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Evaluation of Experiences in Long-Term Radon and Radon Daughter Measurements

Prepared by J. A. Young, P. O. Jackson, V. W. Thomas

Pacific Northwest Laboratory
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Radon Daughter Measurements in Long-Term Radon and Evaluation of Experiences

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ABSTRACT

Pacific Northwest Laboratory (PNL) is performing side-by-side measurements of radon and radon daughter concentrations using several instruments and techniques, and is comparing these measurements with side-by-side measurements made by other investigators at other locations, to determine whether these other instruments and techniques are capable of determining average annual radon daughter concentrations with sufficient accuracy.

PNL has measured average annual radon concentrations using Terradex Track Etch® Type F detectors in 50 buildings in Edgemont, South Dakota, in which average annual radon daughter concentrations were also measured using RPISU's. The standard deviation of the differences between the (natural) logarithms of the Track Etch® radon concentrations and the logarithms of the RPISU radon daughter concentrations ($S.D.-\ln$) was 0.37. The Track Etch® radon concentrations can be converted to radon daughter concentrations by dividing by the average ratio between the Track Etch® and the RPISU concentrations. Using the above $S.D.-\ln$, and the Track Etch® radon daughter concentrations calculated in this manner, it can be calculated that if the Track Etch® radon daughter concentration is 0.010 WL there should be only a 14% probability that the RPISU average would be greater than 0.015 WL, and only a 3% probability that the RPISU average would be greater than 0.020 WL. Inspection of the Edgemont, South Dakota, Track Etch® and RPISU data indicates that if year-long Track Etch® measurements had been made in all the buildings in Edgemont, and if buildings had been cleared from remedial action when the Track Etch® averages were less than 0.010 WL, then about 61% of the buildings would have been cleared from remedial action, and only a few percent of these buildings would have actually had average RPISU concentrations greater than 0.015 WL. A considerable number of buildings would have been scheduled for engineering assessment that actually had annual averages less than 0.015 WL, but the cost of each of these engineering assessments would have been comparable to the cost that is now being expended at Edgemont to perform each year-long RPISU measurement series.

The $S.D.-\ln$ between (1) the Track Etch® radon measurements and the RPISU radon daughter measurements made by ALARA at Grand Junction, (2) the PERM radon measurements and the MOD-225 radon daughter measurements made by Mound Facility at Canonsburg and Middlesex, and (3) the PERM and Track Etch® radon measurements made by Mound Facility at Salt Lake City were similar to the $S.D.-\ln$ between the Track Etch radon measurements and the RPISU radon daughter measurements at Edgemont. This suggests that the conclusions drawn from the Edgemont data can be applied to other locations and to the PERM radon analyzer. However, a much larger $S.D.-\ln$ of 0.76 was found between PERM radon and MOD-225 radon daughter measurements made by Mound Facility in rooms having very different ventilation conditions in Salt Lake City. This suggests that there will be situations where radon concentrations cannot be used to predict radon daughter concentrations. A much larger $S.D.-\ln$ of 0.84 was also found

between the PERM and Track Etch® radon measurements made by Mound Facility at outdoor locations, indicating that at least one of these techniques did not provide accurate outdoor radon measurements under at least some conditions. Many more side-by-side radon and radon daughter measurements are needed to confirm the preliminary conclusions drawn in this report.

PERM has measured average annual radon concentrations using Faraday Track Etch® type F detectors in 50 buildings throughout South Dakota in which average annual radon daughter concentrations were also measured using RP120U. The standard deviation of the difference between the (natural) logarithms of the Track Etch® radon concentrations and the logarithms of the RP120U radon daughter concentrations (2.0-in) was 0.37. The Track Etch® radon concentrations can be converted to radon daughter concentrations by dividing by the average ratio between the Track Etch® and the RP120U concentrations. Using the above 2.0-in and the Track Etch® radon daughter concentrations calculated in this manner, it can be calculated that the Track Etch® radon daughter concentration is 0.010 WL there should be only a 1% probability that the RP120U average would be greater than 0.015 WL, and only a 3% probability that the RP120U average would be greater than 0.020 WL. Inspection of the Edgemont, South Dakota, Track Etch® and RP120U data indicates that if year-long Track Etch® measurements had been made in all the buildings in Edgemont, and if buildings had been cleared from residential action when the Track Etch® averages were less than 0.010 WL, then about 6% of the buildings would have been cleared from residential action, and only a few percent of these buildings would have actually had average RP120U concentrations greater than 0.015 WL. A considerable number of buildings would have been scheduled for engineering assessment that actually had annual averages less than 0.015 WL, but the cost of each of these engineering assessments would have been comparable to the cost that is now being expended at Edgemont to perform each year-long RP120U measurement series.

The 2.0-in between (1) the Track Etch® radon measurements and the RP120U radon daughter measurements made by WARA at Grand Junction, (2) the PERM radon measurements and the MUD-225 radon daughter measurements made by Mound Facility at Grand Junction and Middesex, and (3) the PERM and Track Etch® radon measurements made by Mound Facility at Salt Lake City were similar to the 2.0-in between the Track Etch® radon measurements and the RP120U radon daughter measurements at Edgemont. This suggests that the conclusions drawn from the Edgemont data can be applied to other locations and to the PERM radon analyzer. However, a much larger 2.0-in of 0.15 was found between PERM radon and MUD-225 radon daughter measurements made by Mound Facility in rooms having very different ventilation conditions in Salt Lake City. This suggests that there will be situations where radon concentrations cannot be used to predict radon daughter concentrations. A much larger 2.0-in of 0.84 was also found

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The assistance of R. R. Kinnison of PNL in statistical manipulations and interpretation is also appreciated.

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EVALUATION OF EXPERIENCES IN LONG-TERM RADON AND RADON DAUGHTER MEASUREMENTS

J. A. Young, P. O. Jackson and V. W. Thomas

INTRODUCTION

The Environmental Protection Agency (EPA) has proposed that remedial action should be performed if residual radioactive materials cause average annual radon daughter concentrations exceeding 0.015 working levels (WL)* in occupied or occupiable buildings. This proposed standard of 0.015 WL has been recently revised upward to 0.02 WL as the proposed final working level standard. If this revision stands, then decision levels presented in this summary should be adjusted accordingly. The generally accepted method for determining the annual average has been to make 100-hour measurements every other month for one year using Radon Progeny Integrating Sampling Units (RPISU). The RPISU measures radon daughter concentrations by drawing air through a filter next to which is placed a thermoluminescent dosimeter (TLD) chip. The total exposure of the TLD chip to alpha particles is later measured to obtain the average radon daughter concentration. However, these measurements have proven to be costly and time-consuming to perform. The air filter on the RPISU tends to plug, causing a pressure sensor to turn off the RPISU to prevent the motor from over-heating. This makes it difficult, if not impossible, to use RPISU's to measure radon daughter concentrations in buildings containing high aerosol concentrations, such as those inhabited by smokers. Also, the RPISU's are bulky and noisy, so many home-owners object to their use in measuring radon daughter concentrations. Therefore, it would be very desirable to substitute an instrument or technique that could measure radon daughter concentrations with less effort and less intrusion upon the home owner. It would be particularly desirable to use a passive device that could be installed in a home and left for an entire year, since this would eliminate the errors resulting from intermittent sampling. It also might be true that future radon daughter concentrations could be predicted better by measurements of radon itself, because radon daughter concentrations are very susceptible to the plateout rate, which may change drastically when the occupants of the building change, the life style of the occupants changes, or an air conditioner or central heating system is installed.

There are several active and passive devices that can be used to measure radon and radon daughter concentrations. However, it is not certain that these devices can provide accurate estimates of annual average radon daughter concentrations over a range of conditions such as humidity and aerosol concentrations. Radon daughter measuring devices, for example, are susceptible to errors resulting from the plateout of

* Although working level is considered to be a unit of concentration in 40 CFR 192, working level is more properly a unit of exposure rate. The term, concentration, will be used throughout this report for consistency with 40 CFR 192.

the daughters on the devices themselves. Radon measuring devices cannot be used to estimate radon daughter concentrations if the degree of disequilibrium between radon and its daughters is variable and unpredictable. Therefore, side-by-side measurements must be made with the various radon and radon daughter measuring devices over a wide range of conditions to determine how accurate a measure of radon daughter concentrations each instrument provides.

COMPARISON OF SIDE-BY-SIDE RADON AND RADON DAUGHTER MEASUREMENTS

COMPARISON OF RPISU AND TERRADEx TRACK ETCH® MEASUREMENTS AT EDMONT

PNL has used Terradex Type F detectors to measure radon concentrations continuously for an entire year in 51 buildings in Edgemont, South Dakota. The Type F detector is mounted inside a plastic cup. A special filter is installed over the mouth of the cup to prevent the entry of radon daughters. Therefore, the detector measures only radon (and radon daughters produced by the decay of radon inside the cup). Radon daughter concentrations can be calculated if a value is assumed for the daughter/radon equilibrium ratio (the daughter/radon equilibrium ratio is defined as the ratio of the radon daughter concentration to the concentration that would be present if the radon daughters were in equilibrium with radon). This type of detector was used at Edgemont, rather than a bare detector (Type B), because it has been reported that the variability in the rate of plateout of radon daughters on the surface of the bare detector can lead to a less reliable measure of the radon daughter concentration.

Average radon daughter concentrations were also determined from six bi-monthly RPISU measurements of 100 hours or longer at the same locations in the same buildings as the Track Etch® measurements were made (Table 1). One Track Etch® detector was installed in each of these buildings at the same time as a RPISU was installed. This detector was then replaced by another detector each time the next RPISU was installed (approximately every two months). Another Track Etch® detector was left at the same location in each of these buildings for an entire year.

The ratio of the average annual radon concentration (pCi/l) obtained from the twelve-month Track Etch® measurements to the average annual radon daughter concentration (WL) obtained from six 100-hour RPISU measurements averaged 355 pCi/l/WL for the buildings in Edgemont. This ratio of radon to radon daughter concentration gives a daughter/radon equilibrium ratio of 0.28, which is considerably lower than the equilibrium ratio of 0.50 that is often assumed to be typical for buildings. However, average daughter/radon equilibrium ratios ranging from 0.2 to 0.7 have been reported for different cities (McGregor, et al, 1980; Stranden, et al, 1979).

It was found that the radon concentrations obtained from six two-month Track Etch® measurements were significantly higher than those obtained from the 12-month samples. (To eliminate excess verbiage, the averages of six two-month Track Etch® measurements will be referred to

TABLE 1. Average Annual Radon and Radon Daughter Concentrations
Obtained from RPISU and Terradex Track Etch® Measurements
at Edgemont, South Dakota

Building Identification Number		RPISU Radon Daughter Concentration (WL)	Track Etch Radon Concentration From Six Two-month Measurements (pCi/l)	Track Etch Radon Concentration From a 12-month Measurement (pCi/l)	Track Etch Radon Daughter Concentration From Six Two-month Measurements pCi/l 428 pCi/l/WL	Track Etch Radon Daughter Concentration From a 12-month Measurement pCi/l 355 pCi/l/WL
EPA	PNL					
136	21	0.0059	3.43	1.95	0.0080	0.0055
181	105	0.0065	4.16	2.55	0.0097	0.0072
201	277	0.0065	2.98	1.71	0.0070	0.0048
246	182	0.0102	4.11	2.03	0.0096	0.0057
261	73	0.0174	4.36	7.56	0.0102	0.0203
266	144	0.0255	10.24	6.95	0.0239	0.0196
271	147	0.0260	7.15	5.71	0.0167	0.0161
276	25	0.0159	4.41	4.45	0.0103	0.0125
286	74	0.0037	1.56	1.52	0.0036	0.0043
291	34	0.0073	2.21	1.78	0.0052	0.0050
301	8	0.0087		2.89		0.0081
306	67	0.0142	5.82	2.95	0.0136	0.0083
311	3	0.0119	3.38	2.98	0.0079	0.0084
316	6	0.0086	3.63	1.65	0.0085	0.0046
321	55	0.0097	3.46	3.04	0.0081	0.0086
326	56	0.0069	3.34	2.40	0.0078	0.0068
331	53	0.0203	4.96	4.25	0.0116	0.0120
336	104	0.0076	3.29	2.29	0.0077	0.0065
366	134	0.0096	2.90	3.99	0.0068	0.0112
376	132	0.0108	3.66	4.16	0.0086	0.0117
401	106	0.0054	1.88	1.27	0.0044	0.0036
416	130	0.0058		1.55		0.0044
436	87	0.0104	4.22	3.95	0.0099	0.0111

TABLE 1. Average Annual Radon and Radon Daughter Concentrations
Obtained from RPISU and Terradex Track Etch® Measurements
at Edgemont, South Dakota (continued)

Building Identification Number		RPISU Radon Daughter Concentration (WL)	Track Etch® Radon Concentration From Six Two-month Measurements (pCi/l)	Track Etch® Radon Concentration From a 12-month Measurement (pCi/l)	Track Etch® Radon Daughter Concentration From Six Two-month Measurements pCi/l 428 pCi/l/WL	Track Etch® Radon Daughter Concentration From a 12-month Measurement pCi/l 355 pCi/l/WL
EPA	PNL					
441	283	0.0185	4.74	5.65	0.0111	0.0159
446	48	0.0262	9.45	11.11	0.0221	0.0313
451	200	0.0142	8.96	10.37	0.0209	0.0292
456	2	0.0118	4.12	2.21	0.0096	0.0062
461	94	0.0111	2.42	2.93	0.0057	0.0083
466	282	0.0141	4.52	4.29	0.0106	0.0121
471	287	0.0198	7.91	6.89	0.0185	0.0194
476	129	0.0134	5.76	4.97	0.0135	0.0140
486	107	0.0062	3.87	1.83	0.0090	0.0052
496	123	0.0045	3.90	5.01	0.0091	0.0141
511	15	0.0074	3.44	2.57	0.0080	0.0072
516	9	0.0129	5.02	3.69	0.0117	0.0104
521	7	0.0163	6.01	5.30	0.0140	0.0149
531	295	0.0117	3.46	2.01	0.0081	0.0057
546	131	0.0046	4.35	1.66	0.0102	0.0047
551	91	0.0071	3.56	1.84	0.0083	0.0052
556	35	0.0144	7.02	4.22	0.0164	0.0119
561	153	0.0101	5.99	3.44	0.0140	0.0097
576	133	0.0079	3.99	4.06	0.0093	0.0114
726	1	0.0197	7.48	7.12	0.0175	0.0201
731	21	0.0207	8.06	6.42	0.0188	0.0181
736	66	0.0091	4.04	2.00	0.0094	0.0056
746	362	0.0153	4.01	5.53	0.0094	0.0156
751	176	0.0205	4.73	6.66	0.0111	0.0188
756	149	0.0077	4.55	5.18	0.0106	0.0146
776	250	0.0059	4.64	6.27	0.0108	0.0177
781	95	0.0080	3.93	4.01	0.0092	0.0113
786	298	0.0091	3.01	1.51	0.0070	0.0043

as two-month measurements in subsequent discussions.) Figure 1 shows a plot of 12-month measurements versus two-month measurements. There was considerable variation between the two-month and the 12-month measurements. The ratio of the two-month measurements to the 12-month measurements averaged $1.32 \pm .48$. According to the student's t test, the difference between this ratio and a ratio of one is significant at the $p < 0.001$ level. Therefore, it appears that the difference between the two-month and the 12-month measurements was statistically significant. The ratio of the radon concentrations obtained from the two-month Track Etch® measurements to the radon daughter concentration obtained from six bi-monthly RPISU measurements averaged 428 pCi/l/WL, corresponding to a working level ratio of 0.23.

There are several factors that could have caused the difference between the two-month and the 12-month measurements. It could have been caused by a systematic difference between the sensitivities of the detectors used in the two-month measurements and those used in the 12-month measurements. However, most of the detectors used in the two-month measurements came from the same batch as the detectors used in the 12-month measurements, so it is unlikely that differences in sensitivity were responsible for the bias. The 12-month measurements would also tend to be lower if some of the tracks disappeared over time, since the time between the start of exposure and the analysis would be longer for the 12-month measurements. Terradex has found that the number of tracks in their detectors do not decrease with time. However, it is still remotely possible that fading might occur under presently unidentified field conditions.

The two-month measurements might also tend to be higher if the detectors had a significant background that was not subtracted when the radon concentrations were calculated. The total exposure of the two-month samples would be significantly less than that of the 12-month samples, so any background that was not corrected for would raise the calculated concentration in the two-month samples more than it would the concentrations in the 12-month samples. Some of the detectors that were used for the two-month measurements were stored for as long as 10 months before use. The detectors used for the 12-month measurements were stored for much shorter time periods. It is also possible that the Terradex detectors were exposed significantly during handling. The filter cups containing the Terradex detectors are stored, one inside another, in sealed aluminized mylar bags. However, the bags must be opened when filter cups are removed and placed in buildings. Any radon that entered the bags before they were re-sealed would result in the exposure of the remaining detectors in the bag to radon and its daughters. (The filter is not placed over the mouth of the cup until the cup is removed from the bag for placement at the desired sampling location.) However, at Edgemont the bags containing the detectors were stored in a room with a rather low average radon daughter concentration. Several radon daughter measurements using five-minute air filters indicated that the average concentration was about 0.004 WL.

FIGURE 1. Comparison of Average Radon Concentrations from Six Two-month Terradex Track Etch® Samples with Concentrations in 12-month Track Etch® Samples

To test the possibility that the difference was due to background (or uncorrected for exposure during handling), the ratios of the concentrations from the two-month samples to those from the 12-month samples were compared for the twelve buildings in which the annual average radon daughter concentrations were greater than 0.015 WL. It would be expected that background would have less effect upon the measured Track Etch® concentrations in these buildings because of the higher total exposure. It was found that there was no average difference between the two-month and the 12-month measurements in these houses, suggesting that background was, in fact, responsible for the difference. This result suggested that the two-month measurements could be corrected by subtracting a constant background from each measurement. It was found that the two-month measurements would average the same as 12-month measurements if a background concentration of 0.0025 WL were subtracted from each two-month measurement.

The possibility that background or exposure during handling is responsible for the difference between the two-month and the 12-month measurements is now being checked by sending in for analysis Terradex detectors that have not been exposed in buildings, but have been handled in much the same manner as detectors that have been exposed in buildings. Unexposed detectors and detectors that have been exposed to known radon concentrations should be analyzed periodically for quality control purposes in any measurement program involving Track Etch® or similar detectors.

The simplest method for correcting for the difference between the 12-month and the two-month measurements is to convert the 12-month Track Etch® radon concentrations to radon daughter concentrations by dividing by 355 pCi/l/WL, the average ratio between the 12-month Track Etch® radon concentrations and the RPISU annual average radon daughter concentrations, and to convert the two-month Track Etch® radon concentration by dividing by 428 pCi/l/WL, the average ratio between the two-month Track Etch® radon concentrations and the RPISU annual average radon daughter concentrations. The Track Etch® radon daughter concentrations that will be discussed in the following paragraphs will be obtained by this method.

The real test of the usefulness of the Track Etch® radon daughter measurements lies in how well they predict whether the radon daughter concentration exceeds a remedial action standard, such as 0.015 WL. The probability that the RPISU annual average radon daughter concentration will exceed 0.015 WL can be calculated as a function of the Track Etch® radon daughter concentration from a table of ordinates and areas of the normal distribution using the standard deviation of the differences between the (natural) logarithms of the Track Etch® averages and the logarithms of the RPISU averages (S.D.-ln). The S.D.-ln should be used because the Track Etch® and RPISU measurements both show approximately log-normal distributions (see Figures 2 and 3). The S.D.-ln between the Track Etch® and the RPISU averages was found to be 0.37. It might be expected that the agreement between the RPISU and the Track Etch® measurements would be better at higher concentrations, because the analysis error would be a smaller fraction of the concentration at higher con-

FIGURE 2. Frequency Distribution of Terradex Track Etch® Average Annual Radon Concentration

FIGURE 3. Frequency Distribution of Average Annual RPISU Radon Daughter Concentrations (includes measurements not reported in Table 1)

centrations. However, the agreement actually appeared to be slightly better at lower concentrations. The S.D.-ln between the RPISU and the Track Etch® measurements was 0.31 for cases in which the Track Etch measurements were less than 0.010 WL, and 0.37 for cases in which the Track Etch® measurements were greater than 0.015 WL. Because of the relatively limited number of measurements in each concentration range, it is not possible to be certain that this change in S.D.-ln with concentration is real. Therefore, it will be assumed that S.D.-ln is independent of concentration in subsequent discussions.

Figure 4 shows the probabilities, calculated using S.D.-ln = 0.37, that the RPISU annual average would be greater than 0.015, 0.020, 0.025 and 0.030 WL as a function of the Track Etch® annual average. If the Track Etch® average is 0.015 WL, there should be a 50% probability that the RPISU annual average will be greater than 0.015 WL, but only a 22% probability that the RPISU average will be greater than 0.020 WL, and an 8% probability that it will be greater than 0.025 WL. However, if the Track Etch® average is 0.010 WL, there will only be a 14% probability that the RPISU average will be greater than 0.015 WL, and a 3% probability that the RPISU average will be greater than 0.020 WL. It should be remembered that if all buildings with Track Etch® averages less than or equal to 0.010 WL had been cleared from remedial action at Edgemont, the percentage of buildings cleared that actually had RPISU annual averages greater than 0.015 WL would have been considerably less than 14%. This is because most of the buildings cleared would have had Track Etch® averages less than rather than equal to 0.010 WL, and therefore would have had less than a 14% chance of having RPISU annual averages greater than 0.015 WL. The percentage of buildings cleared that actually had annual averages greater than 0.015 WL would have depended upon the frequency distribution of the average radon daughter concentrations in buildings.

In Figure 5, the actually observed probabilities that the RPISU annual average would be greater than 0.015 WL for given ranges of Track Etch® annual averages are compared with the calculated probabilities. The agreement between the calculated and the observed probabilities is fairly good. The differences that are observed are likely to be due largely to the relatively small number of measurements in each concentration interval. Only one of the buildings that had a Track Etch® radon daughter concentration less than 0.010 WL had a RPISU radon daughter concentration greater than 0.015 WL.

It might be expected that taking the average of the two-month and 12-month Track Etch® measurements in each of the buildings at Edgemont would lead to a better correlation with the RPISU measurements. However, the linear correlation coefficient, r , between the RPISU measurements and the averages of the two-month and the 12-month Track Etch® measurements was 0.78, which is only slightly higher than the linear correlation coefficient of 0.73 between the RPISU and the individual Track Etch® measurements. The S.D.-ln between the RPISU measurements and the averages of the two-month and 12-month Track Etch® measurements was 0.33, which was only slightly smaller than the S.D.-ln of 0.37 between the RPISU measurements and the individual Track Etch® measurements. This

FIGURE 4. Calculated Probability that the RPISU Average Annual Radon Daughter Concentration will be Greater than a Given Value as a Function of the Track Etch® Annual Average

FIGURE 5. Probability that the RPISU Average Annual Radon Daughter Concentration would be Greater than 0.015 WL as a Function of the Track Etch® Annual Average (the numbers in parentheses represent the numbers of measurements)

decrease in the S.D.-ln did not result in a significant increase in the calculated ability of the Track Etch® measurements to predict whether the RPISU average would be greater than a standard, such as 0.015 WL. This indicates that the variation between the RPISU and the Track Etch® measurements was not due primarily to random errors in the Track Etch® measurements. It could have been due to errors in the RPISU measurements, but was more likely to have been due primarily to variations in the daughter/radon equilibrium ratio.

It should be remembered that there is some error involved in the determination of annual average radon daughter concentrations from RPISU measurements. It has been estimated the RPISU annual averages have a precision of about $\pm 15\%$ (Young, et al, 1982; Langner and Franz, 1970). Therefore, some of the time the true average annual radon daughter concentration would have been less than 0.015 WL even though the RPISU average was greater than 0.015 WL, and vice versa. Therefore, the probabilities that the true annual average radon daughter concentrations would be greater than 0.015 WL for given Track Etch® averages that are equal to 0.010 WL could be somewhat greater or somewhat less than is shown in Figures 4 and 5.

The above results indicate that if buildings at Edgemont had been cleared from remedial action when they had Track Etch® annual averages less than 0.010 WL, at most a few percent of the buildings would have been cleared that had RPISU annual averages greater than 0.015 WL, and most of these would have had radon daughter concentrations only slightly greater than 0.015 WL.

However, a larger number of buildings would have been scheduled for engineering assessment even though they had average annual radon daughter concentrations less than 0.015 WL. Figure 4 indicates that if the Track Etch® average were 0.010 WL there would be an 86% probability that the RPISU average would be less than 0.015 WL. If it were 0.015 WL there would be a 50% probability that the RPISU average would be less than 0.015 WL, and if it were 0.020 WL there would be a 22% probability that the RPISU average would be less than 0.015 WL.

It has been estimated that eight man-hours are required to make six RPISU measurements (ALARA, 1980). This is about the same time that has been required to conduct engineering assessments to locate any residual radioactivity present in or around the buildings showing elevated radon daughter concentrations at Edgemont. Since buildings are cleared from remedial action if no residual radioactivity is discovered during engineering assessment, it would appear to be cost-effective to perform engineering assessments, rather than to make six RPISU measurements, if there is a fairly high probability that the average annual radon daughter concentration is greater than 0.015 WL.

The Track Etch® measurements at Edgemont were conducted mostly in buildings that showed radon daughter concentrations ranging from 0.010 to 0.033 WL in five-minute air filters, and 53% of the buildings at Edgemont had five-minute measurements within this range. Fifty-three

percent of the buildings in which Track Etch® measurements were made had Track Etch® averages less than 0.010 WL. These numbers indicate that about 28% of the buildings at Edgemont would have had five-minute measurements ranging from 0.010 to 0.033 WL, and Track Etch® averages less than 0.010 WL ($0.53 \times 0.53 = 0.28$). Thirty-three percent of the buildings at Edgemont had five-minute measurements less than 0.010 WL, and 14% had five-minute measurements greater than 0.033 WL. If it is assumed (1) that all of the buildings that had five-minute measurements less than 0.010 WL would have had Track Etch® averages less than 0.010 WL, and (2) that none of the buildings that had five-minute measurements greater than 0.033 WL would have had Track Etch® averages less than 0.010 WL, then it can be estimated that if year-long Track Etch® measurements had been used to screen all buildings at Edgemont, and if buildings had been cleared from remedial action if they had Track Etch® averages less than 0.010 WL, then 61% of the buildings would have been cleared by this procedure ($28\% + 33\% = 61\%$). The first assumption is more reasonable than it may appear, since the five-minute measurements were made in closed-up buildings, and therefore were found to average 1.7 times the RPISU annual averages.

The EPA has recently proposed that the radon daughter standard be changed to require that radon daughter concentrations shall, to the extent that is practical, achieve 0.020 WL; and shall not exceed 0.030 WL. According to Figure 4, at Edgemont there would have been a 14% probability that the RPISU average annual radon daughter concentration would have been greater than 0.030 WL if the Track Etch® average had been 0.020 WL, but only a 3% probability that the RPISU average would have been greater than 0.030 WL if the Track Etch® average had been 0.015 WL. It therefore appears that this proposed standard would have been satisfied if buildings having Track Etch® averages of 0.015 WL or less had been cleared from remedial action.

COMPARISON OF KODAK® FILM AND RPISU MEASUREMENTS AT EDMONT

Kodak® Pathe® LR-115 film can also be used as a Track Etch® detector. This film has the advantage that it detects primarily alpha particles that are below a certain energy. Therefore, alpha particles from radon daughters have to be degraded in energy by passage through air or an absorber before being detected. As a result, radon daughters that plate out on the film are not detected efficiently, so the film is not as sensitive to variations in plateout as are Terradex detectors. However, we originally had difficulty determining the total exposure of the film to alpha particles, because alpha particles impinging on the film at shallow angles did not make clearly defined tracks. Therefore, a collimating cup type holder was designed to reduce the fraction of alpha particles striking the film at shallow angles. A filter was also placed across the mouth of the cup so that the detector would measure only radon (and radon daughters produced by the decay of radon inside the cup). The tracks in this collimated detector were very easy to distinguish. The collimated detector was calibrated using known radon exposures in homes at Butte, Montana. Comparison of Kodak® film and Terradex detector measurements with 100-hour RPISU measurements in twelve homes at Edgemont

indicated that there was a better linear correlation between the Kodak® film measurements and the RPISU measurements than there was between the Terradex and the RPISU measurements. The better correlation between the Kodak® and the RPISU measurements was probably at least partly due to the fact that the total surface area of each Kodak® film that was analyzed by PNL was considerably larger than the surface area of each Terradex detector that is routinely analyzed by Terradex. Therefore, PNL obtained better counting statistics than are routinely obtained by Terradex. Terradex will analyze larger surface areas for an additional fee.

COMPARISON OF TERRADEX TRACK ETCH® AND RPISU MEASUREMENTS AT GRAND JUNCTION

ALARA (1980) has made year-long radon daughter measurements using Track Etch® films in 98 buildings in Grand Junction in which average radon daughter concentrations were also measured using RPISU's (Table 2). The average S.D.-ln between the Track Etch® measurements and the RPISU averages was 0.65, considerably larger than the S.D.-ln of 0.37 found between the Track Etch® measurements and RPISU measurements at Edgemont. There are several possible reasons for this larger S.D.-ln. For one thing, most of the RPISU averages were based on less than six measurements. If only cases where six RPISU measurements were made are considered, the S.D.-ln is decreased to 0.50 (based on 14 buildings). Also, many of the measurements were made in buildings having very low radon daughter concentrations. If buildings having radon daughter concentrations less than 0.010 WL according to either the Track Etch® or the RPISU measurement are eliminated, the S.D.-ln is lowered to 0.41 (based on 11 buildings). This more nearly corresponds to the S.D.-ln found at Edgemont.

COMPARISON OF PERM AND TERRADEX TRACK ETCH® RADON MEASUREMENTS

Mound Facility of Monsanto Research Corporation has made side-by-side measurements of radon concentrations using Terradex Track Etch® detectors and the RDT-310 Passive Environmental Radon Monitor (PERM) manufactured by EDA Instruments, Inc. They have been kind enough to send us their unpublished data for inclusion in this report.

The PERM uses a lithium fluoride thermoluminescent dosimeter (TLD) chip to measure radon concentrations. The radon in the ambient atmosphere diffuses through a bed of silica gel that removes moisture, and then through a filter that removes radon daughters. The radon enters a chamber where it decays to produce positively charged ^{218}Po ions. A 900 volt electrostatic field then draws the ^{218}Po ions toward a negatively charged TLD chip. Therefore, the TLD chip detects primarily the alpha particles produced by the decay of ^{218}Po or its daughters, although any alpha particles produced by the decay of radon in the chamber that strike the TLD chip would be detected also. When an alpha particle strikes the TLD chip it imparts its energy to the crystalline molecular structure of the chip, producing metastable, elevated electrons. At the end of the sampling period the TLD chip is removed for analysis. During analysis the chip is heated to the temperature at which the energy stored in the crystal lattice is released as light. The light is measured using a photomulti-

TABLE 2. Radon Daughter Concentrations Estimated from Integrating-TLD Samplers (RPISU) and From Passive Track Etch® Films

Location No.-Type ^a	Estimated Gross Annual Average WL	
	RPISU(#) ^b	Film(T/mm ²)
0011-0a	0.059(3)	0.050(102.6)
00097-Ra	0.091(1)	0.069(143.1)
00138-0	0.109(2)	0.073(151.5)
00140-0	0.030(1)	0.028(60.8)
00153-0	0.029(5)	0.029(61.2)
00176-0	0.072(2)	0.072(150.5)
00404-0	0.030(5)	0.021(45.1)
00452-0	0.010(2)	0.016(34.4)
00607-R	0.005(4)	0.009(20.)
00928-R	0.014(6)	0.012(25.0)
00944-R	0.009(4)	0.009(20.3)
00981-0	0.164(2)	0.120(246.4)
02739-R	0.032(2)	0.024(51.6)
02749-0	0.029(6)	0.022(50.6)
03077-R	0.008(4)	0.012(24.6)
03097-R	0.024(1)	0.037(77.8)
03495-R	0.012(6)	0.020(42.0)
03496-R	0.001(4)	0.012(27.0)
03722-R	0.065(2)	0.058(122.7)
03927-R	0.019(5)	0.030(64.5)
04004-R	0.004(4)	0.003(8.9)
04048-R	0.026(3)	0.033(71.2)
04065-R	0.143(2)	0.047(98.8)
04094-R	0.029(2)	0.054(115.0)
04234-R	0.005(4)	0.010(22.8)
04787-R	0.013(6)	0.025(57.2)
04930-R	0.041(2)	0.025(54.9)
05069-R	0.017(6)	0.037(36)
05421-R	0.008(4)	0.009(21.0)
05756-R	0.021(1)	0.017(37.9)
05785-0	0.024(2)	0.018(39.3)
05946-R	0.042(2)	0.033(77.8)
06012-R	0.006(4)	0.020(44.0)
07600-R	0.026(6)	0.016(34.6)
09566-0	0.023(5)	0.017(36.1)
10670-R	0.019(5)	0.010(22.0)
11827-R	0.049(3)	0.032(68.5)
12419-R	0.008(4)	0.007(16.7)
13384-R	0.019(5)	0.034(73.5)
14378-R	0.020(4)	0.029(63.4)
14639-R	0.010(6)	0.012(26.8)
14716-R	0.011(1)	0.007(16.1)
14718-R	0.006(4)	0.005(12.9)
15084-R	0.021(5)	0.026(57.6)

TABLE 2. Radon Daughter Concentrations Estimated from Integrating-TLD Samplers (RPISU) and From Passive Track Etch® Films (continued)

Location No.-Type ^a	Estimated Gross Annual Average WL	
	RPISU(#) ^b	Film(T/mm ²)
15494-R	0.026(4)	0.027(61.3)
17704-0	0.014(4)	0.038(80.0)
00233-R	0.013(3)	0.014(16.0)
00460-0	0.017(5)	0.012(29.0)
00826-0	0.014(2)	0.002(5.6)
00980-R	0.123(2)	0.046(104.6)
01025-0	0.007(3)	0.004(9.5)
01509-0	0.011(6)	0.008(18.8)
02220-R	0.008(4)	0.007(10.4)
03874-0	0.149(2)	0.078(158.5)
04442-R	0.032(3)	0.020(46.3)
04447-0	0.011(3)	0.011(25.1)
04789-R	0.016(6)	0.017(38.2)
04822-R	0.006(4)	0.009(20.8)
05040-0	0.108(3)	0.043(89.7)
05200-0	0.011(5)	0.005(11.8)
05554-0	0.059(4)	0.018(40.3)
05590-R	0.022(6)	0.009(20.0)
05775-0	0.066(4)	0.040(82.8)
05897-0	0.005(5)	0.002(6.0)
05936-R	0.020(4)	0.012(26.6)
06370-0	0.026(4)	0.010(22.5)
07470-R	0.025(4)	0.013(30.7)
14787-R	0.004(2)	0.001(4.8)
00180-0	0.086(5)	0.049(102.8)
02765-R	0.012(2)	0.005(12.4)
02909-R	0.012(3)	0.004(11.6)
02951-R	0.026(2)	0.004(11.8)
09630-R	0.007(2)	0.007(18.0)
00039-R	0.052(1)	0.048(95.6)
00045-0	0.043(6)	0.048(100.0)
00104-0	0.050(5)	0.022(46.1)
00156-R	0.008(4)	0.008(19.2)
00249-R	0.043(3)	0.031(65.0)
00306-0	0.046(5)	0.044(95.3)
00410-R	0.037(3)	0.062(124.7)
00459-0	0.022(3)	0.019(39.2)
30707-0	0.157(1)	0.147(300.0)
00476-0	0.009(5)	0.014(31.1)
00610-R	0.006(3)	0.006(14.2)
00730-R	0.032(5)	0.044(89.5)
01063-R	0.064(3)	0.035(73.6)
02073-R	0.034(4)	0.035(70.0)
03330-R	0.020(5)	0.031(67.9)
03493-R	0.012(5)	0.022(44.2)

TABLE 2. Radon Daughter Concentrations Estimated from Integrating-TLD Samplers (RPISU) and From Passive Track Etch* Films (continued)

Location No.-Type ^a	Estimated Gross Annual Average WL	
	RPISU(#) ^b	Film(T/mm ²)
04339-R	0.007(19)	0.016(34.4)
04752-R	0.039(3)	0.021(45.2)
04894-R	0.009(5)	0.014(29.7)
05056-0	0.005(2)	0.007(14.0)
05058-0	0.006(2)	0.011(36.1)
05193-R	0.010(6)	0.012(33.0)
05555-0	0.007(6)	0.016(35.7)
10556-R	0.014(6)	0.021(44.9)
11938-R	0.006(3)	0.012(27.8)

a. R = Residence or School; 0 = Other

b. Number of weekly RPISU samples

plier to determine the total exposure of the TLD chip. The PERM is thus a passive, continuous radon monitor that determines the average radon concentration for the measurement period chosen.

Indoor Measurements in Salt Lake City, Utah

Mound Facility has made side-by-side radon measurements using PERMS and Terradex Track Etch* detectors in eight buildings in Salt Lake City (Table 3). The correlation between the Track Etch* and the PERM measurements was very good. The linear correlation coefficient, r , was 0.90, considerably better than the linear correlation coefficient of 0.73 between the Terradex Track Etch* radon measurements and the RPISU radon daughter measurements in Edgemont. The S.D.-ln between the PERM and Track Etch* measurements in Salt Lake was 0.33, only slightly better than the S.D.-ln of 0.37 between the RPISU and the Track Etch* measurements in Edgemont. It is somewhat surprising that the S.D.-ln between the PERM measurements and the Track Etch* measurements in Salt Lake was only slightly better than that between the RPISU and Track Etch* measurements in Edgemont, because the RPISU measures radon daughters, while the PERM and Track Etch* measure radon. It would be expected that variations in the daughter/radon equilibrium ratio would cause the S.D.-ln between RPISU and Track Etch* measurements to be significantly poorer than the S.D.-ln between the PERM and the Track Etch* measurements. These results suggest that variations in the daughter/radon equilibrium ratio would not prevent the use of radon measurements for making estimates of radon daughter concentrations. However, only a very few measurements were made in Salt Lake. Many more measurements would be required to confirm this suggestion. Also, the data at Salt Lake and Edgemont are not strictly comparable. The data reported for Edgemont represent year-long averages while the measurements in Salt Lake were over approximately one-month intervals. Also, the RPISU measurement periods were different from those of the Track Etch* in Edgemont, while the PERM and Track Etch* measurement periods were identical in Salt Lake. The Track Etch* measurements at Edgemont were made continuously throughout the year, but only six 100-hour RPISU measurements were made during the year. ALARA, 1980, has estimated that this intermittent sampling schedule introduces about a 20% error into the calculated annual average.

It is possible that there was a systematic difference between the radon concentrations measured using the PERMs and those measured using Track Etch* in Salt Lake. The ratio of the PERM concentrations to the Track Etch* concentrations averaged $1.23 \pm .40$. However, the difference between this ratio and a ratio of 1.00 was not significant at the $p = 0.05$ level, according to the student's t test. More measurements would be required to determine whether the difference between the PERM and the Track Etch* measurements is statistically significant.

Outdoor Measurements in Canonsburg, Pennsylvania

Mound Facility has made side-by-side PERM and Track Etch* radon measurements at 48 outdoor locations in Canonsburg, Pennsylvania (Table 4). The correlation between the measurements was rather poor. The linear

TABLE 3. Indoor Radon Measurements by PERMs and Track Etch®

Salt Lake City, Utah

<u>Dates</u>	<u>Location</u>	<u>No.</u>	<u>PERM (pCi/l)</u>		<u>Track Etch® (pCi/l)</u>
			<u>Average</u>	<u>Std. Error</u>	
1/21/81 - 2/26/81	SL050	4	20.	8.	13.34
1/21/81 - 2/26/81	SL049	4	49.	16.	50.35
1/21/81 - 2/26/81	SL049	4	62.	16.	44.50
1/21/81 - 2/26/81	SL067	4	4.2	0.9	3.60
1/21/81 - 2/26/81	SL067	4	4.6	0.5	2.30
3/5/81 - 4/9/81	SL069	5	7.3	1.5	6.37
3/4/81 - 4/9/81	SL051	5	52.	5.	76.32
3/5/81 - 4/9/81	SL054	5	30.	2.	31.08

TABLE 4. Outdoor Radon Measurements by PERMs and Track Etch®

Canonsburg, PA

5/29/80 - 11/17/80

Location	No.	PERM (pCi/l)		Track Etch® (pCi/l)
		Average	Std. Error	
01	21	0.22	0.02	0.53
02	22	0.61	0.08	1.15
03	22	0.21	0.02	0.62
04	17	0.17	0.02	0.88
05	20	0.27	0.03	0.07
06	20	0.25	0.02	0.75
07	23	0.25	0.02	0.75
08	22	0.25	0.02	0.75
09	21	0.28	0.03	0.32
10	23	0.29	0.03	0.21
11	20	0.23	0.02	0.07
12	23	0.40	0.04	0.96
13	20	0.32	0.06	0.32
14	22	0.23	0.02	0.35
15	22	0.36	0.03	1.02
16	23	0.36	0.05	0.61
17	23	0.32	0.04	0.34
18	22	0.31	0.03	0.61
19	23	0.24	0.03	0.07
20	22	0.26	0.03	0.21
21	23	0.24	0.02	0.48
22	24	0.50	0.05	0.75
23	17	0.44	0.04	1.57
24	18	0.22	0.02	1.15

TABLE 4. Outdoor Radon Measurements by PERMs and Track Etch® (continued)

Canonsburg, PA

Location	No.	PERM (pCi/l)		Track Etch® (pCi/l)
		Average	Std. Error	
25	21	0.26	0.03	0.07
26	24	0.55	0.06	0.48
27	19	0.23	0.02	0.34
28	22	0.25	0.03	2.85
29	20	0.18	0.01	0.34
30	24	0.76	0.06	0.75
31	21	0.73	0.09	1.30
32	19	0.19	0.02	0.21
33	24	0.34	0.03	0.21
34	19	0.28	0.03	0.07
35	24	0.30	0.04	0.61
36	21	0.20	0.02	0.48
37	19	0.24	0.02	0.21
38	24	0.93	0.10	1.15
39	23	0.28	0.03	0.35
40	22	0.21	0.02	0.07
41	21	0.23	0.02	0.21
42	24	0.66	0.05	1.42
43	23	0.29	0.02	0.34
44	22	0.28	0.02	0.21
45	22	0.29	0.04	0.21
46	24	0.41	0.03	1.42
47	23	0.25	0.02	0.61
48	19	0.23	0.02	0.48

correlation coefficient, r , was only 0.40. The S.D.-ln between the measurements was 0.84, much higher than the S.D.-ln between the RPISU and Track Etch® measurements in buildings in Edgemont (0.37), or that between the PERM and the Track Etch® measurements in buildings in Salt Lake (0.33). It appears that either one or both of the measurement techniques did not provide accurate radon measurements at the outdoor locations in Canonsburg. It could be that variations in atmospheric conditions such as temperature, humidity, or wind speed resulted in poor measurement accuracy for at least one of the techniques. For example, moisture condensation on the Track Etch® detector would lead to inaccurate measurements. However, there did not seem to be any systematic difference between the PERM and the Track Etch® measurements at Canonsburg. The ratio of the PERM concentrations to the Track Etch® concentrations averaged 1.04 ± 1.03 .

COMPARISON OF PERM AND MOD-225 MEASUREMENTS IN BUILDINGS

Mound Facility has made side-by-side measurements of radon concentrations using PERMS and radon daughter concentrations using MOD-225 Integrating Radon Daughter Monitors manufactured by EDA Instruments, Inc. The MOD-225 operates on the same principle as the RPISU. Air is drawn through a filter next to which is placed a TLD chip. The total exposure of the TLD chip to alpha particles is later measured to determine the average radon daughter concentrations during the measurement period. According to EDA, the MOD-225 can make radon daughter measurements of up to four weeks duration.

Measurements at Canonsburg, Pennsylvania

Mound Facility has made six side-by-side PERM and MOD-225 measurements at an indoor location in Canonsburg (Table 5). The linear correlation coefficient, r , between the PERM and the MOD-225 measurements was 0.92, about the same as linear correlation coefficient of 0.90 that was found between the PERM and the Terradex Track Etch® measurements at Salt Lake City, and higher than the linear correlation coefficient of 0.73 that was found between the RPISU and Terradex Track Etch® measurements at Edgemont. The S.D.-ln between the PERM and the MOD-225 measurements was 0.38, about the same as the S.D.-ln of 0.33 between the PERM and the Track Etch® measurements at Salt Lake City, and the S.D.-ln of 0.37 between the RPISU and the Track Etch® measurements at Edgemont. The ratio between the PERM radon concentrations and the Track Etch® radon daughter concentrations averaged 130 pCi/l/WL, corresponding to a daughter/radon equilibrium ratio of .77, considerably higher than was found at Edgemont.

Measurements at Middlesex, New Jersey

Mound Facility has made 40 side-by-side PERM and MOD-225 measurements at Middlesex, New Jersey in the basement of a building where the ventilation conditions did not change drastically with time (Table 6). The linear correlation coefficient, r , between these measurements was 0.97, even higher than the correlation coefficient between these instruments at Canonsburg. However, the S.D.-ln between the measurements was 0.54,

TABLE 5. Simultaneous Radon and Radon Daughter Measurements at an Indoor Location in Canonsburg, PA

<u>Dates</u>	<u>PERM Radon (pCi/l)</u>	<u>MOD-225 Radon Daughters (WL)</u>
1/30/81 - 2/6/81	4.1	0.024
2/6/81 - 2/12/81	5.1	0.025
2/12/81 - 2/20/81	6.5	0.044
5/21/81 - 5/28/81	1.7	0.021
5/28/81 - 6/4/81	1.7	0.013
7/15/81 - 7/23/81	0.67	0.009
7/30/81 - 8/6/81	1.4	0.014

TABLE 6. Simultaneous Radon and Radon Daughter Measurements
at an Indoor Location in Middlesex, NJ

<u>Dates</u>	<u>PERM Radon (pCi/l)</u>	<u>MOD-225 Radon Daughters (WL)</u>
6/26/80 - 7/3/80	9.	0.062
7/3/80 - 7/10/80	13.	0.072
7/17/80 - 7/24/80	13.	0.033
7/24/80 - 7/31/80	14.	0.10
7/31/80 - 8/7/80	22.	0.15
8/7/80 - 8/14/80	32.	0.22
8/14/80 - 8/21/80	11.	0.081
8/21/80 - 8/28/80	0.7	0.012
9/4/80 - 9/11/80	2.5	0.010
9/11/80 - 9/18/80	1.3	0.010
9/18/80 - 9/25/80	1.9	0.014
9/25/80 - 10/2/80	1.6	0.029
10/2/80 - 10/9/80	3.7	0.013
10/9/80 - 10/16/80	0.6	0.013
10/16/80 - 10/23/80	3.3	0.020
10/23/80 - 10/30/80	3.4	0.016
11/20/80 - 12/4/80	2.9	0.017
12/4/80 - 12/10/80	3.3	0.016
12/10/80 - 12/17/80	1.3	0.006
12/17/80 - 12/30/80	2.7	0.012

TABLE 6. Simultaneous Radon and Radon Daughter Measurements
at an Indoor Location in Middlesex, NJ (continued)

<u>Dates</u>	<u>PERM Radon (pCi/l)</u>	<u>MOD-225 Radon Daughters (WL)</u>
12/30/80 - 1/14/81	3.2	0.009
1/14/81 - 1/21/81	1.6	0.012
1/21/81 - 1/28/81	3.1	0.009
1/28/81 - 2/4/81	2.0	0.007
2/4/81 - 2/11/81	3.3	0.010
2/18/81 - 2/25/81	2.7	0.010
2/25/81 - 3/4/81	1.4	0.005
3/26/81 - 4/2/81	1.4	0.008
4/2/81 - 4/8/81	1.7	0.010
4/8/81 - 4/16/81	1.5	0.007
4/16/81 - 4/23/81	1.5	0.006
4/23/81 - 4/30/81	1.6	0.009
4/30/81 - 5/7/81	1.2	0.005
5/7/81 - 5/13/81	0.53	0.012
5/13/81 - 5/21/81	0.57	0.008
5/21/81 - 5/27/81	1.5	0.009
6/3/81 - 6/10/81	1.4	0.011
6/10/81 - 6/17/81	1.6	0.014
6/17/81 - 6/25/81	0.91	0.006
6/25/81 - 7/1/81	0.52	0.006

somewhat larger than the S.D.-ln of 0.38 between the PERM and MOD-225 measurements at Canonsburg. The ratio between the PERM radon concentrations and the MOD-225 radon daughter concentrations averaged 186 pCi/l/WL, corresponding to a daughter/radon equilibrium ratio of 0.54.

Measurements at Salt Lake City

Mound Facility has made 52 side-by-side PERM radon and MOD-225 radon daughter measurements in a building in Salt Lake City (Table 7). However, the measurements were made in many different rooms of the building, and the rooms varied from being almost totally unventilated to being virtually open to the outdoors. As a result, it is likely that the daughter/radon equilibrium ratio would have changed significantly from measurement to measurement. This would have led to a low correlation between the radon and the radon daughter concentrations. It was found that the linear correlation coefficient, r , between the PERM radon measurements and the MOD-225 radon daughter measurements was only 0.56, much lower than the correlation coefficients between the PERM and MOD-225 measurements at Canonsburg and Middlesex. The S.D.-ln between the measurements was 0.76 at Salt Lake City, also much higher than the S.D.-ln between the measurements at Canonsburg and Middlesex.

It might be expected that the radon and radon daughter concentrations measured in rooms open to the outside would be much lower than those measured in more tightly sealed rooms. It might also be expected that there would be a difference in the daughter/radon equilibrium ratio between the sealed up rooms and those open to the outdoors. Therefore, eliminating the measurements showing low radon or radon daughter concentrations might lower the S.D.-ln between the remaining measurements. However, the S.D.-ln between the PERM and the MOD-225 measurements was 0.77 for cases in which the PERM radon measurement was 1 pCi/l or greater. This S.D.-ln is virtually identical to the S.D.-ln for the entire set of measurements.

SIDE-BY-SIDE MEASUREMENTS OF RADON AND RADON DAUGHTERS AT BUTTE

The University of Texas is making side-by-side measurements of radon and radon daughter concentrations in homes at Butte, Montana. Measurements are being made using radon gas monitors, passive radon monitors, radon grab samples, Terradex Track Etch® detectors (types B and F), air filters, and working level monitors. Some of the data comparing RPISU and five-minute air filter measurements have been published. This data will be discussed in a subsequent report concerned with short-term measurement techniques. Considerable unpublished data has been obtained by PNL from the Butte study, but only under the understanding that PNL will not report upon this data until it has been published.

MEASUREMENTS PLANNED IN THE FUTURE

Future PNL plans call for continuous side-by-side measurements of radon and radon daughter concentrations in two homes at Edgemont, using a variety of techniques. Radon daughter measurements will be made using five-minute air filters, Alpha Nuclear Radon Progeny Monitors, and RPISU's.

TABLE 7. Simultaneous Radon and Radon Daughter Measurements
at an Indoor Location in Salt Lake City, UT

<u>Dates</u>	<u>PERM Radon (pCi/l)</u>	<u>MOD-225 Radon Daughters (WL)</u>
2/3/82 - 2/18/82	0.31	0.003
2/3/82 - 2/18/82	2.0	0.006
2/3/82 - 2/18/82	0.21	0.003
2/3/82 - 2/18/82	0.24	0.007
2/18/82 - 3/4/82	0.26	0.002
2/18/82 - 3/4/82	0.32	0.006
2/18/82 - 3/4/82	0.30	0.002
3/10/82 - 3/17/82	2.3	0.021
3/10/82 - 3/17/82	10.	0.030
3/10/82 - 3/17/82	2.8	0.019
3/10/82 - 3/17/82	2.9	0.023
3/17/82 - 3/24/82	1.2	0.004
3/17/82 - 3/24/82	0.41	0.002
3/17/82 - 3/24/82	1.7	0.006
3/17/82 - 3/24/82	0.83	0.007
3/24/82 - 3/31/82	0.75	0.001
3/24/82 - 3/31/82	0.70	0.005
3/24/82 - 3/31/82	0.74	0.005
4/7/82 - 4/14/82	0.20	0.001
4/14/82 - 4/21/82	0.13	0.001
5/5/82 - 5/12/82	7.4	0.019
5/5/82 - 5/12/82	2.0	0.013
5/12/82 - 5/26/82	5.0	0.024
5/12/82 - 5/19/82	1.3	0.005
5/19/82 - 5/26/82	2.2	0.002
5/26/82 - 6/3/82	5.2	0.015
5/26/82 - 6/3/82	2.0	0.003

TABLE 7. Simultaneous Radon and Radon Daughter Measurements at an Indoor Location in Salt Lake City, UT (continued)

<u>Dates</u>	PERM	M00-225
	<u>Radon (pCi/l)</u>	<u>Radon Daughters (WL)</u>
6/3/82 - 6/9/82	3.1	0.009
6/3/82 - 6/9/82	1.3	0.006
6/9/82 - 6/16/82	2.4	0.010
6/9/82 - 6/16/82	1.2	0.014
6/16/82 - 6/23/82	1.0	0.008
6/16/82 - 6/23/82	0.35	0.004
6/23/82 - 6/30/82	0.94	0.005
6/23/82 - 6/30/82	0.48	0.003
6/30/82 - 7/8/82	2.8	0.027
6/30/82 - 7/8/82	0.97	0.008
7/8/82 - 7/14/82	0.58	0.008
7/14/82 - 7/28/82	0.45	0.008
7/14/82 - 7/28/82	0.35	0.006
7/28/82 - 8/11/82	0.93	0.008
7/28/82 - 8/11/82	1.0	0.017
8/11/82 - 8/18/82	0.29	0.005
8/11/82 - 8/18/82	0.44	0.011
8/18/82 - 9/1/82	0.65	0.008
8/18/82 - 9/1/82	0.36	0.007
9/1/82 - 9/15/82	2.5	0.047
9/1/82 - 9/15/82	1.7	0.017
9/15/82 - 9/23/82	2.2	0.023
9/15/82 - 9/23/82	2.3	0.022
9/23/82 - 9/29/82	2.6	0.047
9/23/82 - 9/29/82	2.2	0.031

Radon measurements will be made using Terradex and Kodak® Pathe' LR-115 Track Etch® detectors, grab scintillation flasks and Eberline Continuous Radon Monitors. One of the homes will be vacant during the measurements, and the other will be occupied. The occupied house will also be equipped with continuous monitors of condensation nuclei, humidity, temperature, and indoor air exhalation rate. A micrometeorological station will also be monitored. This program is designed to determine the conditions and activities that most significantly affect the measurement of radon daughter concentrations in the home.

Additional comparisons between radon daughter concentrations and Track Etch® measurements in buildings must be made at locations other than Edgemont, Grand Junction and Salt Lake City to determine whether the correlations measured at other locations will be similar to those at these locations. Comparisons under controlled conditions must also be made to determine the factors that affect the correlations. It is quite possible that daughter/radon equilibrium ratios will vary so much from site to site that it will be necessary to determine the average ratio between the radon daughter concentration and the concentration measured using a Track Etch® detector at each site before the Track Etch® detector can be used to measure radon daughter concentrations at that site.

SUMMARY AND CONCLUSIONS

Comparisons between radon and radon daughter measurements in buildings at Edgemont, Grand Junction, Canonsburg, Salt Lake City and Middlesex indicate that radon measurements can be used to provide reasonable estimates of radon daughter concentrations, but only if sufficient side-by-side radon and radon daughter measurements are also made to determine the daughter/radon equilibrium ratio characteristic of the measurement site. The S.D.-ln between the Terradex Track Etch® average annual radon concentrations and the RPISU average annual radon concentrations measured at Edgemont was 0.37. The Track Etch® radon concentrations at Edgemont can be converted to radon daughter concentrations by dividing by the average ratio between the Track Etch and the RPISU concentrations. Using the above S.D.-ln, and the Track Etch® radon daughter concentrations calculated in this manner, it can be calculated that if the Track Etch radon daughter concentration is 0.010 WL, there should be only a 14% probability that the RPISU annual average would be greater than 0.015 WL, and only a 3% probability that it would be greater than 0.020 WL. However, if all buildings with Track Etch® averages less than or equal to 0.010 WL had been cleared from remedial action at Edgemont, the percentage of buildings cleared that actually had annual averages greater than 0.015 WL would have been much less than 14%, because most of the buildings cleared would have had Track Etch® averages less than 0.010 WL. Therefore, they would have had less than a 14% chance of having annual averages greater than 0.015 WL. Of the 100 Track Etch® annual averages measured in Edgemont, only one was less than 0.010 WL in a building in which the RPISU average was greater than 0.015 WL.

If buildings having Track Etch® average annual radon daughter concentrations greater than 0.010 WL had been scheduled for engineering assessment to locate any residual radioactivity present, a considerable number of buildings would have been scheduled for engineering assessment that actually had annual averages less than 0.015 WL. However, the cost of each of these engineering assessments would have been comparable to the cost that is now being expended at Edgemont to perform each year-long RPISU measurement series.

If the decision level were raised above 0.010 WL, the number of buildings scheduled for engineering assessment would be decreased, but the probability of incorrectly clearing a building from remedial action would also be increased. However, most of the buildings incorrectly cleared would have had annual averages only slightly greater than 0.015 WL. The actual decision level chosen will depend upon the probability that can be tolerated that a building will be cleared from remedial action even though it has slightly elevated radon daughter concentrations.

The S.D.-ln between the Track Etch® radon measurements and the RPISU radon daughter measurements at Grand Junction was very similar to that at Edgemont, if measurements showing radon daughter concentrations less than 0.010 WL were not considered. The S.D.-ln between the PERM radon measurements and the MOD-225 radon daughter measurements at Cannonsburg and Middlesex were also similar to the S.D.-ln between the radon and radon daughter measurements at Edgemont. In addition, the S.D.-ln between the PERM and Track Etch® radon measurements at Salt Lake City was only slightly better than the S.D.-ln between the radon and radon daughter measurements at other locations. These results suggest that the conclusions drawn from the Edgemont Track Etch® data can be applied to other indoor locations, and to the PERM radon analyzer. However, the number of side-by-side radon and radon daughter measurements is still rather limited, so these conclusions should be viewed with caution until many more measurements are made. Also, the large S.D.-ln found between the PERM radon and the MOD-225 radon daughter measurements made in rooms having very different ventilation conditions in a building in Salt Lake City indicates that there will be situations in which there will be a poor correlation between radon and radon daughter measurements.

The large S.D.-ln between the PERM and Track Etch® radon concentrations at outdoor locations in Cannonsburg suggests that at least one of these techniques may not provide accurate radon measurements for at least some outdoor conditions. However, many more side-by-side radon measurements using these and other techniques are needed to determine whether one or both of these techniques can generally provide accurate outdoor radon measurements.

REFERENCES

ALARA, Inc. 1980. Grand Junction Remedial Action Program: Analysis of Currently Approved and Proposed Procedures for Establishing Eligibility for Remedial Action, DOE/EV/01621/T1.

Langner, G. H., Jr. and G. A. Franz. 1979. Considerations and Recommendations on Methods for Determining Eligibility, unpublished manuscript submitted to DOE.

McGregor, R. G., P. Vasuder, E. G. Letorneau, R. S. McCullough, F. A. Pranti and H. Taniguchi, 1980. Background Concentrations of Radon and Radon Daughters in Canadian Homes, Health Physics, 39:285-289.

Stranden, E., L. Berteig and F. Ugletveit, 1979. A Study of Radon in Buildings, Health Physics, 36:413-421.

Young, J. A., P. O. Jackson and V. W. Thomas. 1982. Radiological Surveys of Properties Contaminated by Residual Radioactive Materials from Uranium Processing Sites, NUREG/CR-2954, PNL-4264, Report prepared for the Nuclear Regulatory Commission.

APPENDIX

OPERATING CHARACTERISTICS OF CONTINUOUS RADON DAUGHTER ANALYZERS

Introduction

There are several commercially available radon daughter analyzers. Although their accuracy and reliability have not as yet been determined adequately by field intercomparison studies, some insight into the advantages, limitations, and problems of these instruments can be obtained from a consideration of their principles of operation and the technical literature.

The commercially available instruments for monitoring radon daughter concentrations continuously can be divided into two basic types. One type uses a filter in the form of a continuous tape that is intermittently advanced in front of an air sampling port and then in front of a radiation detector. The other type uses a single filter that is mounted permanently in front of a radiation detector. Air is drawn through the filter either continuously or intermittently. Both of these types of instruments have advantages and limitations. Therefore, the choice of instrument to be used will depend upon the particular needs and budget of the user. The characteristics of each type of instrument will be discussed in the following paragraphs.

Moving Filter Instruments

The authors of this report are aware of two companies that manufacture radon daughter analyzers that utilize moving filters; the Harshaw Chemical Company of Solon, Ohio, and the Alpha Nuclear Company of Mississauga, Ontario, Canada. The filter media used in these instruments is advanced in front of the air sampling port by a stepping mechanism. Air is drawn through the filter for a pre-set time interval. Air-tight seals must be maintained between the filter media and the inlet and outlet ports during sampling. After the pre-set interval, the filter is advanced in front of the radiation detector(s). The Alpha Nuclear instrument determines the concentrations of ^{218}Po , ^{214}Pb , ^{214}Bi and ^{214}Po from two or more measurements of the individual ^{218}Po and ^{214}Po emission rates using a collimated surface barrier diode alpha particle spectrometer. The Harshaw system determines the concentrations of these radon daughters from a single simultaneous measurement of the ^{218}Po and ^{214}Po alpha emission rates using a surface barrier alpha particle spectrometer and the total beta emission rate, using a $\text{CaF}_2(\text{Eu})$ beta particle detector.

The Alpha Nuclear instrument has a second surface barrier alpha particle spectrometer located farther downstream in the path of the moving filter. This permits the analysis of the ^{220}Rn (thoron) daughters, ^{212}Bi and ^{212}Po , at a later time when the short-lived radon daughters have decayed to insignificance. A desk top computer is used to program the instrument to analyze the alpha spectral regions appropriate for the determination of the radon and thoron daughters.

These instruments should respond more accurately to changing radon daughter concentrations than fixed filter instruments, because a fresh filter is used for each measurement. Therefore, there is no need to make mathematical corrections for previously deposited radionuclides. This feature is more important for research applications than for continuous monitoring applications where the determination of average concentrations over several time intervals is likely to be the primary objective.

The mechanical complexity of these instruments is likely to prove to be their primary drawback. The necessity of moving the filter and of making proper air-tight seals could lead to maintenance problems. The moving filter tapes have limited reel lengths, and the reels do not, at present, rewind automatically. Therefore, the user will need to have regular access to the instruments to rewind the reels.

Because of their mechanical complexity, these instruments are expensive. The Harshaw Model 100-101 radon daughter analyzer costs \$17,000 (the prices quoted in this report are 1982 prices). The quoted price of the Alpha Nuclear system is greater than \$23,000. However, the Alpha Nuclear system is still in the early stages of production, so its price could change significantly in the future.

As of September 1, 1982, the Harshaw radon daughter analyzer lacked a backup battery for the operation of the control computer module. Therefore, a power failure would result in a loss of the pre-set operational instructions concerning sampling times. The unit also does not record the times that the measurements were taken. These limitations can be serious when measurements are made in remote areas having frequent power outages.

Fixed Filter Instruments

Radon daughter analyzers that use fixed filters are manufactured by EDA Instruments, Inc. of Toronto, Canada, and by the Eberline division of the Thermo Electron Company of Santa Fe, New Mexico. EDA manufactures two separate analyzers, the WLM 300 and the RGA-400. Both of these units use surface barrier alpha particle spectrometers to measure the ^{218}Po and ^{214}Po collected on filters. WLM-300 has been available for about a year, and is primarily intended for long-term remote monitoring of radon daughters. The RGA-400 also measures radon by collecting the radon daughters that are produced by radon decay following the passage of the radon through the filter. The radon daughters are collected using an electrostatic collection device and are measured using a surface barrier detector. The RGA-400 is equipped with a more complex microprocessor than the WLM-300. This microprocessor is capable of storing previous counting data, and its designers intend to introduce software that will enable it to correct each count more precisely for previously deposited radon daughters than is possible for the WLM-300 instrument.

At this time the RGA-400 is just being introduced into the market. This is also true of the Eberline instrument, so written information

concerning the operating procedures and the characteristics of the Eberline have not yet been received.

Instruments that continuously measure varying concentrations of radon daughters on fixed filters must make precise corrections for the decay and ingrowth of radon daughters in material that has previously been deposited on the filter, if the calculated concentrations are to follow the actual concentrations. If procedures for making precise corrections are not available, fixed correction factors can be used that will give concentrations that approximate the actual time variation of the concentrations, especially if the concentrations vary slowly. The authors have not seen the correction algorithms used by either the RGA-400 or the Eberline instrument, so it is not possible at the present time to determine how closely the concentrations determined by these instruments will follow the actual concentrations.

If these instruments are to be able to determine the individual radon daughter concentrations using alpha spectrometry alone, they must be able to use the time variation of the ^{218}Po and ^{214}Po concentrations to calculate the rate of ingrowth of ^{214}Po produced by the decay of the beta emitters, ^{214}Pb and ^{214}Bi , despite the fact that additional ^{218}Po and ^{214}Po are being continually collected on the filter. The authors are not aware of any algorithm that can make such a calculation accurately when sampling is continuous. If each sampling interval was followed by two counting intervals, the concentrations of the individual radon daughters could theoretically be calculated.

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16. ABSTRACT (200 words or less) Pacific Northwest Laboratory (PNL) is performing side-by-side measurements of radon and radon daughter concentrations using several instruments and techniques, and is comparing these measurements with side-by-side measurements made by other investigators at other locations. The standard deviation of the differences between the (natural) logarithms of the Terradex Track Etch radon concentrations and the logarithms of the RPISU radon daughter concentrations (S.D.-ln) measured in 50 buildings in Edgemont, South Dakota, was 0.37. Using this S.D.-ln, it can be calculated that if the Track Etch radon daughter concentration is 0.010 WL there should be only a 14% probability that the RPISU average would be greater than 0.015 WL, and only a 3% probability that the RPISU average would be greater than 0.020 WL. If buildings had been cleared from remedial action when the Track Etch averages were less than 0.010 WL, then about 61% of the buildings would have been cleared from remedial action, and only a few percent of these buildings would have actually had average RPISU concentrations greater than 0.015 WL. The S.D.-ln between (1) the Track Etch radon measurements and the RPISU radon daughter measurements made by ALARA at Grand Junction, (2) the PERM radon measurements and the MOD-225 radon daughter measurements made by Mound Facility at Canonsburg and Middlesex, and (3) the PERM and Track Etch radon measurements made by Mound Facility at Salt Lake City were similar to the S.D.-ln between the Track Etch radon measurements and the RPISU radon daughter measurements at Edgemont.					
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