	UR-ENERGY USA, INC. LOST CREEK ISR, LLC STANDARD OPERATING PROCEDURE	
RADIATION DOSE DETERMINATIONS		
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Reviewed By: JWC 4/11/2013; MDG 4/23/2013; MDG 6/28/2013; CTK 7/2/2013;JWC 7/07/2013;	***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 13:29:56 -06'00'

1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to explain how surveys and monitoring at the Lost Creek ISR (LC-ISR) Project shall be used to demonstrate that workers and members of the public, respectively, will not receive doses in excess of limits set forth in 10 CFR 20.1201 and 20.1301. This SOP also explains how the radiation doses will be calculated for radiation workers, as necessary. The dose determinations and calculations will use the data collected per various health physics (HP) and environmental (ENV) procedures.

2.0 RESPONSIBILITIES

The Radiation Safety Officer (RSO) and/or Health Physics Technician (HPT) and/or Manager EHS and Regulatory Affairs are responsible for:

- Demonstrating workers are not likely to receive a dose in excess of regulatory limits
- Demonstrating that members of the public are not likely to receive a dose in excess of regulatory limits
- Ensuring calculated doses are below regulatory limits
- Practicing ALARA to minimize radiation exposures
- Ensuring associated SOPs are current and are properly applied
- Performing or reviewing calculations and data as a result of the procedures

3.0 PREREQUISITES AND TRAINING

Determination of potential dose is dependent upon data collected as a result of radiological surveys and monitoring. SOPs for surveys and monitoring should be valid and current as verified by the RSO.

The person performing the dose determinations and calculations should be familiar with the facility and all SOPs related to radiation safety of radiation workers and members of the public.

4.0 DEFINITIONS

Annual Limit of Intake (ALI): Derived limit for amount of radiation received by an individual for one year through ingestion or inhalation.

As Low as Reasonably Achievable (ALARA): maintaining occupational doses and doses to members of the public as low as is reasonably achievable using, to the extent practical, procedures and engineering controls based upon sound radiation protection principles.

CDE (Committed Dose Equivalent): The dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

CEDE (Committed Effective Dose Equivalent): The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Deterministic: Model based on clear outcomes, such as falling down stairs causing a sprained ankle. Either the sprained ankle happened or it didn't happen.

DDE (Deep Dose Equivalent): External whole-body exposure dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

EDE (Effective Dose Equivalent): The sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma W_T H_T$).

Effluent Concentration Limit (ECL): The 10 CFR 20, Appendix B, Table 2, ECL values are equivalent to the radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a total effective dose equivalent of 0.05 rem (50 millirem or 0.5 millisieverts)

Gray (Gy): the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Radiation Absorbed Dose (rad): Special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Roentgen Equivalent Man (rem): Special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert).

Sievert (Sv): The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).

Stochastic: Model based on a probabilistic outcome, such as cancer being caused by low levels of radiation. It is difficult to determine, even if the cancer is known, if the radiation caused the cancer in an individual.

TEDE (Total Effective Dose Equivalent): The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Working level (WL): is any combination of short-lived radon daughters (for radon-222: polonium-218, lead-214, bismuth- 214, and polonium-214; and for radon-220: polonium-216, lead-212, bismuth- 212, and polonium-212) in 1 liter of air that will result in the ultimate emission of 1.3×105 MeV of potential alpha particle energy.

Working level month (WLM): means an exposure to 1 working level for 170 hours (2,000 working hours per year/12 months per year=approximately 170 hours per month).

5.0 HAZARD ASSESSMENT AND PPE

N/A

6.0 PROCEDURE

The procedure for dose determination and calculation is grouped into two categories:

- Dose to workers; and
- Dose to members of the public.

Procedures for each respective category of persons describe how to determine that each group will not receive a dose in excess of the regulatory limit. The limits are provided in Table 6-1 as follows:

TABLE 6-1: Dose Limits for Workers and Public

Category	TEDE Limit	Source
Workers	5,000 mrem/yr	10 CFR 20.1201
Public, Individual (exclusive of background)	100 mrem/yr	10 CFR 20.1301
Public, dose compliance (exclusive of background)	50 mrem/yr from effluent; and 50 mrem/yr from external sources	10 CFR 20.1302

Workers will be monitored by:

- Dosimetery, SOP_LC_HP-002_Personnel Radiation Dosimetry
- Radon monitoring, SOP_LC_HP-005_Plant Radon Monitoring and Mitigation
- Airborne particulate sampling, SOP_LC_HP-008_Indoor Airborne Radionuclide Sampling
- Breathing zone monitoring, SOP_LC_HP-017_Breathing Zone Air Monitoring
- Bioassay, SOP_LC_HP-009_Bioassay Monitoring

6.1 Dose to Workers

Data from surveys and monitoring will be used to show that workers have not or are not likely to have received a dose in excess of ten percent of the annual limit.

To show that a worker is not likely to exceed the the annual limit, the data obtained from monitoring will be compared to action limits on Table 6-2:

TABLE 6-2: Worker Dose Action Limits

Data Set	Nuclide	Action Limit	Comment	SOP
Dosimetery	Gamma	500 mrem	10% of the annual limit	SOP_LC_HP-002
Plant radon progeny	Rn-222 + progeny	3E-09 µCi/mL	10% of DAC	SOP_LC_HP-005
Indoor airborne radiological	U-nat (W)	3E-11 µCi/mL	10% of DAC	SOP_LC_HP-008
	Th-230 (W)	3E-13 µCi/mL	10% of DAC	
	Ra-226	3E-11 µCi/mL	10% of DAC	
	Po-210	3E-11 µCi/mL	10% of DAC	
	Pb-210	1E-11 µCi/mL	10% of DAC	
Breathing zone monitoring	U-nat (W)	3E-11 µCi/mL	10% of DAC	SOP_LC_HP-017
Bioassay	U-nat	35 ug/L	Bioassay action limit	SOP_LC_HP-009

If values exceed any action limit or if the sum of the fractions of the action limits result in a dose greater than 10%of the annual worker dose limit, then the following actions shall occur:

- The actual dose will be calculated;
- An ALARA investigation shall be initiated by the RSO to determine the cause and to recommend corrective actions.

As necessary, worker doses will be calculated annually based on the personal dosimeter data, airborne radionuclide concentration measurements (bioassay to be used for confirmation of U-nat inhalations), radon and radon progeny as described in Section 6.1.1 below.

6.1.1 Worker Dose Calculation (TEDE)

If it is necessary to calculate an actual dose to a worker, data from different sources will be used to determine the TEDE. Dose calculation is based on several factors. The dose factors may differ depending on the job of the radiation worker. For example, a dryer operator will be monitored with a breathing zone air sampler, but most employees will not. The breathing zone air sampler will provide more accurate data for individual operator intake values. Dose calculations for workers in other parts of the facility will incorporate data from area air particulate samplers, and depend on assumptions of physiology and work habits. Basically, radiation dose is determined by the following equation:

$$\boldsymbol{TEDE = DDE + CEDE}$$

Where:

DDE is the dose from the dosimeter result in rem (Section 6.1)
CEDE is the combined dose from internal exposure

6.1.2 External Exposure (DDE)

Most of the external radiation dose (DDE) to workers will be based on radiation measured by dosimeters. The results from the personnel dosimetry (SOP_LC_HP-002) will be used to determine the DDE for radiation workers.

When dosimeter measurements are not available, dosimeter measurements of other workers who perform similar tasks may be used to approximate dose.

Another dose estimation method is to calculate the DDE based on HP inspection data, such as gamma measurements and surface contamination. This method is more appropriate for situations when there is reason to believe that an employee without a badge received a dose higher than the dosimeter readings from coworkers with similar duties.

6.1.3 Internal Exposure (CEDE)

Internal dose is determined from data resulting from monitoring radon, air particulates, and breathing zone monitoring.

The CEDE can be calculated from each data set:

$$\boldsymbol{CEDE = CEDE_{radon} + CEDE_{air} + CEDE_{bz}}$$

Where CEDE can be calculated from the following based on the activity value measured from monitoring:

$$\boldsymbol{CEDE_{air\ or\ bz} = \frac{(5\ rem)\ I}{ALI}}$$

$$\boldsymbol{I = \frac{R_{respiration}\ C\ t_{exposure}}{APF}}$$

***CEDE**: Committed effective dose equivalent (rem)*
***ALI**: Annual limit on intake (µCi) from 10CFR 20 App B Table 1*
***I**: Intake (µCi)*
$\boldsymbol{R_{respiration}}$*: The rate of respiration (2 x 10^4 ml/min for reference man)*
***C**: Concentration of contaminate determined from air sampling (µCi/mL)*
$\boldsymbol{t_{exposure}}$ *: The time that the individual was in the contaminated air (min)*
***APF**: The Assigned Protection Factor for worn respirators (50 for full face respirators)*

For radon (Rn-222) concentrations in the air, use the following calculation:

$$D = DCF \sum_i C_i F_i T_i$$

Where:

***D**: annual dose (TEDE) (mrem/yr);*
***DCF**: dose conversion factor for Rn-222 in equilibrium (i.e., 100% equilibrium) with the Rn-222 progeny (10 CFR 20 Appendix B Table 1);*

$$3 \times 10^{-8} \frac{\mu Ci/ml}{2.5 mrem/hour}$$

$\boldsymbol{C_i}$*: average concentration of Rn-222 in air (pCi/L) at the receptor location during the exposure time;*

F_i: radon progeny equilibrium factor (fraction) to adjust the DCF assumption of 100% equilibrium of radon and daughters:

0.7 when outside (based on NCRP 160)

0.4 when in buildings (based on NCRP 160)

***T**: exposure time (occupancy time) (hours)*

2000 hours for the typical number of hours worked in a year

Note: The receptor locations i represent the different locations at which an individual is exposed. For example, if an individual is exposed both indoors and outdoors, i would take two values to represent the indoor portion of exposure and the outdoor portion. If a person is exposed only outdoors, i would only take a single value, to represent that outdoor exposure.

6.2 Dose to Members of the Public

Potential doses to the public have been modeled by MILDOS in the pre-license evaluation of the project as described in the NRC License Technical Report Section 2.9.3.1. However, the values will be verified by the effluent and environmental monitoring program reported in accordance with 10 CFR 40.65. The environmental measurements that will be used to demonstrate potential dose is below the regulatory limit include:

- Air particulate radionuclide concentration
- Radon and radon progeny
- External radiation

The results from each data set will be compared to the effluent concentration limits (ECLs) from 10 CFR 20 Appendix B Table 2 and the compliance dose limit for continuous occupancy of 50 mrem (10 CFR 20.1302).

TABLE 6-3: Effluent Concentration and Dose Limits

Data Set	Nuclide	Effluent Concentration Limit or Exposure Limit	Source	SOP
Air Samples	Unat (W)	9.0E-13	10 CFR 20 Appendix B Table 2	SOP_LC_ENV-004
	Th-230 (W)	2.0E-14		
	Ra-226	9.0E-13		
	Pb-210	6.0E-13		
Environmental Radon	Rn-222 + progeny	1.0E-10	10 CFR 20 Appendix B Table 2	SOP_LC_ENV-014
"Stack Effluent" Radon	Rn-222 + progeny	1.0E-10	10 CFR 20 Appendix B Table 2	SOP_LC_ENV-014
Direct Radiation	Gamma	50 mrem	10 CFR 20.1302	SOP_LC_ENV-013

The actual concentrations will be compared to the limits and the percent value of the limit will be calculated for the result. Demonstrated compliance for members of the public is based on continuous occupancy (occupancy factor = 1). A less stringent occupancy factor may be justified through coordination with NRC if exposures approach the limits.

6.3 Dose to Fetus of Pregnant Workers

The dose to the fetus of a declared pregnant worker will be calculated using the methods described in NRC RG 8.36. The dose to a declared pregnant worker must be monitored if the dose to the fetus is likely to exceed 0.05 rem. The dose to the fetus from internally deposited radionuclides must be determined if the intake is likely to exceed one percent of the Annual Limit on Intake (ALI). Declared pregnant workers will be subject to enhanced radiation monitoring, including monthly exchange of whole body and fetal (lower torso) personal dosimeters and calculation of the dose to the

fetus from inhalation of radionuclides in airborne particulate matter, as necessary. Doses will be calculated on a monthly basis or more frequently if necessary to accurately estimate the dose to the fetus.

7.0 DOCUMENTS AND RECORDS

Dose results, if applicable, will be recorded on NRC Form 5 or equivalent (per RG 8.34), and entries to the dose record will be made at least annually (per 10 CFR 20.2106 (b)). NRC Form 4 is used to record cumulative dose for individuals with a prior occupational dose during the current year (10 CFR 20.2104).

EHS will provide an annual report to each individual monitored under 10 CFR 20.1502 of the dose received in that monitoring year if:

- The individual's occupational dose exceeds 1 mSv (100 mrem) TEDE or 1 mSv (100 mrem) to any individual organ or tissue; or
- The individual requests his or her annual dose report.

Although, such exposures are extremely unlikely, the RSO will follow the applicable exposure reporting requirements of 10 CFR 20.2202 – 20.2205.

The following records shall be maintained for at least the life of the project:

- Radiological monitoring data
- Form 5: Occupational Dose Record for a Monitoring Period
- Records of prior dose on Form 4: Cumulative Occupational Dose History (covered in RG 8.7 sects 1.3 and 1.4)

8.0 REFERENCES

Code of Federal Regulation Title 10 Part 20 Appendix B: *Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure*

NRC, Regulatory Guide 8.7: *Instructions for Recording and Reporting Occupational Radiation Dose Data*, May 2005

NRC, Regulatory Guide 8.34: *Monitoring Criteria and Methods to Calculate Occupational Radiation Doses*, July 1992

NRC License Technical Report, Section 2.9.3.1: *Supplementary MILDOS Modeling*

NRC License Technical Report, Section 5.7.4: *Worker Dose Calculations*

SOP_LC_HP-002: Personnel Radiation Dosimetry

SOP_LC_HP-005: *Plant Radon Monitoring and Mitigation*

SOP_LC_HP-008: Indoor Airborne Radionuclide Sampling

SOP_LC_HP-017: Breathing Zone Monitoring

SOP_LC_ENV-004: *Environmental Radiological Monitoring – Air Particulates*

SOP_LC_ENV-013: *Environmental Radiological Monitoring – Passive Radiation*

SOP_LC_ENV-014: *Environmental Radiological Monitoring – Radon*