	UR-ENERGY USA, INC. LOST CREEK ISR, LLC STANDARD OPERATING PROCEDURE	
INDOOR RADON MONITORING, SAMPLING, AND MITIGATION		
Edition: 15Jul2013	**SOP Number:** SOP_LC_HP-005	**Author:** MDG

Reviewed By: CJP 8/20/2012; MDG 2/13/2013; JWC 2/18/2013; CJP 12Jul2013; JWC 7/12/2013	***Final Approval*:** CHARLES KELSEY	Digitally signed by CHARLES KELSEY DN: cn=CHARLES KELSEY, o=LOST CREEK ISR, ou=UR-ENERGYUSA, email=charles.kelsey@ur-energyusa.com, c=US Date: 2013.07.17 13:45:55 -06'00'

1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to describe procedures for radon monitoring and sampling in the Central Processing Plant (Plant) and wellfield structures at the Lost Creek ISR (LC-ISR) project. Concentrations of radon daughters will be determined in order to calculate potential dose rates from radon. Mitigation and control of radon within the Plant is also discussed. Monitoring and mitigation of radon is provided for the protection of workers within the Plant and for visitors who may be in the Plant.

2.0 RESPONSIBILITIES

The EHS Department and Radiation Safety Officer are responsible for:

- Determining radon and radon daughter concentrations by monitoring;
- Calculating potential dose due to radon;
- Ensuring the proper operation and calibration of radon detection equipment;
- Retaining monitoring and sampling records;
- Ensuring personnel are trained on the hazards of radon exposure, and proper mitigation procedures in response to elevated radon and radon progeny concentrations.

3.0 PREREQUISITES AND TRAINING

Prerequisites include proper training for employees and utilization of the proper equipment for monitoring and sampling of radon.

Training includes reading and understanding this procedure and safety training on radon exposure. Individuals who use radon monitoring equipment shall be trained in its use through instruction and hands-on training by EHS Staff. Employees shall have received general radiation safety training through the Radiation Protection Program (RPP).

4.0 DEFINITIONS

Annual Limit on Intake (ALI): The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue.

Derived Air Concentration: The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate of 1.2 cubic meters of air per hour – 2L/min), results in an intake of one ALI.

Radon: (Rn-222) A colorless, odorless, naturally occurring radioactive gas with a half-life of 3.8 days which decays 100% by alpha particle emission. Radon is a product of the decay of Ra-226 which is in turn a progeny in the U-238 decay chain. Radon is heavier-than-air which has potential to collect in low-lying areas, tanks, and sumps.

Radon daughters: (also radon progeny or radon decay products) Radon daughters include the short-lived radionuclide progeny polonium-218, lead-214, bismuth-214, and polonium-214.

Working Level (WL): Any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha particle energy (from *Intro to Health Physics*, by Cember).

5.0 HAZARD ASSESSMENT AND PPE

Within the Plant, radon will likely be released during ion exchange resin transfers and subsequent ore processing steps. The work areas of concern for radon exposure are at the shaker decks and the vents from: the bleed storage tanks, the resin transfer points, the fluid collection sumps, and the yellowcake slurry loading area, as well as low-lying areas and confined spaces.

Safety procedures apply when sampling radon within the Plant. Samplers should be aware of radiation zones within the restricted area, piping and other obstacles, footing, overhead hazards, etc.

Wellfield structures, including header houses, may accumulate radon due to its potential concentration in pregnant lixiviant.

Exposure to radon can be reduced through ventilation or limited exposure durations. The primary health effect associated with chronic exposure to radon and radon progeny is lung cancer. Persons who smoke are at a much greater risk for health effects from radon exposure.

Personal Protective Equipment (PPE) shall be worn within the Plant or in the mine units when performing surveys including:

- Standard LC-ISR PPE including:
  - Hard hat;
  - Safety eyewear; and
  - Safety-toed footwear.
- Personal dosimeter
- Disposable gloves, as necessary;
- Coveralls or lab coat, as necessary.

6.0 PROCEDURE

6.1 Radon Monitoring

One method of Radon monitoring utilizes a Continuous Working Level (CWL) monitor that measures the Working Level (WL) concentration of radon progeny in air. LCI will use a detector such as the SabreAlert2 or equivalent to monitor radon. The CWL monitor will include an alarm system to alert employees of increases in radon levels. If the working level for radon exceeds 25 percent of the Derived Air Concentration (0.08 WL), corrective actions will be taken, as described in section 6.3. The RSO or Health Physics Technician (HPT) will be notified of the elevated radon level. Given the limited accuracy of a CWL, monitoring results will not be used to calculate dose.

Initially, the CWL monitor will be near the control room. The results from other radon sampling in the plant may be used to show alternative locations for the CWL.

The procedures for routine use of the SabreAlert2 are detailed in section 6.1.1 below. When changes to the settings of the instrument are desired, or for other non-routine uses, refer to the operator manual. The SabreAlert2 manual can be found on the Bladwerx website, or ask a member of the HP staff for a copy.

6.1.1 Operational Use Procedures of SabreAlert2

1.) Replace the filter in the instrument with tweezers or similar tool. Make sure the filter is facing the correct way, with side without writing facing the detector window.
2.) Set up the instrument in the desired sampling location with the alarm light up if desired. The unit should be a reasonable sampling location where it will collect a representative sample, and will not be disturbed by mining operations.
3.) Press the red button on the side of the unit to turn it on, or if already on then open the SabreAlert program from the desktop with the stylus.
4.) Before leaving the pump, ensure the unit is pumping correctly, by sound and flow reading.
5.) The alarm for the SabreAlert2 is set for the radon action limit of 0.08 WL. If the alarms, the plant operators will open the bay doors for increased ventilation. If the operators know what caused the alarm to sound then point source ventilation may be used instead. The operators will alert the RSO if he is on duty, or will record the incident in their logbooks.
6.) To reset the alarm, press the “Alarm ACK” button. It will reactivate within 1min if the action limit is still exceeded.

6.1.2 Radiation Detector Calibration of SabreAlert2

Calibrations will be performed at least annually, and whenever maintenance of the instrument is performed. Calibrations will be performed by the manufacturer.

6.1.3 Flow Calibration of SabreAlert2

1.) The flow calibration setup (see Figure 1 below) is set up by:
  a. Opening the filter holder of the SabreAlert2 and remove the filter.
  b. Attaching the calibration fixture to the filter holder assembly.
  c. Connecting the Mini Calibrator and the open end of the calibration fixture on the SabreAlert2. Make sure the flow of air will be going in the direction indicated on the Mini Calibrator; air will flow into the SabreAlert2.

d. Securing a clamp on the rubber hose connecting the two instruments. Adjusting the clamp will modify the flow rate. Substitutes, such as pliers with a fine adjustment screw or a needle valve, can be used as long as the device can maintain a constant effect on the flow rate.

Figure 1 Flow Calibration Setup

2.) Turn on the Mini Calibrator, Model MC-15L, and check that the temperature and barometric pressure readings are reasonable.
3.) Turn on the SabreAlert2.
4.) Turn on the SabreAlert2 pump and wait at least 5 minutes before running the calibration program.
5.) On the SabreAlert2, select the drop down menu “Calibration”, and then select “Flow…”.
6.) Adjusting the clamp, set the flow rate, as read by the Mini Calibrator, to 4 L/min.

7.) On the SabreAlert2, select "Start Calibration" and wait for the window to change the Measured Flow box.
8.) Adjusting the clamp, set the flow rate, as read by the Mini Calibrator, to 5 L/min.
9.) On the SabreAlert2, select "Continue" and wait for the window to change the Measured Flow box.
10.) Release the clamp.
11.) On the Mini Calibrator, read the measurement when the display has stabilized; this is the highest flow rate.
12.) On the SabreAlert2, enter the highest flow rate into the Measured Flow box.
13.) On the SabreAlert2, select "Continue" and wait for the window to change the Measured Flow box.
14.) Return the clamp to the hose and adjust the flow to read 5.5 L/min on the Mini Calibrator. If this is higher than the highest flow, or close to the highest flow, then select a different flow rate. A flow rate of 4.5 L/min would be reasonable for this step. If a different flow rate is used, then enter that information into the Measured Flow box.
15.) On the SabreAlert2, select "Validate" and wait for the window to change the Measured Flow box.
16.) If the percent error of the validation is less than 5% then close the calibration window. If the result is not less than 5%, then investigate for possible sources of error and recalibrate.

6.2 Radon Progeny Sampling

Radon Progeny sampling refers to the grab sampling of the air at various locations. Measurements of Rn-222 decay products will be used versus direct measurements of Rn-222 to determine dose, because the daughter products are the significant contributors. Samples will be collected with an air sampler, like the F & J DF-40L-8, on glass fiber filters and then analyzed in the health physics lab using a filter counter as described in Section 6.2.2 below.

6.2.1 Sampling Frequency and Locations

Initially, extra samples will be collected and sampled to characterize the radon progeny distribution in the plant. The extra sampling locations and frequency will be at the discretion of the RSO. Radon will be sampled at prescribed locations shown on

Technical Report (TR) Figure 5.7-1 (included at the end of this SOP) and according to the following schedule:

Quarterly
Quarterly sampling for Rn-222 daughters will occur in areas where previous measurements have shown the daughters are not normally present in concentrations exceeding 0.03 WL (ten percent of the limit) but where proximity to sources of Rn-222 may allow them to be present. As a minimum, quarterly Rn-222 daughter sampling will occur in the following locations:

- Office area;
- Shop area;
- Laboratory area;
- Near raw water storage tanks; and
- Yellow cake storage area

Monthly
Measurements of Rn-222 daughters will be taken on a monthly schedule in areas where Ra-222 daughters routinely exceed ten percent of the limit or 0.03 WL above background. The RSO will use professional judgment and knowledge of changes to plant conditions and operations to determine if additional locations should be sampled routinely. Rn-222 daughter measurements will be taken in at least the following locations:

- Near the center of the reverse osmosis bank;
- Near the center of the commercial ion exchange columns;
- Near the eluant make-up tank
- Near the resin handling water tank
- On top of the resin shaker deck;
- Near the center of the elution circuit tankage;

Weekly
According to RG 8.30, if Rn-222 daughter concentrations are greater than 0.08 working level (25 percent of limit of 0.33 WL as per NRC Regulations found in 10 CFR Part 20 Appendix B), sampling frequency will increase to weekly until four consecutive weekly samples indicate the concentrations of Rn-222 daughters are below 0.08 WL. Any time the Rn-222 daughter concentration exceeds 0.08 WL, a documented inspection shall

be performed by the RSO to determine and mitigate the cause of the increased concentration.

Supplementary

Additionally, the RSO or HPT may collect radon daughter samples if there is an upset condition, maintenance, or a change in operations which may result in the release of radon. For example, radon samples will be collected and analyzed before any employee will be allowed to perform a confined space entry into a vessel that has the potential to contain radon. Radon daughter samples will be collected in the immediate vicinity of the potential source of radon. When issuing an RWP, the RSO or HPT will determine the need for collecting radon daughter samples. The results of sampling will be used to ensure the employee will not be exposed to elevated radon and to verify that existing procedures are ALARA.

6.2.2 Sample Collection and Analysis

The modified Kusnetz method will be used for measuring Rn-222 working levels. This is the standard, generally accepted method for determining radon decay product concentrations in air. The Kusnetz method involves collecting an air sample for, nominally, 5 minutes on a high efficiency glass fiber filter. The filter will be counted with an alpha detector set on scaler mode for 10 minutes after a decay time of 40 to 90 minutes.

Record all relevant information using FORM_LC_HP-005A: *Radon Monitoring Log (Attached)*.

The following procedure is for sample collection for collecting radon decay products:

1. Collect air filter samples as described in Section 6.1 of SOP_LC_HP-008: *Indoor Airborne Radionuclide Sampling*.
2. The sample will be collected at a rate of 3 to 10 liters per minute (L/min) for at least 5 minutes.
3. After filter is removed from sampling device, let filter set for 90 minutes.
4. After 40 - 90 minutes have elapsed since the end of the sample collection period, count sample in the alpha/beta counting system as described in SOP_LC_HP-018: *Alpha/Beta Counting Systems*.
5. Count sample for 10 minutes to get gross alpha counts.

6. Perform the modified Kusnetz calculation (Section 6.2.3) for the radon working level calculation.

6.2.3 Radon Working Level Calculation

One WL is that concentration of radon decay products in one liter of air that will result in the emission of 1.3 x 10^5 MeV of alpha energy when all of the decay products present decay to Pb-210. The total alpha disintegration rate is divided by the volume of air sampled and an empirical factor (Kusnetz factor) that relates alpha activity per liter to WL for a specified decay period. The calculation is as follows:

$$WL = \frac{R}{\varepsilon s T K}$$

Where:

R = net count rate [background subtracted] (in cpm)
ε = counting efficiency (decimal fraction specific to instrument)
s = sampling rate (L/min)
T = sampling time (minutes)
K = Kusnetz factor which is a function of the delay time (t) between end of sampling and midpoint of the count time

To calculate K:

$$K = 230 - 2t \text{ (when } 40 \le t \le 70)$$

$$K = 195 - 1.5t \text{ (when } 70 \le t \le 90)$$

Or use the following table:

t (min)	40	45	50	55	60	65	70	75	80	85	90
K	150	140	130	120	110	100	90	83	75	67	60

t = time from end of sampling to the midpoint of count time

6.3 Radon Mitigation and Ventilation

As described in TR Section 4.1.2.2 and TR Section 5.7.1.1, mitigation and controls of radon will be used for various Plant components, areas, and wellfield structures. Potential radon exposure will be primarily eliminated or reduced with the use of ventilation to the outside of the Plant with high-volume exhaust fans. If surveys show the persistence of radon in the plant air, the existing and alternate engineering controls will be evaluated as to how to improve their effectiveness as opposed to implementing PPE or reducing exposure time. The Plant will have a general ventilation system that purges plant air with a capacity of six volumes of air per hour.

For specific components of the Plant, certain systems have potential for radon accumulation and will be vented individually. Wellfield structures are ventilated. Mitigation shall occur according to the following summary:

Component or Area	Description	Mitigation Technique
Main Plant building	The general accumulation of radon could occur.	Passive ventilation by opening bay doors Plant ventilation system; Point source ventilation using localized fans
Bleed storage tanks	Temporary storage of production bleed fluid to be discharged to the DDW with potential accumulation of radon at atmospheric pressure	Active ventilation with redundant exhaust fans through stacks to Plant exterior
Resin transfer points	Transfer of resin from IX Circuit to Elution Circuit potentially liberating radon	Pressure-relief ventilation through KO tank during loaded resin transfers
	Resin shakers on shaker deck potentially liberating radon during transfer and operation	Active ventilation with redundant exhaust fans through hooded system to Plant exterior

Yellowcake drying and packaging area	Area where yellowcake drying and packaging occurs	Dedicated negative-pressure HVAC for dryer room
Yellowcake dryers	Two rotary vacuum dryers with potential buildup of radon during drying which is pulled through vacuum system	Dryer vacuum system routed through filters and condensers exhausted back into dryer room
Deep Disposal Well (DDW) Pumphouses	Buildings enclosing the DDW for injection of production bleed and waste fluids	Active ventilation with exhaust fans to exterior
Header Houses	Buildings located in the wellfields which contain a sump that could accumulate radon.	Passive ventilation by open doors; Area ventilation using wall fan venting from the sump to the rear of the building

6.4 Potential Dose from Radon Emissions to Atmosphere

Radon and decay products are exhausted outside of the Plant and other buildings and will disperse rapidly in the atmosphere. Also, there is potential for radon to be emitted from wellhead venting, or purge water. However, potential radon doses to the public and workers were determined with the use of MILDOS modeling to demonstrate potential exposures are within regulatory limits as described in TR Section 7.2. Passive radon monitors are placed throughout the project site to measure radon concentrations as described in SOP_LC_ENV-014: *Environmental Radiological Monitoring: Passive Radon*.

6.5 Quality Assurance/Quality Control

6.5.1 Data Objectives

The LLD for Rn-222 daughter measurements will be no greater than 0.03 WL (ten percent of the DAC) as described in SOP_LC_HP-004: *Radiation Detection Instrumentation*. The LLD is set high enough to provide a high degree of confidence that 95 percent of the measured values above the LLD are accurate and do not represent false positive values.

6.5.2 Measurement Quality Control

A blank filter sample will be analyzed with every batch of filters measured. Also, a daily function check of the radiation detection instruments used will be performed.

6.5.3 Calibration

Radon sampling equipment and associated counting equipment shall be calibrated according to the instrument specifications provided in the Operator's Manual. Instruments will be serviced as necessary according to manufacturer's recommendation. Calibration is also described in SOP_LC_HP-004: *Instrument Calibration*, and calibration for the air sampling pump is in SOP_LC_ENV-006: *Air Sampling Maintenance and Calibration.*

6.5.4 Data Verification and Validation

Data verification is also discussed in SOP_LC_AD-008: *Data Management*.

6.5.5 Audits/Corrective Actions/ALARA

Audits are also discussed in SOP_LC_AD-007: *Internal Audit and Corrective Action Program*.

Calculated data shall be charted over time to compare the values to determine trends. If upward trends occur, an ALARA investigation should take place and the results included in the annual RPP/ALARA report along with recommendations and corrective action plans on how to reduce radon levels in the areas of increasing radon.

7.0 DOCUMENTS AND RECORDS

The following documents and records will be maintained for the life of the project which may include:

- Radon WL calculations
- Calibration and maintenance records for samplers and counting devices
- Annual RPP/ALARA Report

8.0 REFERENCES

Canadian Nuclear Safety Commission, Regulatory Guide: *Measuring Airborne Radon Progeny at Uranium Mines and Mills*, June 2003

EPA, website, Radiation Protection: *Radon* http://www.epa.gov/radiation/radionuclides/radon.html

Cember, 2009. *Introduction to Health Physics*. 4th ed.

NCRP 160 Ionizing Radiation Exposure of the Population of the United States

NRC License Application, Technical Report, Section 4.1.2.2: *Radon*, April 2010

NRC License Application, Technical Report, Section 5.7.3.3: *Surveys for Radon-222 and Its Decay Products*, April 2010

NRC License Application, Technical Report, Section 7.2: *Radiological Effects*, April 2010

NRC License Application Technical Report, Figure 5.7-1

NRC License Application Technical Report, Table 5.7-1

NRC, Regulatory Guide 8.30: *Health Physics Surveys in Uranium Recovery Facilities* May 2002

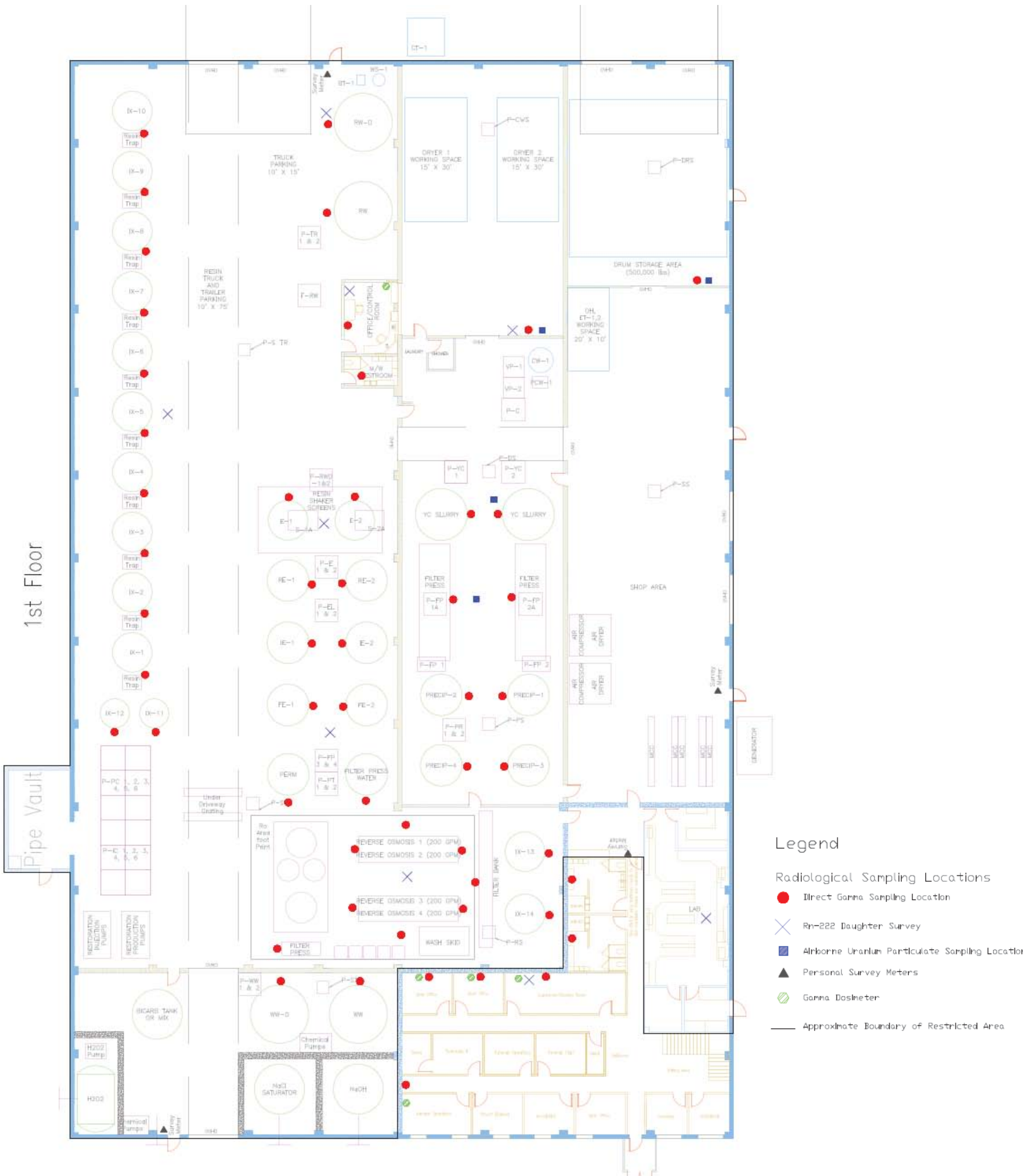
SOP_LC_ENV-14: *Environmental Radiological Monitoring – Radon*

SOP_LC_ENV-006: *Air Sampling Maintenance and Calibration*

SOP_LC_HP-004: *Radiation Detection Instrumentation*

SOP_LC_HP-008: *Indoor Airborne Radionuclide Sampling*

SOP_LC_HP-018: *Alpha/Beta Counting Systems*



1st Floor
Pipe Vault
TRUCK PARKING 15' X 15'
RESIN TRUCK AND TRAILER PARKING 10' X 75'
DRYER 1 WORKING SPACE 15' X 30'
DRYER 2 WORKING SPACE 15' X 30'
DRUM STORAGE AREA (500,000 lbs)
SHOP AREA
YC SLURRY
FILTER PRESS
REVERSE OSMOSIS 1 (200 GPM)
REVERSE OSMOSIS 2 (200 GPM)
REVERSE OSMOSIS 3 (200 GPM)
REVERSE OSMOSIS 4 (200 GPM)
WASH SKID
LAB
GENERATOR
Legend
Radiological Sampling Locations
Direct Gamma Sampling Location
Rn-222 Daughter Survey
Airborne Uranium Particulate Sampling Location
Personal Survey Meters
Gamma Dosimeter
Approximate Boundary of Restricted Area

	UR-ENERGY USA, INC. LOST CREEK ISR, LLC STANDARD FORM	
RADON MONITORING LOG		
Edition:	**FORM Number:** FORM_LC_HP-008A	**Approval:**

Date:
Sampler Name:

Air Sampler Instrument
Type:
Model:
Serial #:

Radiation Detection Instrument
Type:
Model:
Serial #:
Efficiency:

Sample #	Location	Sample Frequency Type*	Sampling Start Time	Sample Duration (min)	Flow Rate (L/min)	Sample Volume (L)	Count Start Time	Count Time (min)	Sample Counts	Kusnetz K Factor	Sample Concentration (WL)

***** Frequency Abbreviations: D=Daily, W=Weekly, Q=Quarterly, A=Annually, Sp=Spot (or Ad hoc)

Comments

Nuclide Action Level

<0.03 WL	**No action necessary**
<0.08 WL	**Sample at this location monthly**
>0.08 WL	**Sample at this location weekly, and mitigation might be necessary**

Kusnetz K Factor

K = 230 – 2t (when 40 ≤ t ≤ 70)

K = 195 – 1.5t (when 70 ≤ t ≤ 90)

Or use the following table:

t (min)	40	45	50	55	60	65	70	75	80	85	90
K	150	140	130	120	110	100	90	83	75	67	60

Air Sample Equation

$$V = \frac{F}{T} \times \frac{1000ml}{1L}$$

V = Volume (ml)
F = Flow rate (L/min)
T = sample time (min)

Radiation Measurement Equation

$$WL = \frac{R}{\varepsilon\, s\, T\, K} = \frac{R}{\varepsilon\, V\, K}$$

R = net count rate [background subtracted] (cpm)
ε = counting efficiency (decimal fraction specific to instrument)
s = air sampling rate (L/min)
T = sampling time (min)
K = Kusnetz factor which is a function of the delay time (t) between end of sampling and midpoint of the count time