From: John Schmuck [John_Schmuck@Cameco.com]
Sent: Monday, August 08, 2011 1:20 PM
To: Burrows, Ronald
Subject: FW: PADs for environmental sampling
Attachments: Brochure PAD RSI 2008.pdf

Ron - Enclosed please find the commercially information available on the Active Alpha Track radon monitors we are proposing for use at Crow Butte. As Kari noted ours will be set up with constant flow pumps suitable for the environmental monitoring.

If you have questions please give a call.

thanks. .john

-----Original Message-----
From: Kari Toews
Sent: Monday, August 08, 2011 11:09 AM
To: John Schmuck
Subject: FW: PADs for environmental sampling

Hi John,

Here are the technical details for the alpha track system. It is based on the personal alpha dosimeter (PAD) used by the Sask mine sites and licensed by the Canadian Nuclear Safety Commission for official dosimetry. The key difference is this one uses an external power supply to run the pump for extended time periods (mine sites ones have a 12 hour battery) and the constant flow pumps used for environmental sampling have a higher flow rate than the personal pumps.

Kari

From: Brent Preston [mailto:BPreston@radiationsafety.ca]
Sent: Monday, August 08, 2011 8:09 AM
To: Kari Toews
Subject: RE: PADs for environmental sampling - Info request for Monday morning if possible.

Hi Kari,

This is the best document I have for the PAD head. Please note that it does focus on the PAD system, but it does provide quite a bit of technical information.

Brent Preston, MSc

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RADIATION SAFETY INSTITUTE
OF CANADA

INSTITUT DE RADIOPROTECTION DU CANADA

The PAD Dosimetry Service

of the

Radiation Safety Institute of Canada

Radon and Thoron Progeny

Long-Lived Radioactive Dust

Alpha Spectroscopy Service

August 2008

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THE PAD DOSIMETRY SERVICE

Technical Description

1. Introduction

The Radiation Safety Institute of Canada offers comprehensive personal alpha dosimetry services to clients concerned about individual exposures to radon and thoron progeny and to long-lived radioactive dust (LLRD) in the workplace or environment.

Individuals are monitored using the Personal Alpha Dosimeter (PAD). The PAD is a portable, light-weight personal monitoring system designed to measure the exposure of individuals to radon and thoron progeny and to LLRD.

The PAD consists of a track etch detector, commonly referred to as a dosimeter head, mounted in an individual air sampling system and worn on the belt of the individual being monitored [1][2]. The PAD was designed by ALGADE of France; the dosimeter head was modified by the Radiation Safety Institute to withstand the harsh mining conditions in Canada.

The PAD is worn by the individual for a period of one month. At the end of the month, the dosimeter head is removed from the PAD and returned to the Institute's National Laboratories in Saskatoon, Saskatchewan, for processing. Exposure results are supplied to the clients on a monthly basis.

2. The PAD

2.1 Individual Sampler

The individual sampler is an air pumping system designed to draw air through the dosimeter head. A battery operated centrifuge pump is enclosed in a durable polycarbonate box designed to be worn on the belt of the individual being monitored.

A diagram showing the PAD and its orientation on an individual's belt is shown in Figure 1. An exploded view of the individual sampler and the dosimeter head is shown in Figure 2.

The individual sampler (when loaded with a dosimeter head) is designed to generate a nominal air flow rate of 4 l/h ± 20%. Typical air flow rate stability data for the individual sampler (Mark II) is shown in Figure 3. Even though the individual sampler's air flow rate is not regulated, the air flow rate remains constant to within 20% during operating periods [3].

The following is a list of the technical specifications of the individual sampler:

- A moulded polycarbonate box which houses the system
- A centrifuge pump driven by a dc motor
- An electronic module embodying:
  - a nickel-cadmium rechargeable battery
  - a constant current charger
  - a switch controlling the motor operation
  - a light emitting diode illuminated when the battery is charging
  - a magnet controlling the start-up of the charger
- Operating time: in excess of 12 hours
- Battery charging time: 12 hours
- Dimensions: 94 x 79 x 63 cm
- Weight: 230 g (excluding measuring head)
- Relative humidity: 0 to 100%
- Operating temperature: -10°C to 45°C

2.2 Charging Unit

The individual samplers are recharged using an charging unit as shown in Figure 4. The individual charging unit consists of a polycarbonate box forming a cell into which the individual sampler is placed.

The charger includes:

- An electronic card which generates a high frequency alternating current that feeds a coil. This coil supplies by induction the energy necessary to recharge the battery in the individual sampler.
- A magnetically operated switch which gates the power supply to the electronic card when the sampler is placed in the cell and controls an hour-meter, makes it possible to measure the operating time of the sampler (optional).
- Individual protection by a 0.5 A fuse, with blown-fuse indication by means of a light-emitting diode.

The chargers are available in sets of 5, 10 or 25.

2.3 Dosimeter Head

The dosimeter head, designed and manufactured in Canada, is shown in Figure 5. The dosimeter head is an adaptation of an integrated measuring head originally developed and patented by the Atomic Energy Commission of France (CEA) [2].

The adaptation of the dosimeter head was carried out by the Radiation Safety Institute under a research contract awarded by the Government of Canada (Atomic Energy Control Board of Canada and the Department of Energy, Mines and Resources). Laboratory testing was conducted at the CANMET Elliot Lake Laboratories. Field testing was carried out in selected Canadian uranium mines. The mould for the production model of the dosimeter head was made by the Saskatchewan Research Council. The dosimeter heads are manufactured by a Saskatchewan company. The dosimeter head is designed to detect the presence of radon and thoron progeny and LLRD.

The dosimeter head is, in essence, an alpha particle spectrometer capable of detecting separately, without electronics, the 5.99 MeV and the 7.69 MeV alpha particles from radon progeny (Po-218 (RaA) and Po-214 (RaC')) and the 8.78 MeV alpha particle from thoron progeny (Po-212 (ThC')). The alpha particles are detected by the damage they create on a cellulose nitrate film [1] [4].

Spectroscopic separation of the alpha particles is achieved by using a three-channel collimator (Figure 6). Each channel is fitted with an energy-absorbing mylar strip whose thickness is chosen specifically for the alpha particle the channel is designed to identify. The design is such that the three alpha particles of interest hit the cellulose nitrate film when their dE/dx (energy loss) is at a maximum (the "Bragg peak" in the dE/dx versus E curve). They produce easily identifiable holes in the film after etching.

The following is a list of the technical characteristics of the dosimeter head:

- High density polyethylene end cap, barrel, collimator and barrel holder
- Filter used: 25 mm diameter, 1.2 μm pore size
- Film used: Kodak cellulose nitrate LR-115 Type II film
- Absorbers used: Mylar absorbers
- Diameter: 37 mm
- Height: 43 mm
- Weight: 21 g

The following is a list of the collection efficiencies for aerosols for the dosimeter head:

- AMD < 10^{-2} μm ρc > 20%; Q = 5 l/h
- 10^{-2} < AMD < 1 μm ρc > 50%; Q = 5 l/h
- AMD > 1 μm ρc > 90%; Q = 5 l/h
- AMD high cut-off: 10 μm

The parameter AMD refers to the Aerodynamic Median Diameter. The efficiencies are given for velocities of the air circulating around the head at less than 1 m/s [5][6][7][8][9]. The aerosol collection efficiency of the PAD is shown in Figure 7.

3. PAD Operation

In the operation of the PAD, the sampler draws air through the dosimeter head at a nominal air flow rate of 4 l/h (Figure 6). Any attached radon and thoron progeny and LLRD in the air will become trapped on the filter inside the measuring head.

As the radon and thoron progeny and LLRD decay, alpha radiation is emitted. Some of the alpha radiation given off from the filter will travel up the three-channel collimator and pass through the absorbers attached to the collimator. Any alpha particles making it through the absorbers will strike the detector film located on top of the collimator.

The detector film used in the dosimeter head is sensitive to alpha radiation, provided that the alpha particles have an energy of approximately 2.7 ± 1.2 MeV.

To obtain the desired energy discrimination between the different alpha particles, each collimator is fitted with a mylar absorber of a specific thickness. The different thicknesses were chosen so that the alpha particles of interest emerge from the mylar absorber with an approximate energy of 2.7 ± 1.2 MeV. Other alpha particles will either be stopped by the absorber or pass through with an energy greater than the optimal 2.7 ± 1.2 MeV required to leave clear uniform tracks on the film.

Slight variations in the absorber thicknesses can be used on the collimators as long as the alpha energies are between 1.5 and 4.0 MeV when they strike the LR-115 film.

All of the energy discriminated alpha particles emitted by the radon and thoron progeny are registered as tiny lines of damaged molecules on the film.

The sub-microscopic tracks on the film are enlarged by etching in a sodium hydroxide ($NaOH$) solution at a temperature of 60 °C. The enlarged tracks created by the etching process are approximately 5 μm in diameter. The enlarged tracks can then be counted using a microscope and by placing a light source below the detector film.

The alpha activity of LLRD deposited on the dosimeter head filter is measured using a low background alpha/beta counter equipped with an automatic sample changer system.

4. The PAD Service

The PAD is worn daily by the individuals to be monitored. At the end of each working day, the PAD is placed into a charging unit overnight to recharge the PAD battery.

Radiation safety staff at the client's work site are responsible for taking some of the necessary measurements required to determine the average air flow rates through the

PAD's during the monitoring period.

At the end of each month, the exposed dosimeter heads are removed from the individual samplers and replaced with fresh dosimeter heads. The exposed dosimeter heads, together with PAD assignment and air flow rate information, are then returned to the Institute's National Laboratories for processing. Monthly dosimetry reports are generated by the Institute and distributed to the client.

5. Analytical Methods Used in the PAD Service

5.1 Personal Alpha Dosimeter Air Flow Rate

The individual sampler uses a battery operated centrifuge pump to pull air through the dosimeter head at a nominal flow rate of 4 l/h. Two independent techniques are used to measure the average air flow rate generated by each PAD.

The air flow rate through the PAD is measured using an indirect technique which utilizes the basic principles of air flow circuit dynamics. By measuring air flow circuit parameters such as the individual sampler stall pressure (the pressure exerted by the sampler at zero air flow) and the pressure drop across the dosimeter head (at constant air flow rate 4 l/h), the air flow rate through the PAD can be calculated using the expression:

$$Q_{Average}\ [l/h] = 4\ [l/h] \times [\frac{2 \times P_{Avg}}{\Delta P_1 + \Delta P_2}]\ .$$

The parameter P_{Avg} denotes the average PAD stall pressure. Stall pressure measurements are taken weekly by radiation protection personnel at the work site. The terms ΔP_1 and ΔP_2 refer to the initial and final pressure drops across the dosimeter head. These pressure drop measurements are taken before the new dosimeter heads are sent to the client and after the exposed dosimeter heads have been returned to the Institute's National Laboratories.

Both the PAD stall pressure measurements and the dosimeter head pressure drop measurements are taken using a standard magnehelic pressure gauge.

5.2 Track Counting

As discussed earlier, the alpha particles emitted by the radon and thoron progeny are energy reduced and energy discriminated by attaching mylar absorbers to the collimator barrel. Alpha particles which strike the detector film with the an energy of approximately 2.7 ± 1.2 MeV, leave sub-microscopic tracks that can be easily counted after the film has been etched.

Each channel of the collimator barrel is 6 mm in diameter. Therefore, the exposed film will consist of three 6 mm diameter circles corresponding to the RaA, RaC' and ThC' regions. The surface area of each region is 28.27 mm^2. A sketch of an exposed dosimeter head film is shown in Figure 8.

By etching the exposed film in a NaOH solution, the alpha particle tracks are enlarged so that they can be counted using a microscope.

Alpha tracks are counted using a modern Image Analysis System (IAS). The IAS currently used consists of a computerized image grabber connected to a solid state camera. The optical counting system is connected to a Nikon microscope which is used to view the films.

In the counting process, the tracks on each channel of each film are counted in several locations (the exact number depending upon the resolution setting of the IAS) and the average number of tracks is calculated.

The total number of tracks in each of the RaA, RaC' and ThC' regions can then be determined by the expression:

$$N_{\text{channel}} = \frac{\text{Average Number of Tracks (for n counts)} \times A_{\text{film channel}}\ (\text{mm}^2)}{A_{\text{IAS}}\ (\text{mm}^2)} \quad ,$$

where $A_{\text{film channel}}$ refers to the total area of each irradiated region (28.27 mm^2) on the film and A_{IAS} to the area counted by the IAS.

5.3 Radon Progeny Working Level Month Calculation

Once the PAD air flow rates have been determined and the number of RaA, RaC' and ThC' tracks have been counted on the etched films, the exposures due to radon and thoron progeny can be calculated.

The Working Level Hour (WLH) value of individual's exposure to radon progeny is calculated using the expression:

$$\text{WLH (Radon Progeny)} = \frac{7.69 \times \text{NRaC}' + 5.99 \times (\text{NRaA} - 0.56 \times \text{NThC}')}{0.8 \times 0.001037 \times 1.3 \times 10^5 \times Q} \quad ,$$

where:

- NRaA, NRaC' and NThC' refer to the number of tracks on the dosimeter head film above the appropriate absorber (for the full 6 mm diameter area).
- The constant 0.001037 is the efficiency factor of the dosimeter head. This factor includes the dosimeter head geometric efficiency and the LR-115 film registration efficiency.
- The factor 0.8 is the collection efficiency for radon and thoron progeny attached aerosols [6].
- The constant 1.3 x 10^5 denotes the conversion factor from MeV/l to Working Levels (WL).
- Q is the average air flow rate through the PAD in l/h.

To determine the individual's exposure in Working Level Months (WLM), the WLH value is divided by the conversion factor 170, where 170 represent the number of hours worked per month.

$$\text{WLM (Radon Progeny)} = \frac{\text{WLH (Radon Progeny)}}{170}$$

In the WLH expression, 0.56 (NThC') is subtracted from the number of RaA tracks counted. This is because the ThC (Bi-212) can decay into ThC" by emitting a 6.08 MeV alpha particle or into ThC' by emitting a 2.25 MeV beta particle. The branching ratio for the ThC decay reaction is 0.36 for the decay to ThC" and 0.64 for the decay to ThC'. Because some of the alpha particles emitted by the thoron progeny will have an energy of approximately 6 MeV, they will be detected on the RaA channel. Therefore, the factor 0.56(NThC') is included in the expression to remove the number of alpha particles due to the decay of ThC to ThC" which falsely contribute to the number of RaA tracks. A simplified diagram displaying the branching for ThC is shown in Figure 9.

5.4 Thoron Progeny Working Level Month Calculation

Similarly, the WLH value for thoron progeny can be determined using the expression:

$$\text{WLH (Thoron Progeny)} = \frac{8.78 \times \text{NThC}' + 0.56 \times 6.08 \times \text{NThC}'}{0.8 \times 0.001037 \times 1.3\text{x}10^5 \times \text{Q}} \quad .$$

As in the case for computing WLH values for radon progeny, a factor of 0.56(6.08)NThC' is added to account for the additional 6.08 MeV alpha particles counted in the RaA channel which correspond to the decay of ThC to ThC".

To determine the individual's exposure to thoron progeny in WLM, the following expression is used:

$$\text{WLM (Thoron Progeny)} = \frac{\text{WLH (Thoron Progeny)}}{170},$$

where 170 represent the number of hours worked per month.

5.5 Long-Lived Radioactive Dust Detection

The PAD also measures the presence of long-lived radioactive dust (LLRD). Any traces of LLRD present on the filter inside the dosimeter head will remain there for an extended period and can be detected using conventional alpha radiation detectors.

Following a minimum waiting period to allow all radon and thoron progeny to decay (1 day for radon progeny and 4 days for thoron progeny), the gross alpha activity of the LLRD on the dosimeter head filter is measured using an OXFORD Series 5 HP Low Background Alpha/Beta Counting System equipped with an automatic sample changer.

The alpha activity from LLRD present on the dosimeter head filter is calculated using the expression:

$$\text{LLRD}_{\text{PAD}}\ [\text{Bq}] = \frac{\text{Gross Count Rate [CPS]} - \text{Average Background Count Rate [CPS]}}{\varepsilon},$$

where ε refers to the counting system's efficiency.

The alpha radiation activity concentration is calculated using the expression:

$$\text{LLRD Activity Concentration } [\text{Bq/m}^3] = \frac{\text{LLRD}_{\text{PAD}}[\text{Bq}] \times 1000\,[\text{l/m}^3]}{\text{Q}[\text{l/h}] \times 170\,[\text{h}]}.$$

To convert the LLRD activity measured on the dosimeter head filters to an exposure, one must account for the individual's average breathing rate during work activities. Using the ICRP 23 Reference Man average breathing rate for light activity (0.02 m^3/min or 1200 l/h), LLRD exposure can be expressed as:

$$\text{LLRD Exposrue [Bq]} = \frac{\text{LLRD}_{\text{PAD}}\ [\text{Bq}] \times 1200\ [\text{l/h}]}{\text{Q}\ [\text{l/h}]}.$$

6. PAD Detection Limits

6.1 Lower Limits of Detection for the Measurement of Radon and Thoron Progeny

The limits of detection for the measurement of radon and thoron progeny with the PAD are governed by the ability to accurately determine the number of tracks on the exposed track etch film.

Technically, the PAD's can measure radon and thoron exposures as low as 0 WLM (corresponding to 0 tracks on the film). However, at very low exposures, the uncertainty in the results due to statistical errors is very large.

For exposures below 5 mWLM, the statistical uncertainty in the measurement exceeds 50 % and approaches 100 % uncertainty for the measurement of both radon and thoron progeny as the exposure level drops below 1 mWLM.

The lower limit of detection for the PAD is governed by the number of background tracks present on the film prior to exposure. Background on the LR-115 film is typically comprised of surface defects and/or tracks which are present on the film before the film is loaded into a dosimeter head for use. The background levels on the LR-115 film are typically very low (fewer than 5 tracks in each region) and, therefore, have a negligible effect on the radon and thoron progeny exposures measured (<1 mWLM).

It is not possible to measure the background tracks directly on the films prior to use as this would require the films to be etched and counted. It is also difficult to determine a definite background on the films as small variations can occur between film lots. However, the background tracks on the film are monitored monthly using numerous test films drawn from the film lot used in the dosimeter heads.

The Detection Limit L_d, assuming a 95% confidence interval, is given by the expression:

$$L_d = 4.65 \, s_B + 2.71 \quad ,$$

where s_B refers to the standard deviation in the background present on the film [10]. Assuming an average background upper limit of 5 tracks per irradiated region, the Detection Limit for the dosimeter head is L_d = 14 tracks per region. This translates into a lower detection limit of approximately 2 mWLM.

Because the background level is typically very low and not easily measured on exposed films, the lower limit of detection is neglected in the computation of WLM values.

6.2 Upper Limits of Detection for the Measurement of Radon and Thoron Progeny

The upper limit of detection for the PAD is governed by the track density on the film and the resolution of the track counting system being used.

Typical semi-automatic counting systems currently in use can measure up to (and sometimes in excess of, depending upon the system's resolution) 100,000 tracks in any given region. Assuming a nominal air flow rate of 4 l/h and a monitoring period of one month (170 hours), the upper limit of detection for the measurement of radon and thoron progeny is between 11 and 18 WLM. The exact upper limit of detection will depend upon the track ratio NRaA/NRaC'.

6.3 Minimum Detectable Amount for LLRD

The Minimum Detectable Amount (MDA) for the measurement of LLRD using the Institute's alpha counting system is determined by the expression:

$$\mathrm{MDA} = \frac{4.65 s_B + 3}{K\ T} \quad ,$$

where s_B refers to the standard deviation in the number of background counts for a given counting time T. The parameter K denotes an overall sensitivity factor which includes the detector efficiency [10][11].

The MDA value for the Institute's alpha counting system is:

- MDA < 0.03 Bq for a counting time of 10 minutes

6.4 PAD Testing

The PAD has undergone extensive independent testing in Canada, the United States and Europe for the measurement of radon and thoron progeny and LLRD and was found to provide exposure results which are consistent with testing facility reference systems.

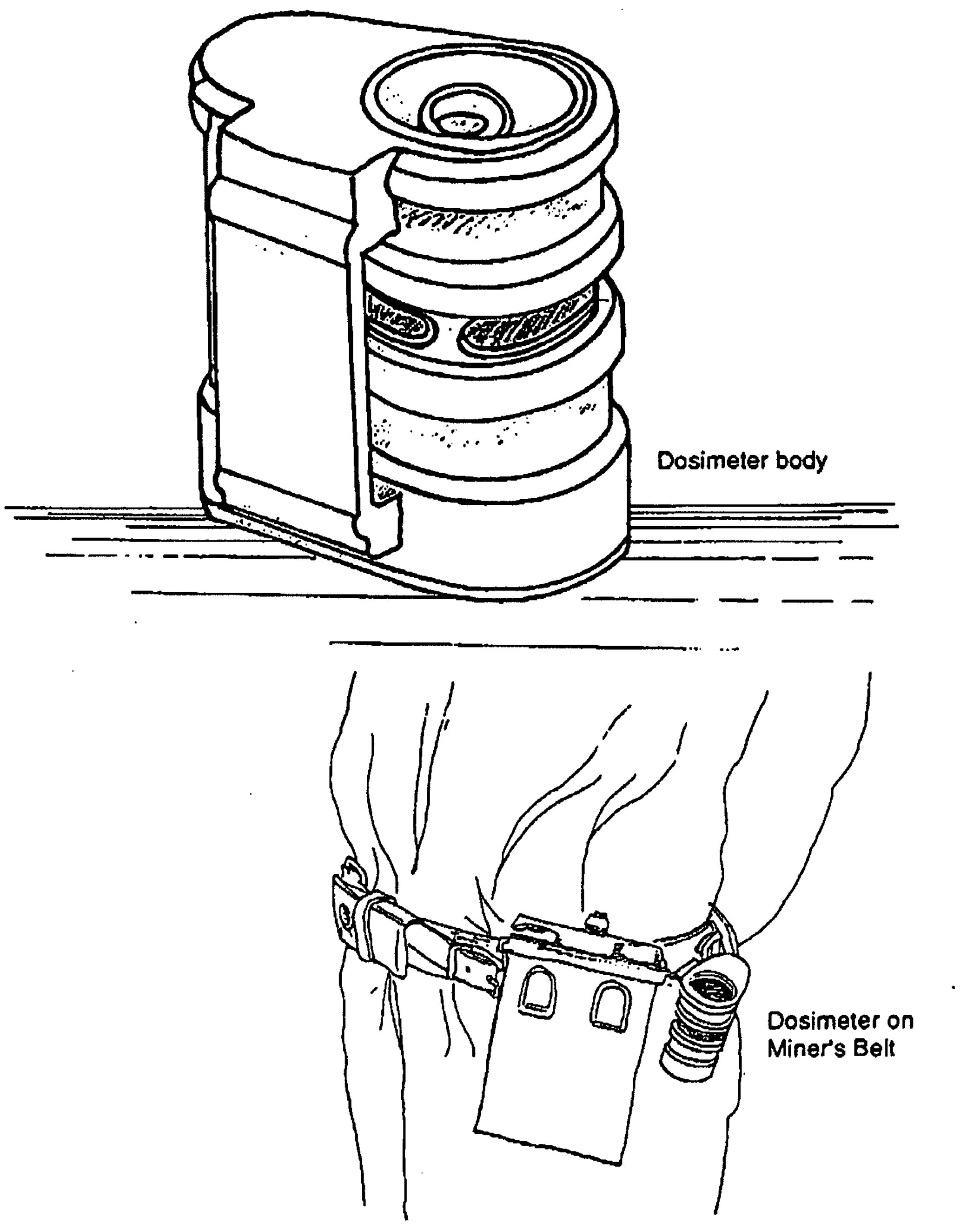

Figure 1: Personal Alpha Dosimeter.

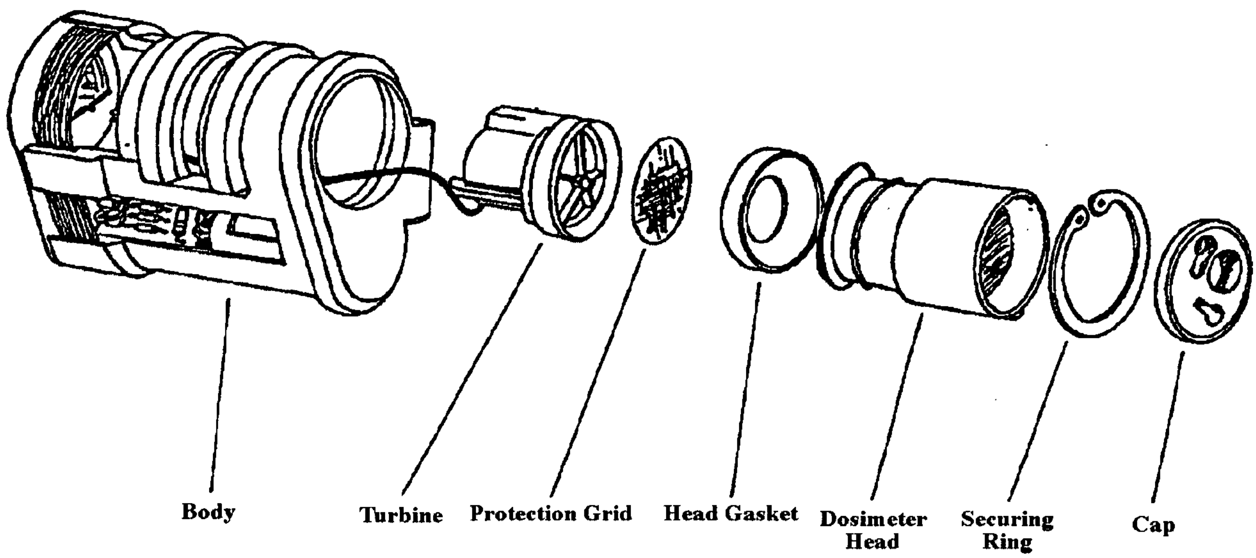

Figure 2: Personal Alpha Dosimeter Components.

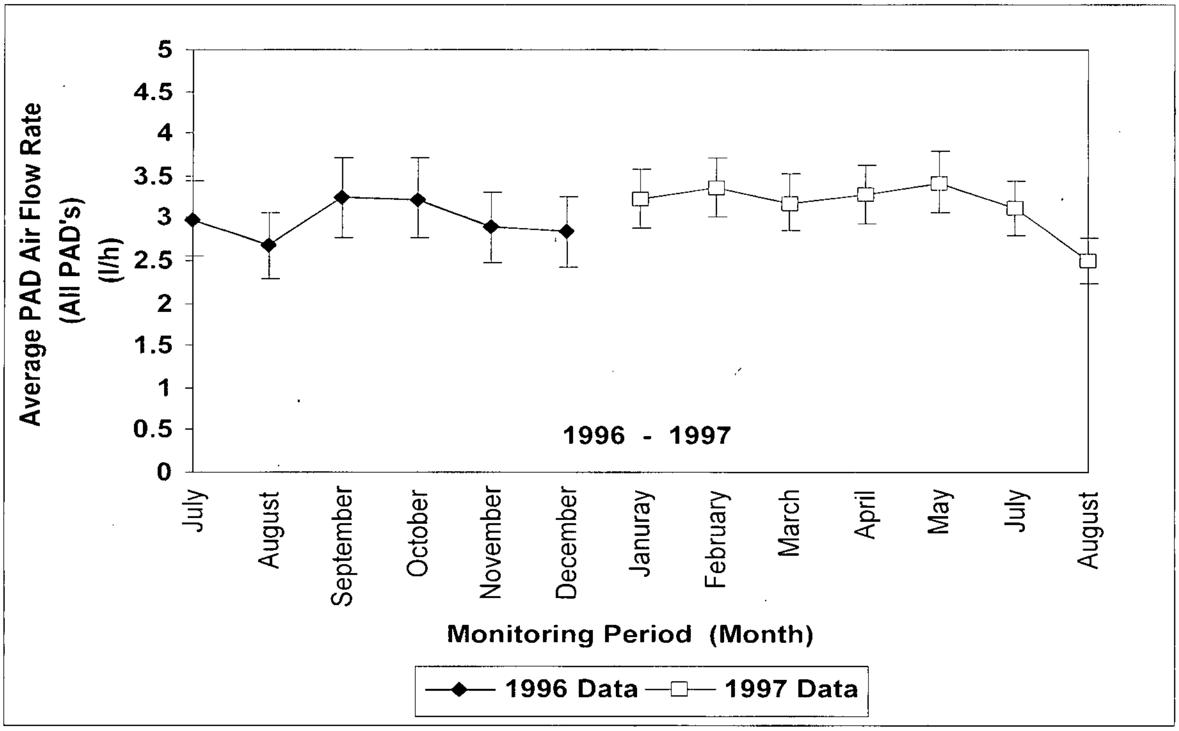

Figure 3: PAD Air flow rate stability data. PAD air flow rate data collected from operating uranium mines in Saskatchewan in 1996 and 1997. The air flow rates shown are the average air flow rates of all PAD's examined during the monitoring period. The error bars shown represent the average sample standard deviation of the weekly measurements collected during the monitoring period. All PAD's examined (in excess of 1000 PAD's) generated a stable air flow rate to within ±20%.

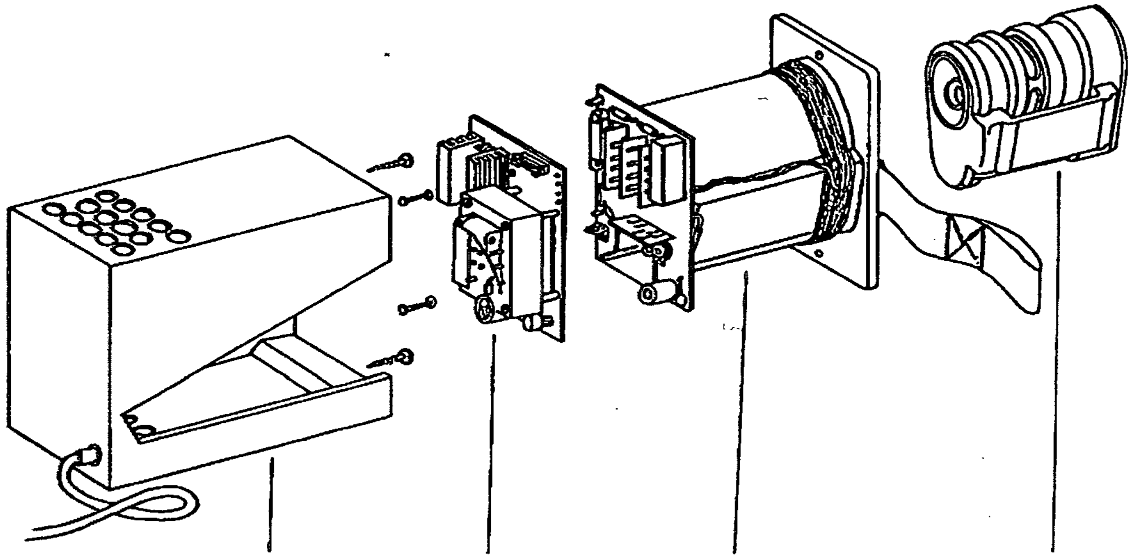

Figure 4: PAD and PAD Charging Unit.

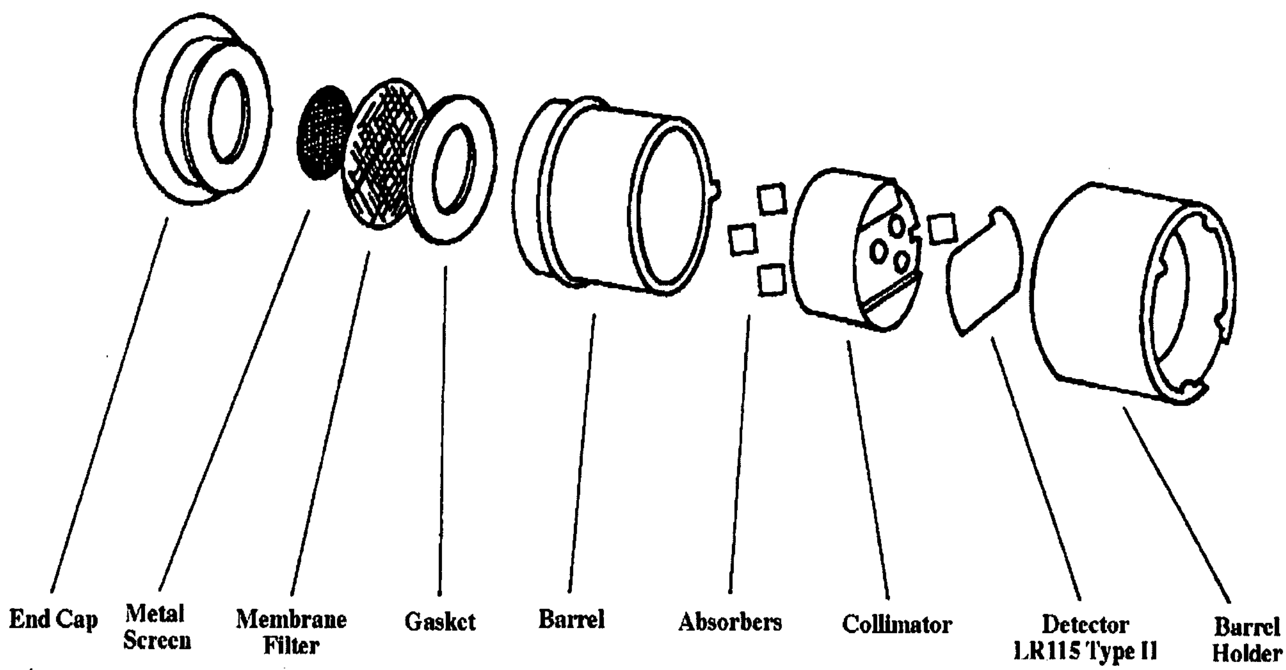

Figure 5. Dosimeter Head Components.

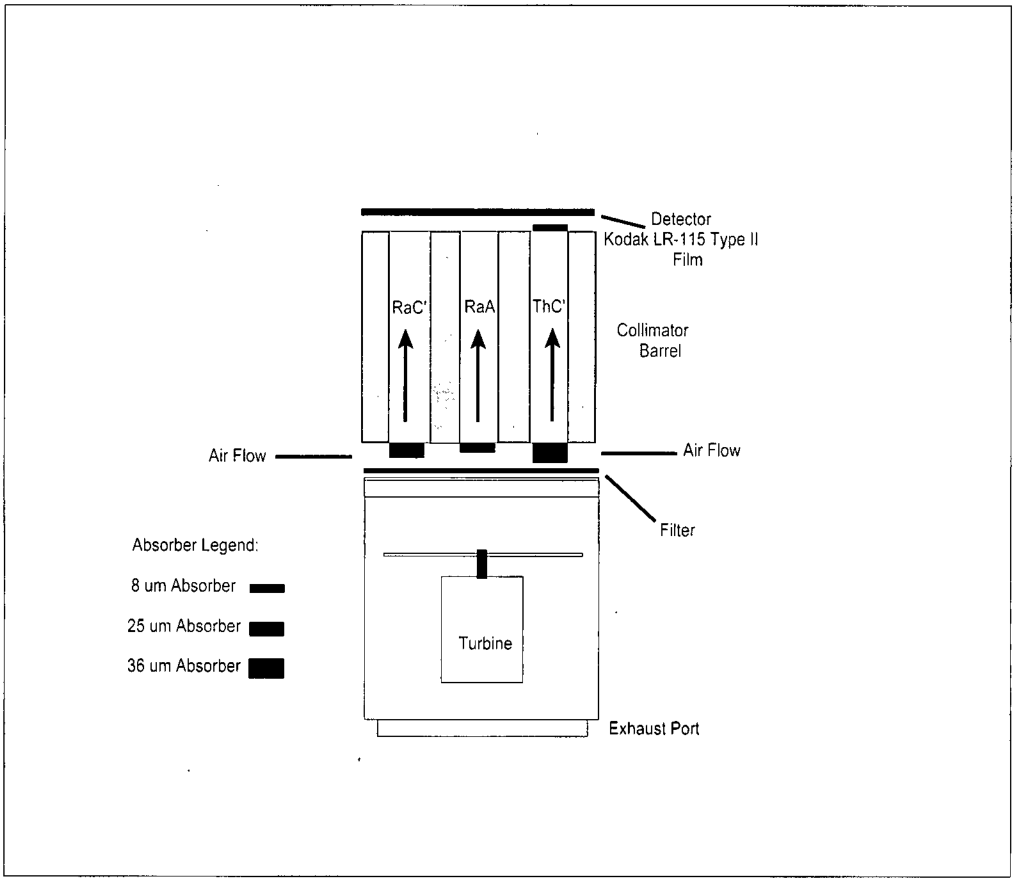

Figure 6. Dosimeter Head Diagram.

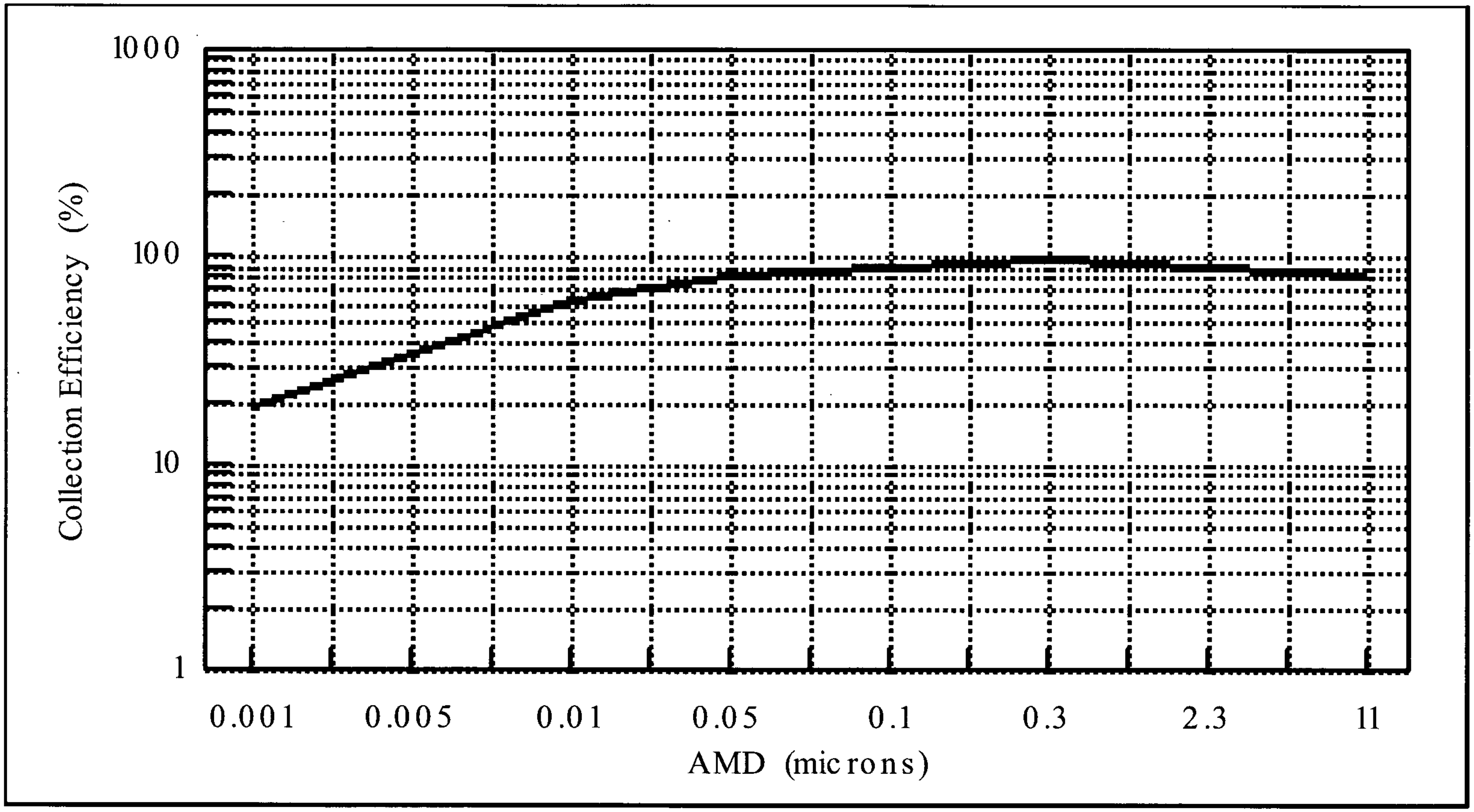

Figure 7: Aerosol Collection Efficiency for the PAD

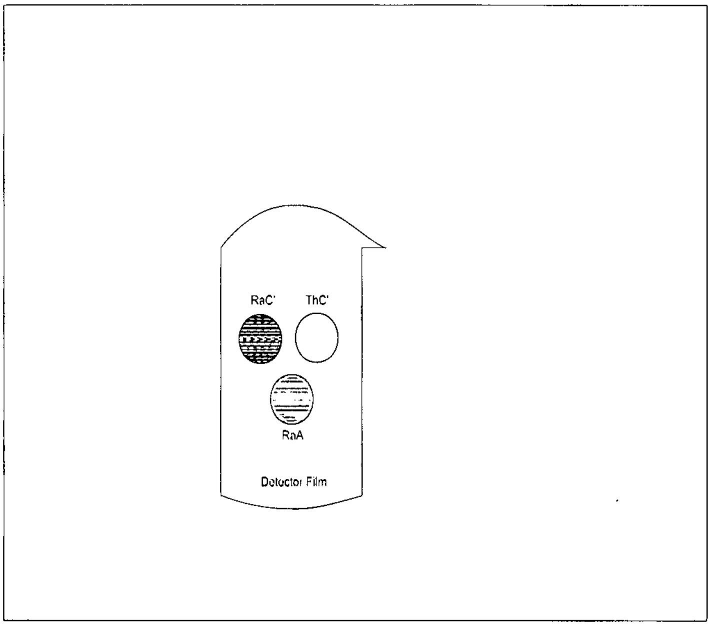

Figure 8. Dosimeter Head Track Etch Film.

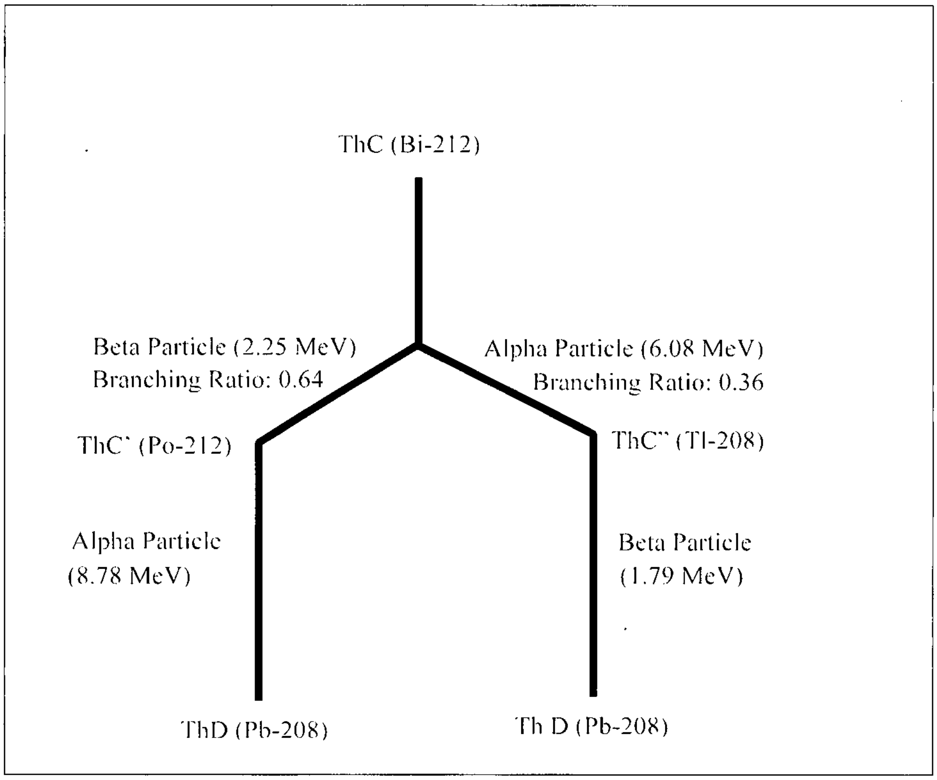

Figure 9: Branching Diagram for the Decay of ThC (Bi-212).

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The PAD Dosimetry Service

of the Radiation Safety Institute

Alpha Spectroscopy Service

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Alpha Spectroscopy Service

of the Radiation Safety Institute

Technical Description

1. Introduction

As a complement to the PAD service, the Institute offers clients a full range of alpha spectroscopy services. Dust samples collected by Personal Alpha Dosimeters (PAD's), area monitors and by gravimetric technique can be further analyzed to determine radionuclide composition and abundance.

Spectral analysis has a direct application in the exposure assessment and assignment of appropriate annual limits of intake (ALI) of mill workers who may commonly be exposed to both uranium ore dust and yellowcake.

Samples are analyzed using state-of-the-art silicon detectors, signal processing equipment and analysis software.

2. Spectral Analysis

Alpha spectroscopy systems are used to generate alpha radiation spectra as a function of particle energy. Unlike gross alpha counting systems, spectroscopy systems can be used to identify radionuclides and their abundance on a sample.

For dosimetry applications in the uranium mining industry, three types of alpha spectra are commonly observed on filter samples:

- Pure ore dust (uranium and all of its decay products)
- Pure yellowcake
- A combination of ore dust and yellowcake

Characteristic spectra for ore dust and yellowcake are shown in Figures 1 and 2 respectively. Ore dust spectra include five identifiable peaks according to alpha particle energy:

- Peak #1: ^{238}U(4.20 MeV)
- Peak #2: ^{234}U(4.77 MeV), ^{230}Th(4.68 MeV) and ^{226}Ra(4.78 MeV)
- Peak #3: ^{222}Rn(5.49 MeV) and ^{210}Po(5.30 MeV)
- Peak #4: ^{218}Po(5.99 MeV)
- Peak #5: ^{214}Po(7.69 MeV)

As yellowcake is comprised of ^{238}U and ^{234}U, filters containing pure yellowcake will yield an alpha spectrua containing two peaks (see Figure 2).

Samples containing a combination of ore dust and yellowcake will generate an alpha spectrum similar to that for ore dust. However, the relative amplitude of the ^{238}U and ^{234}U peaks (peaks #1 and #2) in such samples will be characteristically larger than for pure ore dust.

All filters requiring spectral analysis will first be counted for gross alpha activity using an OXFORD LB Series 5 low background alpha/beta gas proportional counter[1].

For PAD filters, exposures to long-lived radioactive dust (LLRD) will be determined from the gross alpha count data. Measured filter activities below the counting system minimum detectable activity (< 0.03 Bq) will not generally require spectral analysis[2].

To achieve the highest resolution, all filters will be counted under vacuum conditions for approximately 2-3 days. This is necessary to acquire sufficient sampling statistics.

The presence of ore dust, yellowcake or a combination thereof on the filter is determined from the presence of the ^{218}Po and ^{214}Po alpha peaks on the spectrum. Using accepted radon retention values and assuming conditions of secular equilibrium, the ^{218}Po and ^{214}Po alpha peaks can be used to determine the expected magnitude of the ^{238}U and ^{234}U alpha peaks (peaks #1 and #2 as shown in Figure 1). Alpha counts in the ^{238}U and ^{234}U peaks in excess of the expected numbers are from the presence of yellowcake on the sample.

To obtain the greatest accuracy, it is strongly recommended that site specific radon retention values be determined for ore dust. In a study conducted by the Radiation Safety Institute in 1991 called, *"An Investigation of Long-lived Radioactive Dust in Saskatchewan Uranium Mines"*[3], the radon retention was measured on a number of samples and was found to be between 70% and 80%. This is significantly larger than the Atomic Energy Control Board's default value of 50%.

Radon retention default values can be readily measured using alpha spectroscopy techniques

[1] The OXFORD alpha counter is the standard equipment used for PAD processing to measure the presence of LLRD on the PAD filters.

[2] Filters with very low alpha activities require several days or even weeks to acquire sufficient statistics in order to perform spectral analysis.

[3] Becker, E, Cubbon, G. and Kaletsch, K. *"An Investigation of Long-Lived Radioactive Dust in Saskatchewam Uranium Mines"*, CAIRS, 1992.

prior to the start of spectroscopy services.

3. Alpha Spectroscopy Services

The Institute offers two types of alpha spectroscopy services:

Qualitative Analysis

Qualitative analysis includes the following:

- Generation of an alpha spectrum from the sample
- Examination of the spectrum to determine if the sample is pure yellowcake or contains a combination of yellowcake and ore dust
- Analysis report

Detailed Spectral Analysis

Detailed spectral analysis includes the following:
- Generation of an alpha spectrum from the sample
- Peak identification, separation and overlap correction
- Quantitative estimate of relative abundance of ore dust and yellowcake present on the sample
- Analysis report

4. Equipment

Following is a summary of the equipment used in the Institute's alpha spectroscopy system:

Detectors
- OXFORD passivated ion-implanted silicon detector
- EG & G ORTEC ruggedized silicon charged particle detector

Signal electronics
- OXFORD TC 954A alpha spectroscopy high voltage supply
- EG & G ORTEC Model 142 preamplifier
- OXFORD TC 241 spectroscopy amplifier
- Nucleus DMR digital multichannel analyzer
- OXFORD PCA-II Personal Computer Analyzer
- Tektronix SC 504 80 MHz Oscilloscope

Environmental systems
- Vacuum chamber and pump system

Calibration equipment

- NIST traceable ^{241}Am, ^{230}Th and ^{239}Pu calibration sources
- BK Precision pulse generator

Analysis software

- DataFit

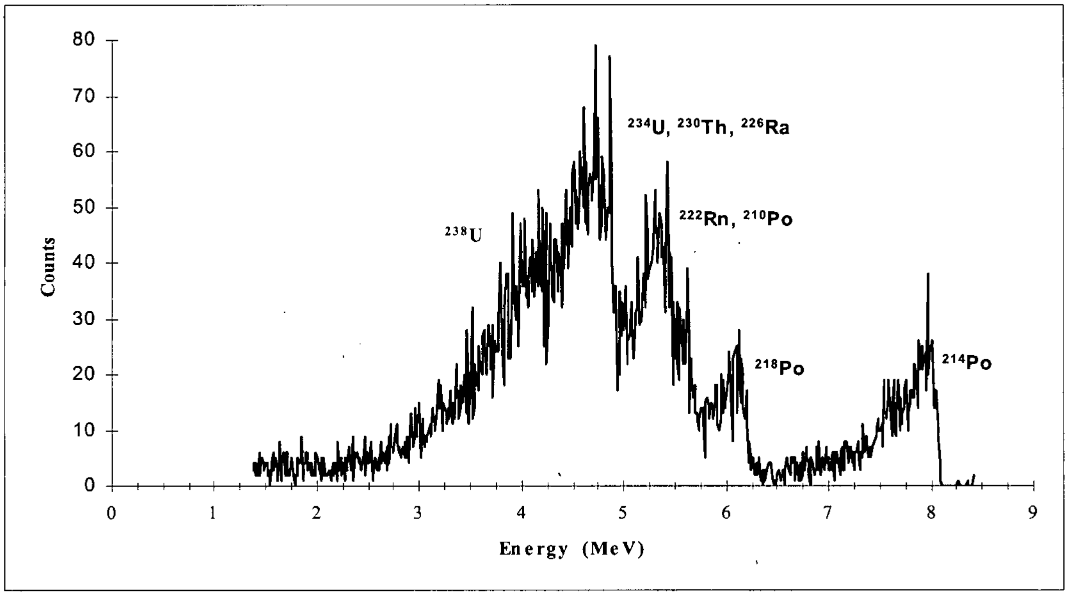

Figure 1: Typical alpha spectrum of pure ore dust.

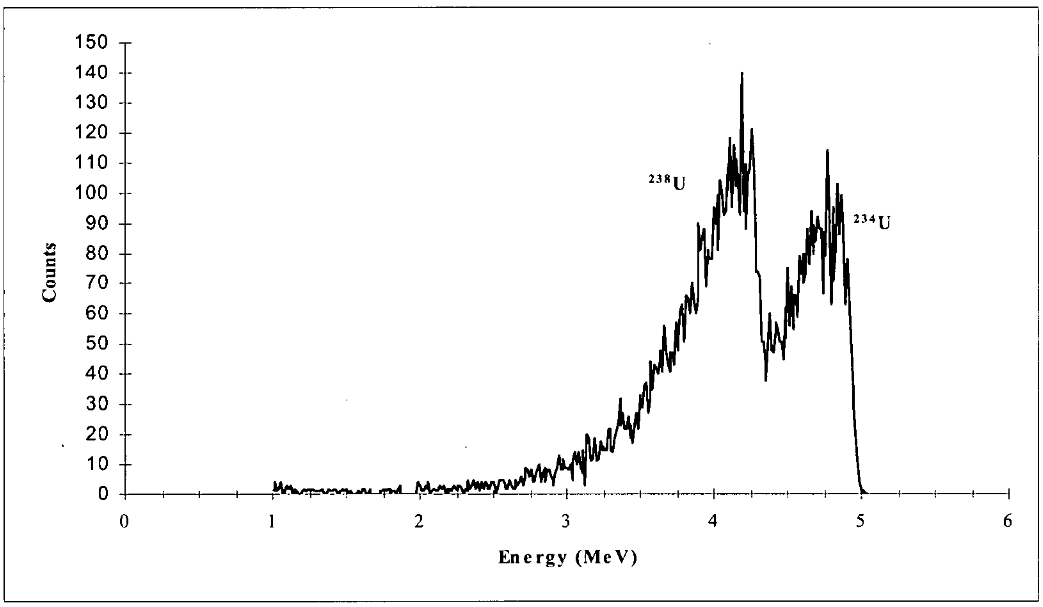

Figure 2: Typical alpha spectrum of yellowcake.