License Condition 10.8

Proposed lLicence condition 10.8 states that “the licensee shall conduct isotopic analyses for alpha and beta emitting radionuclides on airborne samples at each in-plant particulate sampling location at a frequency of once every six months for the first two years and annually thereafter to ensure compliance with 10 CFR 20.1204 (g). For any changes to operations, the licensee shall conduct an evaluation to determine if more frequent isotopic analyses are required.”

The origin of this requirement is the regulation, 10 CFR 20.1204 (g), which states that when a mixture of radionuclides in air exists, licensees may disregard certain radionuclides within the mixture if:

> a) the licensee uses the total activity of the mixture in demonstrating compliance with the dose limits in 10CFR20.1201 and in complying with the monitoring requirements in 10CFR20.1502(b), and
>
> b) the concentration of any radionuclide disregarded is less than 10 percent of its DAC, and
>
> c) the sum of these percentages for all the radionuclides disregarded in the mixture does not exceed 30%.

As per Regulatory Guide 4.14, airborne particulate samples from the in-plant sampling stations were analyzed for natural uranium, thorium-230, radium-226 and lead-210. The purpose of this sampling is to determine if the concentrations of these radionuclides are below 10% of their respective DACs in the facility and the total percentage of any disregarded radionuclides is below 30% of the mixture. The DAC for Class W Th230, which is lower than for Class Y, is 3x10$^{-12}$ μCi/ml. To meet the DAC requirement, Th230 must be present at less than a concentration of 3x10$^{-13}$ μCi/ml. Similarly, Ra226 must be present at concentration less than 3x10$^{-11}$ μCi/ml, which is 10% of its DAC of 3x10$^{-10}$ μCi/ml, and Pb210 must be present at concentration less than 1x10$^{-11}$ μCi/ml, which is 10% of its DAC of 1x10$^{-10}$ μCi/ml. A DAC of 5x10$^{-10}$ μCi/ml was used for natural uranium as solubility studies performed for both the Crow Butte and Smith Ranch-Highland operations have demonstrated that the uranium is of class D solubility.

Tables 1 and 2 present the analysis of the samples collected from Smith Ranch – Highland and operations Crow Butte, respectively. To date, Crow Butte has collected one sample set consisting of 7 samples, five from the routine sampling locations and two from additional locations within the plant during the first half of 2013. Smith Ranch – Highland has collected a total of 58 samples from sampling locations within the main plant, satellites and wellfield over the period of July 2009 to February 2011. Samples were collected using a high-flow pump run for approximately one week, with particulate collected on a 47mm filter.



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**Table 1: Isotopic Analysis of Airborne Dust Samples at Smith Ranch - Highland**

| Date | Area | Alpha Emitters | | | Beta Emitter |
|---|---|---|---|---|---|
| | | Lab Result Unat (µCi/ml) | Lab Result Th-230 (µCi/ml) | Lab Result Ra-226 (µCi/ml) | Lab Result Pb-210 (µCi/ml) |
| | **Average** | 1.07E-12 | 0.00E+00 | 4.06E-15 | 2.52E-14 |
| | **DAC** | 5.00E-10 | 3.00E-12 | 3.00E-10 | 1.00E-10 |
| | **Average as % of DAC** | 0.2% | 0.00% | 0.001% | 0.03% |
| | **% of Total Activity** | 97.3% | 0.0% | 0.4% | 2.3% |

**Table 2: Isotopic Analysis of Airborne Dust Samples at Crow Butte**

| Date | Area | Alpha Emitters | | | Beta Emitter |
|---|---|---|---|---|---|
| | | Lab Result Unat (µCi/ml) | Lab Result Th-230 (µCi/ml) | Lab Result Ra-226 (µCi/ml) | Lab Result Pb-210 (µCi/ml) |
| | **Average** | 2.25E-13 | 2.71E-16 | 1.53E-15 | 1.74E-14 |
| | **DAC** | 5.00E-10 | 3.00E-12 | 3.00E-10 | 1.00E-10 |
| | **Average as % of DAC** | 0.04% | 0.00% | 0.001% | 0.02% |
| | **% of Total Activity** | 92% | 0% | 1% | 7% |

As shown in Tables 1 and 2, all of the isotopes analyzed were present in concentrations significantly below 10% of their respective DACs and Th230, Ra226 and Pb210 combined contributed significantly less than 30% of the total activity of the material.

Smith Ranch – Highland has sampled over ~~approximately~~ a two-year period with consistent results demonstrating the activity from radionuclides other than natural uranium is both below 10% of the respective DACs and the total activity of these radionuclides (Th230, Ra226 and P210) is below 30% of the total activity. However, even though Pb210 is below the criteria for disregarding it in the determination of the DAC, because the determination of the activity present on airborne particulate sampling filters is based on alpha counting Pb210 is not explicitly included in the total activity. To account for the presence of Pb210, the natural uranium DAC must be modified. Following the method in Regulatory Guide 8.30, the DAC for the mixture of natural uranium and Pb210 is $4.6\times10^{-10}$ µCi/ml, which rounded to one decimal place as per the values in 10 CFR 20 remains $5\times10^{-10}$ µCi/ml. Based on these results it is proposed this DAC



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remain as is and any further sampling at Smith Ranch – Highland operation only be performed once per license period and after changes to operations.

The results from Crow Butte are comparable to those from Smith Ranch – Highland, however, Crow Butte has only completed one round of sampling at this time and currently has a slightly higher percentage of Pb210 present. Crow Butte will complete the sampling, as per license condition 10.8, prior to determining if the DAC needs to be revised; based on the data to date the DAC would be modified to $4x10^{-10}$ µCi/ml.

<u>License Condition 11.10</u>~~:~~

Proposed l~~L~~icense condition 11.10 states that "The licensee shall develop a survey program for beta/gamma contamination for personnel exiting ~~from~~ restricted areas, and beta/gamma contamination in unrestricted and restricted areas that will meet the requirements of 10 CFR Part 20, Subpart F and submit to the NRC for review and written verification. The licensee shall provide for NRC review and written verification the surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDA for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for alpha and beta radiation expected shall be provided in terms of dpm per 100 $cm^2$."

This condition is referenced to 10CRF20 Subpart F, in which section 20.1501 deals with general requirements and 20.1502 deals with requirements related to dose. As this condition is only related to scanning, not dose calculation, 20.1501 is the applicable reference. Specific to contamination scanning, the regulations state:

(a) Each licensee shall make or cause to be made, surveys of areas, including the subsurface, that--

- (1) May be necessary for the licensee to comply with the regulations in this part; and
- (2) Are reasonable under the circumstances to evaluate--
  - (i) The magnitude and extent of radiation levels; and
  - (ii) Concentrations or quantities of residual radioactivity; and
  - (iii) The potential radiological hazards of the radiation levels and residual radioactivity detected.

Currently, alpha contamination surveys are used to monitor personnel and equipment for surface contamination at the boundaries of the restricted area. To incorporate beta/gamma contamination monitoring, the process included characterization of beta/gamma background conditions, equipment trials, scanning method selection and MDC calculation. A more detailed discussion is provided below.~~, however~~ ~~I~~in summary, it was determined that where background conditions made direct measurement of beta/gamma contamination prohibitive, a ratio between



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beta/gamma and alpha contamination would be required as part of the survey program. The ratios proposed are 2.5:1 for personnel and 4:1 for equipment. The different ratios were determined based on experimental data involving the monitoring of a variety of different materials and personnel at the Crow Butte and Smith Ranch- Highland plants. In acceptable background conditions, i.e. those that would allow for MDCs of 50% of the contamination limit or less, direct measurement of both contamination types could be performed and results calculated directly, rather than through use of ratios.

The first activity was to attempt to characterize the potential for contamination in the dust present in the main plant at Crow Butte. The process of collecting smears was used~~decided on~~ because samples could be collected from higher background areas of the plant, and then counted in a low background area on a Ludlum 2929 dual channel alpha and beta/gamma detector. ~~To do this, a~~A total of 44 smear samples were collected throughout the main plant and counted for both contamination types. Following this, a ratio of alpha to beta/gamma contamination was determined. The beta/gamma to alpha ratio calculated from these measurements was 2.3, with all samples being included in the average. It was noted that some samples could be considered outliers due to having very high dust loadings - excluding three highly loaded samples, the average dropped to 1.4. The expected average result was a ratio of one-to-one, as after equilibrium is reached between uranium and its short lived decay products there are two alpha and two beta/gamma emitters present. However, as some of the areas surveyed had significant amounts of dust present, alpha self-shielding was a factor and resulted in an average ratio somewhat above the theoretical. This experiment served to demonstrate that alpha and beta/gamma contamination levels were both present and likely at equilibrium concentrations; therefore some form of surveying for both contamination types was warranted under 10CFR20.1501.

Experiments with different monitoring devices was conducted and it was determined that the Ludlum 43-93 dual channel alpha/beta detector was the best choice. ~~This is because I~~It can perform monitoring for both radiation types simultaneously, should this be required, and it produced consistent and reliable results. Also the larger probe size, compared to Ludlum 44-9 or 44-94 alpha/beta/gamma detectors, means that lower MDCs could be achieved. It is worth noting that the 43-93 detector's beta channel, as per the manufactures specifications, is sensitive to gamma radiation at a rate of 15 – 20 cpm per uR/hr.

Prior to ~~beginning~~ development of a survey program for beta/gamma contamination, knowledge of background conditions are required, as this will impact MDC and scanning methodology. Background alpha and beta/gamma measurements were made using a Ludlum dual channel alpha/beta 43-93 probe at the personal frisking stations. Using the scalar mode of the detector at these locations, background alpha measurements averaged approximately 25 counts in 5 minutes (or 5 cpm), and the beta/gamma measurements averaged approximately 5900 counts in 5 minutes (or 1180 cpm). As an example, the resulting MDC for the beta/gamma component, assuming a 5 minute background count of 5900, a 30 second scalar sample count, probe size of 100 $cm^2$ and





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efficiency of 20% is 868 dpm/100cm$^2$, based on the method by Strom and Stansbury as referenced in NUREG 1507 (equation 1 below). Though still below 1000 dpm/100 cm$^2$, this MDC value is quite high and would result in significant uncertainty in the final result. Also, areas somewhat above the average background used in the example could have MDCs in excess of the limit.



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$$MDA\left(\frac{DPM}{100cm^2}\right) = \frac{3+3.29\sqrt{R_b\, t_g(1+\frac{t_g}{b})}}{\varepsilon t_g(\frac{SA}{100cm^2})} \qquad (1)$$

where: $R_b$ = the background count rate
$t_g$ = the sample count time
$t_b$ = the background count time
$\varepsilon$ = the counter efficiency
SA = probe surface area ($cm^2$)

Given these background conditions, the use of beta/gamma radiation measurements for releases with a limit of 1000 dpm/100cm$^2$ to non-restricted areas is not achievable at some locations in the plant. As a result, we are proposing an alternate method for surveying of beta/gamma contamination for personnel, using alpha measurements and a ratio of beta/gamma to alpha contamination levels. For equipment releases, this method is also proposed when background conditions result in an unreasonable MDC. Note if the limit of 5000 dpm/100cm$^2$ for total beta/gamma contamination is being used for the equipment release criteria, or background conditions are low, direct beta/gamma measurements can be used. The criteria will be discussed further below.

A sampling campaign was conducted to determine a reasonable ratio between alpha and beta/gamma contamination. This campaign was conducted at both Smith Ranch-Highland (SRH) and Crow Butte (CB) sites, and consisted of a large cross-section of regularly scanned equipment and locations, as well as additional places~~spots~~ of interest. In total, 554 observations were collected, 167 from SRH and 387 from CB. However, particularly in locations with higher beta/gamma background levels, it was found that many measurements were at or below background measurements; it is likely this is in part due to measuring very low contamination levels and higher uncertainty due to elevated background conditions. Of the total samples collected, 234 of the measurements, 69 from SRH and 171 from CB, were used in the analysis. From this point, a distribution based outlier detection method for univariate data, with the assumption of a normally distributed population, was used to determine and filter outliers from the data set. The parameters for a model distribution were estimated using regression of the sorted data on their QQ-plot positions. A value in the data is considered an outlier when it is unlikely to be drawn from the estimated distribution.

Once the outliers were filtered out, a density estimate and plot were generated. The beta/gamma to alpha ratios that resulted in the maximum density were then taken to be the most statistically significant ratios. Based on this analysis including all data points, the overall beta/gamma to





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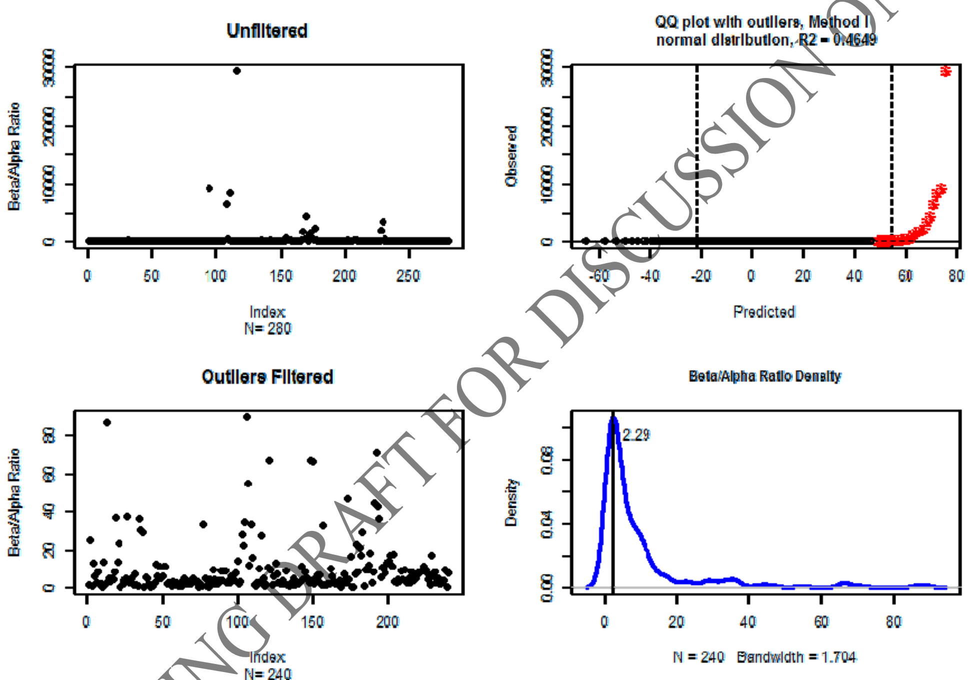
alpha ratio is 2.3, as is shown in Figure 1. This is the same value as determined through use of smear sampling.

In addition to the above analysis, a breakdown of factors that could impact beta/gamma to alpha scan ratios was explored, including site, material, and survey area; this data is presented in Table 1. Despite many varying conditions, the results were generally consistent.

Figure 1: Distribution Analysis of Beta/Gamma to Alpha Ratios




**(top left)** Plot of the distribution of beta to alpha ratios. **(top right)** QQ-plot with observed against predicted ratios plotted. Red stars indicate points determined to be outliers. **(bottom left)** Plot of the distribution of beta to alpha ratios, with outliers filtered out. **(bottom right)** Density plot of filtered beta to alpha ratios, with a ratio at maximum density of 2.29.



Table 1: Summary of beta/gamma to alpha contamination ratios based on different factors

Sites:

| Site | Ratio | Number of Data |
|---|---|---|



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| | | Points |
|---|---|---|
| CB | 2.5 | 171 |
| SRH | 2.3 | 69 |

Materials:

| Material | Ratio | Number of Data Points |
|---|---|---|
| Concrete | 8.9 | 21 |
| Fabric | 2.0 | 39 |
| Metal | 3.9 | 37 |
| Plastic | 1.2 | 12 |
| Rubber | 1.9 | 20 |
| Skin | 2.5 | 84 |

Areas:

| Area | Ratio | Number of Data Points |
|---|---|---|
| Lunch Room | 1.7 | 15 |
| Person | 2.3 | 117 |
| Restricted Outdoor Storage Area | 1.8 | 13 |
| Vehicle | 3.6 | 21 |

Based on the material specific results, a ratio of 2.5:1 beta/gamma to alpha is suggested for personnel surveys and 4:1 for equipment surveys. A ratio of 1:9 was observed for concrete, however this was primarily from plant floor surveys and is not directly applicable to personnel or equipment release surveys. For situations where these ratios are used, only alpha measurements would be performed, with that result multiplied by the applicable ratio to determine the beta/gamma contamination present.

The second aspect of the license condition is to provide the survey method MDC. It is proposed that the MDC for measurements be 50% of the contamination limit or less. As presented below, for alpha monitoring, an MDC of 200 – 300 dpm/100cm$^2$ (20 – 30% of the limit) is achievable while maintaining reasonable measurement times. However, because beta/gamma background is always higher than alpha, lower MDCs are difficult to achieve.

For personnel scanning, the most accurate survey method both from a user ability and accuracy perspective is static integrated counting of the hands, feet and clothing. At low levels, rate meter mode results are highly influenced by individual emissions, and the analog display makes it difficult to perform accurate background subtraction or select a specific number to use to multiply the beta/gamma to alpha ratio by. Though it is possible to use scanning and a scan MDC, it is difficult from a user and human performance perspective to have plant personnel attempting to move the probe at specified speeds (e.g. 2 cm per second) in specified geometry (e.g. move in the direction of the long axis of the probe), in addition to trying to perform background subtraction and multiplication from a variable analog output.

For these reasons, for personnel scanning we are proposing use of a 30 second scalar count, covering the hands, feet and clothing. Using some conservative assumptions, including a background count of 50 counts in 5 minutes (higher than observed at any frisking station), a detector efficiency of 18% and probe size of 50 $cm^2$, the resulting MDC is 238 dpm/100 $cm^2$ (as per Equation 1 above). This method achieves a comparable result (area coverage and MDC) to a 30 second moving scan covering the hands, feet and clothing, while avoiding the issues of proper scanning speed and direction and, if using ratemeter mode, the issues noted above with the analog display. All frisking stations at Crow Butte are below the conservative background assumption and this will be verified weekly by HPTs. Also, all frisking stations currently have a Ludlum 43-5 probe in use, which meets the probe size assumption of 50 $cm^2$. There are currently two options being considered for the meter: (1) purchase of a Ludlum scalar meter, likely a model 2241-3, or (2) using the pulse output from the 9-pin plug on the back of the existing Ludlum 177 benchtop ratemeters to produce and report a 30 second integrated count. The feasibility of the second option is still under investigation. An additional feature being considered is a system to signal personnel that it is time to move the probe to ensure equal time for all surfaces being scanned, e.g. a beep every 6 seconds or display saying ‘left hand’, ‘right hand’, etc. This feature is also uncertain and is being investigated for feasibility.

Using the conservative assumptions above, and a beta/gamma-to-alpha ratio of 2.5:1, a total count of 23 or less in 30 seconds means that the individual is below both the alpha and beta/gamma criteria of 1000 dpm/100 $cm^2$. The operation may set a lower default background if this can be verified based on ongoing measurements. The site will develop a procedure to describe this process.

For equipment releases, the current practice involves 1 minute scalar measurements of specified points. We plan to continue with the use of the procedure. The associated MDC for an alpha measurement, using the assumptions of a 50 $cm^2$ probe, an efficiency of 18%, a background of 10 counts in 1 minute and a 1 minute count time, is 197 dpm/100 $cm^2$. In areas with elevated background beta/gamma radiation, where an MDC of 50% of the limit cannot be achieved, a factor of 4 would be applied to the alpha contamination result to determine the beta/gamma contamination present. In areas where the MDC guidance of 50% of the limit can be achieved, the beta/gamma contamination could be measured directly using the same methodology and a 43-93 probe.



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Licence Condition 11.11

Proposed l~~L~~icence condition~~s~~ 11.11 states that "The licensee shall provide the following information for the airborne effluent and environmental monitoring program for which is shall develop written procedures for NRC written verification to:

A) Discuss how, in accordance with 10 CFR 40.65, the quality of the principal radionuclides from all point and diffuse sources will be accounted for, and verified by surveys and/or monitoring.
B) Evaluate the member(s) of the public likely to receive the highest exposures from licensed operations consistent with 10 CFR 20.1302.
C) Discuss and identify how radon (radon-222) progeny will be factored into analyzing potential public dose from operations consistent with 10 CFR Part 20, Appendix B, Table 2.
D) Discuss how, in accordance with 10 CFR 20.1501, the occupational dose (gaseous and particulate) received through the entire License Area from licensed operation will be accounted for, and verified by, surveys and monitoring."

Based on the data ~~we have been able to~~ gathered to date, our ~~planned~~ long-term strategy is to combine modelling with co-located track etch cup measurements to calculat~~ed~~ public dose. ~~and~~ The ~~an~~ interim strategy employs~~plan based on~~ long-term averaging rather than individual background subtracted samples. Both plans will incorporate location specific equilibrium factors for inclusion of radon progeny, rather than use of the default assumption of 100% equilibrium. The following discusses the data gathered ~~and analyzed~~ to date ~~and plans made based on this information~~.

~~To begin t~~To address this license condition, the first aspect considered was the method by which radon progeny will be factored into the calculation of public dose. The Radon-222 table within 10 CFR Part 20, Appendix B, Table 2 provides DAC values for radon "with daughters" and "without daughters". The "with daughters" value in this table assumes that radon-222 and its progeny are in full equilibrium. This is a conservative assumption and, based on distance and travel times to the site boundaries, not representative of conditions at the Crow Butte site. The Crow Butte operation has undertaken a sampling campaign to measure both radon gas and radon progeny at numerous site locations over a period of one year. The purpose of this sampling was~~is~~ to ~~attempt to~~ quantify the equilibrium factor at ~~these locations, including~~ key receptor locations.



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Radon progeny concentrations in the ambient air at Crow Butte are very low. To attempt to quantify the equilibrium factor it was felt that long-term measurements of radon progeny would be more accurate and important to collect on a single~~one-time~~ campaign basis in addition to short-term samples using Kuznetz sampling. To collect long-term measurements, we have deployed continuous radon daughter measurement devices, known as Personal Alpha Dosimeters (PADs) distributed by the Radiation Safety Institute of Canada. These instruments are continuous flow monitors that are deployed in the field for 30 to 60 days and sample the radon progeny concentration for that entire time period. Because they monitor continuously for an extended period of time, they provide a long-term average measurement of radon progeny and are less susceptible to short-term fluctuations. In addition, the LDL for this equipment is 0.0002 WL, which is significantly lower than Kuznetz sampling. Kuznetz samples are being collected in addition to the PAD results for comparison and consideration for use as a future sampling method if results are comparable.

The PADs were placed at 19 locations throughout the site; four sites were placed close to the main plant (TE 1-4), one on each side of the facility, four were place outside well houses (WH 9, 17, 47 and 50), and 11 were placed at routine monitoring locations (AM 1-8 and AM 22-25). At each PAD location a track etch cup was also deployed. Due to detection limits, the track etch cups were placed in the field for 3 to 6 months, the near-plant TE 1-4 stations for 3 months the farther afield stations for 6 months, rather than being changed on the same frequency as PADs.

At very low radon gas concentrations, it has been recognized that there is uncertainty in individual measurements. To attempt to quantify this situation, a statistical analysis of the semi-annual track etch cup results from stations AM1 – AM8, from 2000 – 2013 was undertaken. The data from these locations are best fit by lognormal distributions. Table 1 shows the results of the distribution analysis. It is important to note that the stations with the lowest statistically significant fits all had several results that were at or below the detection limit of the instrument. A value of DL was used for samples that were "<DL", which biased the results slightly high and skewed the distributions slightly. A review of the normal probability plots for the lognormal distributions indicated that this is a reasonable fit to the data. This analysis shows that over the long term data from each location fluctuates about a mean with the individual results falling within a distribution about that mean.

Table 1 – Results of Distribution Analysis of Track Etch Cup Data

| | Arithmetic Mean | Arithmetic Standard Deviation | Geometric Mean | GSD | p-value (Shapiro-Wilk test) |
|---|---|---|---|---|---|
| AM-1 | 0.65 | 0.72 | 0.47 | 2.08 | 0.01 |
| AM-2 | 0.84 | 0.68 | 0.66 | 2.00 | 0.54 |
| AM-3 | 0.52 | 0.52 | 0.39 | 2.00 | 0.002 |





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| | | | | | |
|---|---|---|---|---|---|
| AM-4 | 0.60 | 0.54 | 0.46 | 1.97 | 0.05 |
| AM-5 | 0.84 | 0.46 | 0.76 | 1.58 | 0.19 |
| AM-6 | 0.60 | 0.48 | 0.47 | 1.96 | 0.05 |
| AM-8 | 0.92 | 0.74 | 0.72 | 2.00 | 0.87 |

Station AM-6 is considered the background station.~~, however,~~ Bbased on the analysis, it appears that stations AM-1, AM-3 and AM-4 are all comparable to background. In addition, stations AM-2, AM-5 and AM-8 have long term averages that are somewhat higher than background. These results are expected as the stations with higher concentrations are located either in the prevailing wind direction (i.e. downwind) or in the wellfields. For each location, it was also determined that on average about 10% of results fell outside the upper and lower 95$^{th}$ percentiles of these distributions, which is the expected amount. In addition to further supporting the data having a lognormal distribution, this indicated that any one sample has a 10% chance of being considered an “outlier”.

Since we have seven stations at very low concentrations, each with a 10% chance of being an outlier, this has prompted the proposal that until a revised monitoring strategy is put in place, long term arithmetic averages of track etch data be used rather than individual background subtracted values for public dose calculations and for calculation of equilibrium factors. It is proposed that the best way to make use of the historical data is to use long term averaging as is it the more stable than use of individual data points from within the distributions (i.e. individual track etch results).

In order to determine the equilibrium factor at each location, the results of the PADs were compared with ambient radon gas concentrations; equation (1) provides the formula to determine the equilibrium factor. Though the PADs have a low LDL, at very low concentrations there is still uncertainty in the final results. Because the PADs and track etch cups were not deployed for exactly the same time frames and to try reduce some of the uncertainty the measurements, we will be using the 12-month average background corrected radon progeny concentration at each location measured by PADs compared to the location specific background corrected, long-term radon gas concentrations, where available, to calculate equilibrium factors. For stations AM 1 – 8, the location specific, background corrected average over the period 2000 – 2013 will be used for calculation of equilibrium factor. For the other stations, long term data is not available therefore the average of data collected throughout 2013 will be used once it is available. In addition, the expected equilibrium factor will be modelled using the radon progeny ingrowth equation from Evans (1969), equation (2), and nominal wind speeds based on the site wind rose, as reference in the license application.

$$Equilibrium\ Factor\ (F) = \frac{(RnP_L - RnP_B) * (100\frac{pCi}{L} per\ WL)}{(RnG_L - RnG_B)} \qquad (1)$$





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Where: $RnP_L$ = radon progeny concentration (WL) measured at location L
$RnP_B$ = background radon progeny concentration (WL)
$RnG_L$ = radon gas concentration (pCi/L) measured at location L
$RnG_B$ = background radon gas concentration (pCi/L)

$$WL = 0.023\, t^{0.85} \qquad (2)$$

Where t = travel time of the air in minutes.

Table 2 presents the expected and measured equilibrium factors at the long term monitoring stations based on the average of the radon progeny measured to date by PADs and long term average radon gas results. For the majority of the other stations, only one radon gas measurements is available so far, once more data has been collected equilibrium factors at these stations will be calculated. In terms of the long term stations, where there is radon gas measurable above background, the estimated and calculated equilibrium factors are quite comparable. It is important to note that at this point, the modelled equilibrium factor is based on ingrowth only and has not incorporated additional factors such as dispersion and plate-out. As a result, the modelled equilibrium factor is expected to be slightly higher than the measured in locations downwind of the plant and likely significantly higher in non-prevailing wind directions (stations AM-1, AM-3 and AM-4); this expectation matches the actual results. Based on the agreement of the measured to predicted results, it is reasonable to use the location specific equilibrium factors in the calculation of public dose rather than the assumption of full equilibrium. To be conservative, for the moment, the modelled factors which are somewhat higher than the measured will be used. Once more detailed modelling is performed, this decision will be reviewed and a final plan proposed to the NRC.

Table 2: Modelled and Measured Equilibrium Factors at Long Term Monitoring Locations

| | Distance from Centre of Plant(m) | Nominal Wind Speed (m/s) | Travel Time (min) | Modelled Equilibrium Factor (F) | Measured Equilibrium Factor (F) |
|---|---|---|---|---|---|
| AM-1 | 905 | 4.32 | 3.5 | 0.07 | 0.01 |
| AM-2 | 1269 | 4.32 | 4.9 | 0.09 | 0.08 |
| AM-3 | 2136 | 4.32 | 8.2 | 0.14 | |
| AM-4 | 1271 | 4.32 | 4.9 | 0.09 | |
| AM-5 | 3004 | 4.32 | 11.6 | 0.18 | 0.14 |
| AM-8 | 821 | 4.32 | 3.2 | 0.06 | 0.04 |

It is proposed that for 2013, we will use the location specific equilibrium factor from Table 1 along with long term arithmetic average radon gas concentrations to estimate public dose for radon gas and radon progeny in these locations. Based on individual sample uncertainty, it is believed that use of the long term average values provide a much more stable and accurate estimate of public dose. The calculation of dose, incorporating equilibrium factors is shown in equation 3.

$$Dose_{RnG+RnG}(mrem) = \frac{(average\ concentration\ of\ RnG\ \left(\frac{\mu Ci}{ml}\right)*50\ mrem*F)}{10\ CFR\ 20\ App\ B, Table\ 2\ value\ in\ \mu Ci/ml} \quad (3)$$

In the long term, because individual direct measurements of both radon progeny and radon gas has proven to have measureable uncertainty, it is proposed that improved facility modelling including modelling of source terms, background, dispersion and radon progeny ingrowth be used as the basis for public dose calculation in the future. In order to provide ongoing validation of this modelling, it is proposed that at each of the monitoring stations used for public dose that 3 track etch cups be used rather than a single device. The results of all three devices would be average to attempt to give a more stable result for each location for each time interval. If any individual device is found to be an outlier, based on the statistical analysis of the distributions presented earlier, that device would be excluded from the average. Though use of multiple detectors is expected to yield more stable results, we are still attempting to discern a small perturbation (e.g. the site impact) from a higher background that is modified by numerous conditions including weather and natural soils and doing so close to the detection limits of the instrument. For this reason, we believe that modelling provides the only stable and reliable means of determining the public dose due to emissions from the operation.



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