or after the designated exposure time, the detector will include this exposure with the total exposure. There is also a variation in the quality of the plastic that is used for the detector.

This paper is an attempt to quantify the accuracy of these types of detectors exposed under real time conditions. Most calibration of long term radon detectors is done in a radon

chamber that typically holds the radon levels to a steady concentration. Also the chamber is often run at high concentrations in order to shorten the exposure time. Real time conditions have constantly varying radon levels.

RADON CHAMBER

The detectors were exposed in the author's own basement for 60 days. The author's house is a 100 year old wood frame with a rubble stone foundation. The basement floor is concrete with a vapor barrier under it, but no sub-floor gravel. The heating system is oil fired hot water. A three point sub-slab suction system was installed a few years ago. The exhaust pipework runs outside and below grade to a fan installed about thirty feet from the house in some shrubbery. The radon levels in the basement, with the fan system turned off, vary from 5 to 60 pCi/l. The radon on the first and second floor of the dwelling is considerably less because the ceiling of the basement is insulated with sprayed in place urethane and the basement to first floor door is weatherstripped. With the radon system fan activated, the radon levels in the basement drop to 1 to 5 pCi/l. The comparison test was done with the radon system turned off. The basement temperature varies from 58 to 61 degrees Fahrenheit. The humidity varies from 75% to 90%. There are no windows in the basement and no measurable air flow.

MONITOR CALIBRATION

Two Pylon AB-5 radon monitors, each with passive radon diffusion heads (PRD), were used to determine the radon levels in the basement during the test. These units were on loan from

the Pa. DER. They had been used for an earlier study of charcoal canisters and E-perms. The background counts of the PRD and signal noise of the instruments was determined by running nitrogen through the PRD head for 24 hours so that an absolute background could be attained. The units, along with a third pylon had been calibrated at Radon QC the first week in September, 1989. The three units were calibrated again by placing them in the yellow chamber, which is the middle concentration, at Radon QC for three days, from 3/13 to 3/16/90. Refer to the Radon QC - Pylon Comp. figure. The average concentration reported from Radon QC was 31.97. Using the calibration factors developed from the previous session the units reported 31.74, 32.15, 31.81. This is less than 1% difference from the reported value. The calibration factors were adjusted this small amount to match the exact reported value of Radon QC. An Eberline working level monitor was also placed in the chamber and checked for calibration. This unit fell with the reported values of two Radon QC WL monitors that were in the chamber at the same time. Refer to the Radon QC - WL Comp. figure.

MONITORS IN THE STUDY

A number of manufacturers were contacted about the study. They were informed what kind of study it would be and that it was not funded. They were asked if they would provide free test kits. Of those contacted, the following generously provided test kits for free: Tech/Ops Landauer, Kodalpha, Rad Elec, Radon Environmental Monitoring, Radiation Safety Services. The following companies were also contacted about the study but they

did not supply any detectors and thus were not included in the comparison: Target Radon Services, Honeywell, Threshold Technical Products, Femto-Tech. The only detectors purchased for the study were from Ramses II. The author had access to three At-Ease radon monitors that were also included in the study. The At Ease units were compared with different amounts of exposure time to see how the readings might vary.

THE COMPARISON

The comparison test was run for sixty days from 4/5/90 to 6/3/90. The test exposure included six long term standard size E-perms, eight small chamber E-perms with long term electrets, six RSSI alpha tracks, six Kodak film detectors, six Radtrak detectors from Tech/Ops, four old style REM alpha track detectors, six new pink pouch REM detectors, four alpha track detectors from Ramses II, three At Ease monitors which included a professional unit and a unit that had just been upgraded with the new higher sensitivity. The actual radon concentrations were determined with two AB-5 Pylons. A number of detectors were also left sealed in their bags in the basement for ninety days, and then opened briefly before returning them to the companies for analysis. The daily average radon levels varied from 12 pCi/l to 25 pCi/l until the last six days of the study. For some unknown reason the levels shot up to over forty pCi/l and then down to eight pCi/l during the last six days. A graph of the daily radon concentrations is titled Long Term Radon Test. The individual daily pylon averages are included

COMPANY PROMPTNESS

All of the detectors were mailed back to the labs on Monday, 6/4/90. The E-perms, At Ease monitors and Pylons were analyzed and recorded the same day. The promptness of response from the detector companies varied widely. RSSI wins the award for fastest lab turn around time. They had the detectors analyzed on 6/7/90 and, upon request, faxed the results on 6/8/90. I was impressed. Kodak, which had to be mailed all the way to France, faxed me the report on 6/14/90. Tech/Ops did the analysis on 6/15/90 and then mailed the results. Tech/Ops said it was not possible to get a fax of the results. REM, after a few phone calls, faxed the results on 6/21/90. Ramses II was the slowest response. After many calls, they final gave the results over the phone the first week of July. This was almost a month after receiving the detectors.

TEST RESULTS AND COMPANY RESPONSES

The Pylon averages were extremely close, less than 1% different. However on a daily average there were variations between the two units as much as 9% in each direction with an overall average variation of 2.7%. The individual results are listed as well as the ARE and the MARE. The standard deviation is included but one must realize that the more detectors exposed the better the standard deviation looks. The opposite effect happens with the variation from highest to lowest being greater with a larger sampling.

After the test results were obtained from each company the

comparison to the Pylon averages were revealed to them. The responses varied considerably.

Ramses II gave me the results over the phone. Unfortunately, I made the mistake of sending them the results of the study before they had sent me the written results of their detectors. A week after they had gotten the results from the study, they informed me in writing that the test results from their detectors were invalid because they had only been exposed for sixty days instead of the ninety days specified in the instructions. I called and inquired what was the minimum exposure they could detect in pCi/l days since the detectors were exposed to over 1000 pCi/l days. They did not have a clear answer. They also claimed that the detectors were invalid since they were not sent back in the plastic bags that they were shipped in. This might be a valid point, since they mentioned that their lab has a background level of almost 2 pCi/l. Since it took a month to analyze the detector, this could be a serious factor; but since their detectors were 35% low compared to the known value, the additional exposure the detectors might have received in an unsealed bag should have helped their results! The written results were never sent, which upset me since I had paid for the detectors. The results given over the phone are listed. The standard deviation was 3.9 and there was a variation of 132.9% from the highest to the lowest detector level. The two unexposed detectors included one that would have been calculated at 5.1 pCi/l if the exposure time was given as 60 days.

Kodak Kodalpha results were 20.4% low with a standard deviation of 1.6 and the greatest variation from highest to lowest

of 26.6%. Kodak asked if any thoron had been measured in my basement. They claim that a 10% thoron daughter concentration gives approximately a 6% increase reading with their detector. An Eberline WL monitor in my basement does report as much as 7% thoron. I attempted to measure the thoron difference with a Pylon hooked to a fifty foot coil of hose in order to delay the exposure long enough for the thoron to decay. The results were inconclusive. If there is any thoron, then the average variation of one pylon to the other masked over the difference that would be caused by excluding thoron entry from one unit.

They also inquired about the altitude of the test location since a change in the atmospheric pressure decreases about 1% with every 100 meters of altitude. This increases the free circulation of alpha particles by about 1% and needs to be included in the calculation if relevant. In this case we are in a valley and although the exact elevation is not known, it is estimated we are between 100 to 200 meters above sea level.

The equilibrium ratio was measured once during the exposure and a second time immediately after the exposure. The range of 40 to 55% equilibrium measured is considered an optimum range for their film detector.

Kodak responded back at a later date that they had concluded that their Kodalpha was over responding about 20% and that their calibration factor had been changed accordingly.

Tech/Ops had a tight cluster of readings with a standard deviation of .7 and a 14% variation from the highest to the lowest detector. They were biased 16.2% low. Tech/Ops wrote back after

the study and claimed that they periodically check the plastic they use for slight differences and change the algorithms used to calculate the results according. They had not checked the plastic used in the detectors included in the study. After completing the check, they changed the algorithms and supplied new results that now averaged provided an average for the six detectors of 17.45 pCi/l. This brings their bias to 1.3% higher than the Pylons.

The four blank detectors which averaged 16.87 pCi/l days now would average 19.21 pCi/l days with the new algorithm. This would give a background reading of .3 pCi/l for a 60 day exposure.

RSSI had the closest result of all the detectors to the Pylon averages, with a difference of only 1.6%. The background detectors were also the lowest of all the alpha track detectors.

REM provided both their older alpha tracks which came in a white bag and their new units that come in a foil bag and use a thin pink plastic bag for the filter. The six new detectors that were exposed were all considerably lower than the Pylons. Only one unit was within the 25% error allowed by the RMP program. The older units averaged closer to the Pylons but had the largest variation of all the detectors, with a standard deviation of 5.6 and a highest to lowest variation of 142.9%. The new pink bag units were tighter but still had a variation of 66.7% from the highest to the lowest unit. The background detectors were also showing significant elevations from leakage through the bag or defects in the plastic. The background counts would have given readings of from .68 to 22.9 pCi/l for a 60 day exposure and this does not include the one unit with a visible tear in the package.

LONG TERM TEST COMPARISON

The standard E-Perms averaged 2.2% higher than the Pylons with the least variation of all of the passive detectors. The new LLT E-Perms were 7.1% higher than the Pylons with a variation from highest to lowest of 11.5% and a .6 standard deviation. One of the LLT E-perms had a voltage drop that was three times greater than the others and was not listed in the study because it was assumed to be caused by poor handling.

The At-Ease monitors were not exposed consistently through the exposure period in order to determine the variation in response. There were three types of detectors. Unit 2115 was recently upgraded to the new higher sensitivity. Unit 3989 is a professional unit. Unit 8926 is a standard At Ease. All of the monitors showed a bias that seemed to be fairly consistent through the exposure length. The new upgraded unit was the closest to the mark at 12 to 13% low. The professional model varied from 19.1 to 22.4% high compared to the Pylons. The standard unit was the farthest off at 29.5 to 16.3% low. Unfortunately one deficiency in these units is that they can only be adjusted with 20% change. There is a need then to know what the bias of each detector is in order to feel confident about the readings.

OUTDOOR MEASUREMENT COMPARISON

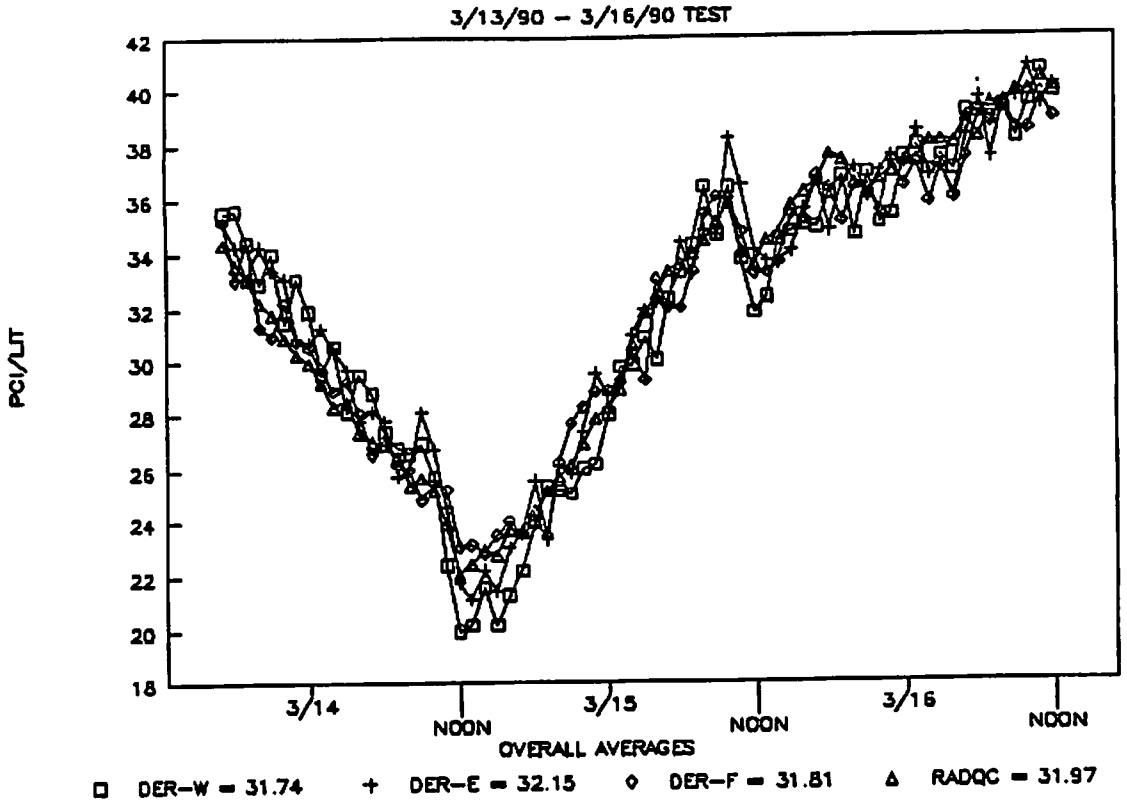
Detectors were exposed outdoors in a covered but open garage for 108 days from 3/5/90 to 6/21/90. The results are listed in a separate chart. There was no Pylon exposed at the same time, so no reference measurement is available. Included is some results from a second exposure of 82 days from 6/21/90 to 9/11/90. The results vary widely from detector company to detector company,

however, with brands there is reasonable uniformity. As the Congressional goal of achieving ambient levels indoors is attempted, it becomes more critical to be able to measure these very low concentrations. It is also obvious from the results that there is significant radon in the outdoor air of some communities.

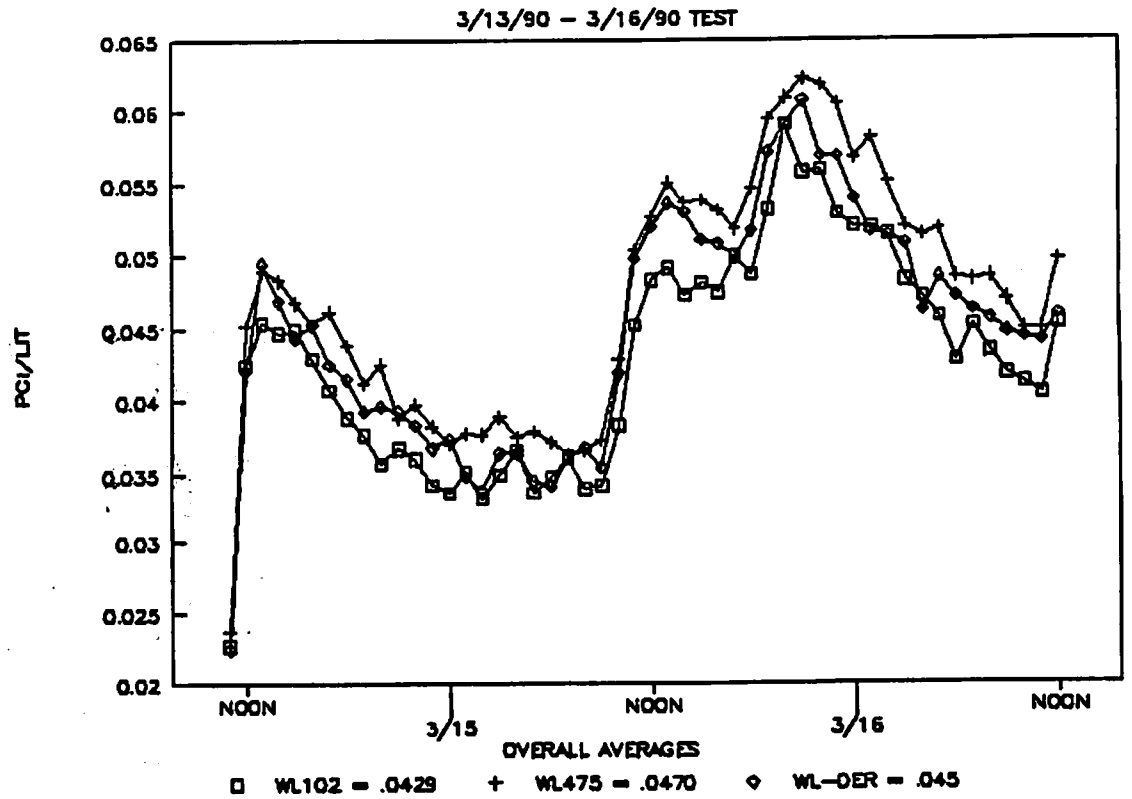
CONCLUSION

Although it might appear that the ability to measure radon for long periods of time with the detectors listed here is questionable, the answer is that the measurement can be very accurate if the correct detector is used and the proper procedures are followed. The wrong detector or improper handling can produce disastrous results. This is especially true with long term detectors that are stored away. Radon has the ability to get into a sealed container through the smallest of openings. It is critical that every study contain a number of blank samples to determine whether a background count has built up to the level of being significant.

RADON QC – PYLON COMP.



RADON QC – WL COMP.



WPB ENTERPRISES, INC.
LONG TERM BASEMENT COMPARISON 4/5 TO 6/3/90

PYLON DAILY AVERAGES

		DER-E	DER-F
1	4/5	16.9	16.8
2		15.5	14.9
3		14.3	14.2
4		14.7	14.1
5		16.0	16.1
6		20.7	21.3
7		15.2	15.3
8	4/12	15.0	14.6
9		15.8	15.3
10		17.2	16.8
11		18.4	18.3
12		17.4	17.7
13		18.0	17.9
14		16.3	15.9
15	4/19	16.9	16.9
16		21.5	21.3
17		19.5	20.2
18		17.9	18.4
19		13.5	13.4
20		13.8	12.6
21		18.6	17.8
22	4/26	12.8	12.4
23		14.9	15.2
24		15.4	16.3
25		13.4	13.7
26		15.1	15.3
27		20.4	20.6
28		20.3	19.8
29	5/3	18.2	17.2
30		18.5	18.2
31		22.0	20.6
32		17.0	15.5
33		16.2	15.4
34		15.3	15.8
35		13.0	14.0
36	5/10	24.9	24.3
37		15.1	13.7
38		14.1	13.0
39		18.5	18.2
40		14.1	13.7
41		16.6	16.2
42		18.7	18.6
43	5/17	22.6	22.7
44		18.8	18.3
45		15.1	15.2
46		12.3	12.3
47		15.8	15.9
48		15.1	15.0
49		20.5	20.0
50	5/24	16.9	16.8
51		15.2	15.4
52		20.6	20.7
53		18.3	18.9
54		16.1	16.4
55		39.5	43.1
56		38.6	39.5
57	5/31	14.3	14.0
58		8.5	8.6
59		8.6	8.4
60	6/3	11.6	11.6

AT EASE MONITOR RESULTS

4/5-4/6 PYLON AVG.S = 16.01
2115 = 14.0 -> DIF. = 87.4%
3989 = 19.6 -> DIF. = 122.4%

4/5-4/10 PYLON AVG.S = 16.29
2115 = 14.2 -> DIF. = 87.2%
3989 = 19.4 -> DIF. = 119.1%

4/5-4/12 PYLON AVG.S = 15.97
2115 = 14.0 -> DIF. = 87.7%
3989 = 19.1 -> DIF. = 119.6%

4/5-4/21 PYLON AVG.S = 17.02
2115 = 15.0 -> DIF. = 88.1%

4/5-4/28 PYLON AVG.S = 16.52
2115 = 14.5 -> DIF. = 87.8%

4/5-5/3 PYLON AVG.S = 16.7
2115 = 14.7 -> DIF. = 88.1%

4/26-5/3 PYLON AVG.S = 16.32
8926 = 11.5 -> DIF. = 70.5%

RESTARTED AT EASE UNITS 5/5/90

5/5 - 5/7 PYLON AVG.S = 18.39
2115 = 14.5 -> DIF. = 78.8%
8926 = 13.0 -> DIF. = 70.7%

AVG. EQUIL. RATIO 5/15 - 5/16 = 53.9

pCi/l	WL
17.64	0.0951

5/5 - 5/18 PYLON AVG.S = 17.39
2115 = 14.7 -> DIF. = 84.5%
8926 = 13.5 -> DIF. = 77.6%

5/5 - 5/29 PYLON AVG.S = 18.04
2115 = 16.5 -> DIF. = 91.4%
8926 = 15.1 -> DIF. = 83.7%

5/5 - 6/3 PYLON AVG.S = 17.77
2115 = 15.8 -> DIF. = 88.9%
8926 = 14.5 -> DIF. = 81.6%

AVG. EQUIL. RATIO 6/5 = 41.9%

pCi/l	WL
23.87	0.100

TOTAL AVG. = 17.27 17.18
PYLON DIFFERENCE = 00.5% AVERAGE OF BOTH UNITS = 17.22

WPB ENTERPRISES, INC.
BASEMENT 60 DAY COMPARISON TEST 4/5/90 TO 6/3/90

PYLON AVERAGES FOR 60 DAYS — AVG. of PYLONS
DER-E = 17.27 DER-F = 17.18 17.23

(ARE) Absolute Relative Error = (Measured-Actual)/Actual

	LT EP		LLT EP		RSSI		KODAK	
	17.7	2.7%	18.7	8.4%	17.8	3.3%	19.5	13.2%
	17.4	1.0%	18.9	9.9%	16.5	-4.2%	20.6	19.6%
	18.0	4.5%	19.2	11.3%	16.2	-6.0%	20.3	17.8%
	17.0	-1.3%	18.7	8.4%	17.4	1.0%	23.8	38.1%
	18.3	6.2%	17.2	-0.2%	17.6	2.1%	21.5	24.8%
	17.3	0.4%	17.7	2.6%	16.2	-6.0%	18.8	9.1%
			18.4	6.8%				
			18.9	9.8%				
MARE =	17.62	2.7%	18.46	7.2%	16.95	3.8%	20.75	20.4%
AVG. ARE =	2.2%		7.1%		-1.6%		20.4%	
% OF VARIATION FROM THE HIGHEST TO THE LOWEST READING								
	7.6%		11.5%		9.9%		26.6%	
ST.DEV.=	0.4		0.6		0.7		1.6	

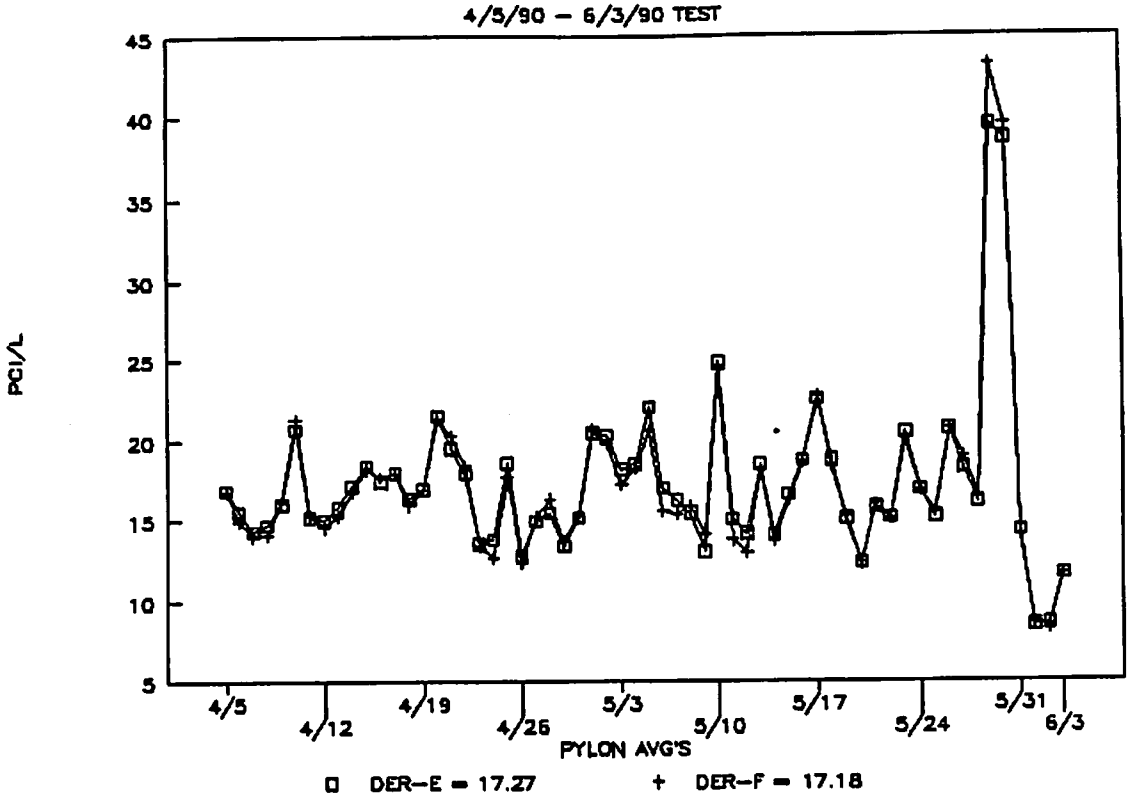
	TECH/OPS		OLD REM		NEW REM		RAMSES	
	15.1	-12.4%	25.5	48.0%	9.2	-46.6%	7.6	-55.9%
	13.8	-19.9%	16.4	-4.8%	10.5	-39.1%	10.7	-37.9%
	14.2	-17.6%	13.6	-21.1%	8.7	-49.5%	17.7	2.7%
	14.8	-14.1%	10.5	-39.1%	8.9	-48.3%	9.1	-47.2%
	13.4	-22.2%			14.5	-15.8%		
	15.3	-11.2%			8.9	-48.3%		
MARE =	14.43	16.2%	16.50	28.2%	10.12	41.3%	11.28	35.9%
AVG. ARE =	-16.2%		-4.2%		-41.3%		-34.6%	
% OF VARIATION FROM THE HIGHEST TO THE LOWEST READING								
	14.2%		142.9%		66.7%		132.9%	
ST.DEV.=	0.7		5.6		2.0		3.9	

BACKGROUND FROM 90 DAYS IN 17 pCi BASEMENT OF UNEXPOSED ATD

TECH/OPS	OLD REM	NEW REM	RSSI	RAMSES	KODAK
14.2	1373.5	41.9	3.9	12	0
10.7	847.2	285.6	8.7	306	
19.5	503.1		3.9		0
23.0	2044.7 HOLE IN BAG				0
					0
					0

LONG TERM RADON TEST

4/5/90 – 6/3/90 TEST



WPB ENTERPRISES, INC.
OUTDOOR 108 DAY COMPARISON TEST 3/5/90 TO 6/21/90

ST EP	RSSI	KODAK
0.52	0.36	1.2
5.70	0.34	1.2

TECH/OPS	OLD REM	NEW REM
<.3	4.2	0.17
<.3	3.2	0.20

OUTDOOR 82 DAY OUTDOOR COMPARISON TEST 6/21/90 TO 9/11/90

ST EP	LST EP	KODAK
0.64	0.65	N/A
0.72	7.70	
1.01		
0.62		

RSSI	TECH/OPS
N/A	N/A