CAMECO RESOURCES
CROW BUTTE OPERATION

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June 30, 2015

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Attn: Document Control Desk, Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Additional Information for Response to License Condition 11.11
Crow Butte Resources, Inc., Crawford, Nebraska
Source Materials License SUA-1534
TAC No: L00762

Dear Director:

By letter dated April 2, 2015, (received April 13, 2015) the U.S. Nuclear Regulatory Commission (NRC) staff, upon review of Crow Butte's letter dated January 2, 2015 in response to License Condition 11.11 in renewed Source Material License SUA-1534 issued (November 2014) to Crow Butte Resources, Inc., (TAC J00555), has found deficiencies in Crow Butte's response and has requested additional information. The requests and Crow Butte's responses are summarized below.

License Condition 11.11(A) "Discuss how, in accordance with 10 CFR 40.65, the quantity of the principal radionuclides from all point and diffuse sources will be accounted for, verified by, surveys and/or monitoring".

Since the Crow Butte project utilizes a vacuum dryer prior to packaging to reduce the moisture in the final uranium product, the principal radionuclides released from the facility are radon and its associated daughter products. Cameco has identified three locations at the Crow Butte project that have the potential for release of radon and its daughters. These locations are the Main Plant, the Wellhouses, and, to a lesser extent, the wellfields. How the quantity of principal radionuclides released from each of these potential sources will be accounted for will be discussed in more detail.

Main Plant

NMSS01

Emissions from the Main Plant will be determined based on the following assumptions and measurements. The total radon emission from the Main Plant will be the sum of the radon released from the tank vents of the tanks with the potential to contain significant quantities of radon plus the ambient radon in the facilities that is vented through the building's exhaust fans.

Releases of radon from vented tanks will be calculated by measuring the concentration of radon being emitted from the tank vents. Lucas cells will be used to sample the air in the vent and quantify the concentration of radon at each vent. The attached figure shows the location of the vents to be sampled with the Lucas cell. The use of scintillation cells for the measurement radon is an approved method, as outlined in Method 115 from 40 CFR 61 Appendix B. While the method describes the use of scintillation cells for underground mining and tailing piles, it can be applied to this application.

Measurements of the radon from tank vents will be performed at a minimum of once a quarter. Samples will be taken during highest predicted concentrations and will be used to determine the effluent of radon from vented tanks. To evaluate the conditions that would represent the highest concentration of radon in the vents, samples will be collected during different stages of the tank's operation. These stages will be filling, emptying, mixing and static. These samples will be collected during the first quarter after approval of this program. After the initial sampling, a single sample will be collected from each vent on a quarterly basis to represent the radon concentration in the tank vent.

Once the concentration of radon in the tank's vent is determined the quantity of radon emitted from the vent can be calculated assuming the manufacturer's flowrate (cf/min) for the ventilation fan associated with the tank vent. Fans will be assumed to be running continuously, and total releases from vented tanks will be calculated and added to total radon released from the plant.

The amount of radon in the plant air will be determined using Track Etch cups with semi-annual exposures. There will be six sample locations throughout the facility (floor exhaust vents) and these locations are depicted on the attached figure. Each semi-annual sample results from the six locations will be averaged to determine the ambient radon concentration in the facilities air. The rate of radon released from the process facility will be based on the manufactures flowrate for each of the exhaust fans. It will be assumed that the fans are operational 100% of the time which will represent the worst case.

A total radon released from the Main Plant will be calculated semi-annually based on the sum of the radon released from the tank vents and the ambient radon released as a result

of the building ventilation. This release rate will be reported semiannually in agreement with 10 CFR 40.65.

The history of particulate sampling at the Crow Butte project indicates that, as expected, there are not significant quantities of the particulate radionuclides released from the facility. Cameco proposes that for one year, the emission of particulates will be estimated based upon semi-annual isotopic analysis. The concentrations of the radionuclides reported from the analysis of the filters by an outside accredited lab will be used to calculate the quantity of the particulate radionuclides released from the facility. The exhaust fan rates that are used for the radon estimate will be used for the airborne particulate release calculations. The fans will be assumed to operate 100% of the time. Total effluents for each radionuclide will be reported on a semi-annual basis in agreement with 10 CFR 40.65. If after one year the NRC agrees that these emission rates are insignificant Cameco will submit a written request to discontinue this reporting.

RAI 1:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) for radon releases from the main plant.

Basis for Request

NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) refer, in part, to the As Low As Reasonably Achievable (ALARA) aspects of Regulatory Guide (RG) 8.37. RG 8.37 states, in part, "When practicable, releases of airborne radioactive effluents should be from monitored release points (e.g., monitored stacks, discharges, vents) to ensure that the magnitude of such effluents is known with a sufficient degree of confidence to estimate public exposure."

The staff requires additional clarification of Cameco's proposed radon monitoring program for the main plant.

Request for Additional Information

Please provide the following information:

A. Please describe how radon daughter activity will be addressed for all radon sources originating from the main plant.

Crow Butte Response

Radon daughter measurements will be performed concurrently with the radon gas measurements from the tank vents listed in response 11.11(A) and converted to an equivalent radon gas concentration using the conversion 0.33 WL is equivalent to 3E-8 μCi/ml. As with the results of the Lucas cell measurements, the emissions from the vent can be calculated assuming the manufacturer's flowrate (cf/min) for the ventilation fan associated with the tank vent. The radon progeny releases from tanks will be added to the total radon emission from the plant.

Radon daughter concentrations are taken at routine sampling locations throughout the main plant on a schedule approved within the license. On a semi-annual basis these samples will be averaged and converted to an equivalent radon gas concentration as described above. The rate of radon released from the process facility will be based on the manufactures flowrate for each of the exhaust fans. It will be assumed that the fans are operational 100% of the time which will represent the worst case scenario. These emissions will be added to the total plant emissions.

B. Please provide a drawing that details current tank vent connections so that staff can verify the tank vent locations shown in the drawing "Tank Vent Locations" attached to Cameco's January 2, 2015, submittal.

Crow Butte Response

Included is a drawing showing the tank vent connections; based on this drawing, CBO has added an additional sampling point to account for resin cleaning.

C. Please provide assumptions for air flow through open doors and justification for disregarding this pathway if applicable.

Crow Butte Response

An assessment of the ventilation (LRA - Appendix C) was performed at the Crow Butte facility to determine the flow rates and volumes within the facility and the impact of the positioning of doors at the facility. There are large roll-up, garage style doors at the Crow Butte plant. Typically, these doors have openings measuring 12 feet wide by 16 feet high. During operations these roll-up doors may be positioned fully opened, partially opened and sometimes fully closed. On a particular day, this positioning of the doors may change for a number of reasons, like opening/closing doors for retrieval of resin, deliveries, facility temperature control and general personnel/equipment access.

Field air velocity measurements were taken within the facility to determine the effect of air flow with the opening and closing of the garage style roll-up doors. As the doors were moved to various positions, it was noted that air velocity (and also air flow) measurements did not vary more than approximately 10%, which is comparable to typical variations in air flow operation over the course of time and within the accuracy of the measurements, which was 15%. This field data shows that when the roll-up doors were closed there were alternate and adequately-sized openings for air flow to continue. These openings include louvers, vents, doors and other openings that allowed air flow.

The airflow through the doors has not been disregarded, the flow rates and air exchange rates for the overall facility remains generally constant regardless of door positioning. Emissions from all pathways have been accounted for by using the total air exchange rate for the ambient plant air in the calculations. It should also be noted that the facility is under negative pressure, generally air would enter these doors rather than exiting, meaning that typically the exhaust is still primarily though the vents and blowers, not the doors themselves.

RAI 2:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) for the particulate releases from the main plant.

Basis for Request

NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) refer, in part, to the ALARA aspects of RG 8.37. RG 8.37 states, in part, "When practicable, releases of airborne radioactive effluents should be from monitored release points (e.g., monitored stacks, discharges, vents) to ensure that the magnitude of such effluents is known with a sufficient degree of confidence to estimate public exposure."

The staff requires additional clarification of Cameco's proposed particulate monitoring program for the main plant.

Request for Additional Information

A. Please provide clarification on the historical particulate sampling data for the Main Plant as discussed in Cameco's submittal. Please provide this data if not already submitted.

Crow Butte Response

Semi-annually, since 2013, Cameco has been collecting samples from seven locations throughout the main plant for isotopic analysis, five from the routine sampling locations and two from additional locations within the plant. This data is analyzed currently for U^{-nat}, Th^{230}, Ra^{226} and Pb^{210}. This information can be used to calculate emissions and has also been used to demonstrate that all isotopes present are well below the criteria set out in 10 CFR 20.1204(g) for disregarding radionuclides in a mixture, as discussed further in RAI 9A and can also be used to assess emissions.

The following table provides a summary of the average annual concentrations for each of the measured radionuclides. Laboratory results are provided in Appendix A. The data presented is not corrected for background concentrations and where samples were less than the laboratory detection limit, a value of one half of the detection limit was used for performing the average concentration calculation.

In addition, the table shows the calculated annual emissions rate from these particulates. From the plant ventilation study referred to in RAI 1C; the flow rate for the main plant is 49,780 CFM. Multiplying the average concentrations by this flow rate, assuming that the flow rate is constant over the entire year, gives the emissions shown:

Year	Average U^{-nat} (µCi/ml)	Average Th^{230} (µCi/ml)	Average Ra^{226} (µCi/ml)	Average Pb^{210} (µCi/ml)	Annual Emissions (Ci/year)
2013	2.57E-13	5.39E-16	1.63E-15	3.51E-14	0.0002
2014	2.48E-13	8.14E-16	1.76E-15	1.27E-13	0.0003
2015	7.14E-13	1.29E-16	2.40E-15	3.00E-14	0.0006

The results in the table demonstrate that this pathway represents an extremely small emissions source term, with all emissions below 0.001 Ci/year.

B. Please provide additional information on the proposed semi-annual isotopic analysis proposed in Cameco's submittal including location of filters, a description of the sampling method, isotopes to be analyzed, and assumptions regarding air flow through open doors and justification for disregarding this pathway if applicable.

Crow Butte Response

Semi-annual isotopic sampling is performed at seven locations throughout the plant, five from the routine sampling locations as specified in the license, and two from additional locations within the plant. Specifically:

Between Upflow IX Trains
Below Thickener Tank
Top of PPT-B
Belt Filter Room
Top of Tall White Tanks
Dryer Change Room
R.O. Building

The isotopes analyzed are: U^{-nat}, Th^{230}, Ra^{226} and Pb^{210}. Samples were collected using a high-flow pump running for approximately one week, with particulate collected on a 47mm filter. (Laboratory results are provided in Appendix A).

Doors as a pathway are discussed in RAI 1C.

During previous conversations with the NRC staff, not including Po^{210} was discussed. Samples have not been collected for this radionuclide as there is no chemical or physical mechanism to separate or generate Po^{210}. A reasonable assumption would be equilibrium with Pb^{210}, which would mean the same total annual emissions as Pb^{210}. Specifically; 4e-5 Ci/year as an annual average, without background correction. As with the other radionuclides, this is a very small value and makes an insignificant contribution to total emissions. As such, Crow Butte does not intend to perform monitoring for this radionuclide based on the fact that it is not justified by risk, cost or contribution to total emissions.

Wellhouses

Radon emissions from wellhouses will be estimated based on the following assumptions and measurements. The concentration of radon in air released from the wellhouse will be based on radon measurements taken within the wellhouse utilizing Track Etch cups with a six month exposure time. The average semi-annual radon concentrations will be used along with the manufacture's rating on the wellhouse exhaust fan to determine the total radon released from the wellhouse. This assumes that all radon in the wellhouse is

released into the environment at a rate of the exhaust fan. The exhaust fans in the wellhouses are operated on a continual basis.

Four productions and four restoration wellhouses will be monitored as described above and the average radon emission per wellhouse will be attributed to the remaining operational wellhouses in each group. The emissions from the operational wellhouses will be totaled on a semi-annual basis and reported in the semi-annual report consistent with the requirements of 10 CFR 40.65.

Emissions of particulate radionuclides will be estimated based upon semi-annual isotopic analysis of filters used for semi-annual air particulate in air samples in each of the wellhouses that are monitored for radon. The wellhouse exhaust rate will be based on the manufactures rating on the fans in the wellhouses. The total of all of the operational wellhouses emissions will be reported in the semi-annual report consistent with the requirements of 10 CFR 40.65. If after one year the NRC agrees that these emission rates are insignificant, Cameco will submit a written request to discontinue this reporting.

RAI 3:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) for radon releases from the wellhouses

Basis for Request

NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) refer, in part, to the ALARA aspects of RG 8.37. RG 8.37 states, in part, "When practicable, releases of airborne radioactive effluents should be from monitored release points (e.g., monitored stacks, discharges, vents) to ensure that the magnitude of such effluents is known with a sufficient degree of confidence to estimate public exposure."

In its submittal, the licensee stated that radon concentrations in air released from the wellhouses will be based on four production and four restoration wellhouses monitored with Track Etch cups. The average radon emission per wellhouse will be attributed to the remaining operational wellhouses in each group.

The staff requires additional clarification of Cameco's proposed radon monitoring program for the wellhouses.

Request for Additional Information

A. Please describe how radon daughter activity will be addressed for radon sources originating from the wellhouses.

Crow Butte Response

Radon daughters measurements will be collected semi-annually within the wellhouses in which radon gas samples are collected and converted to an equivalent radon gas concentration using the conversion factor 0.33 WL equals 3E-8 μCi/ml. These average semi-annual radon concentrations will be used along with the manufacture's rating on the wellhouse exhaust fan to determine the total radon released from the wellhouses.

B. Regarding the four monitored wellhouses in each operational group (i.e., production and restoration), will the original four monitored wellhouses remain constant from year to year or will other wellhouses be included in the monitoring program on a random or other basis?

Crow Butte Response

Four wellhouses from each operational group will be sampled annually and rotated annually with four different wellhouses so that each wellhouse is sampled over time.

Wellfield

Injection wells have sealed well heads and the potential for radon release is minimal. Potential emission of radon in the wellfield is limited to the production wells; however this source is also minimal. The release of radon from production wells is considered to be negligible. The submersible pumps are positioned just above the production zone of the wellfield and approximately 450' to 500' below ground surface with several feet of water above them. These submersible pumps are extracting production fluids containing dissolved radon from the formation and transfer these solutions to the nearest wellhouse through a closed poly pipe line under pressure. This production fluid is the source of the radon measured in the wellhouses.

The stagnant nature of the fluid above the pump lacks the turbulence to release a significant amount of radon gas into the well bore above the fluid surface. The stagnant water in the well above the pump is raised or lowered within the well bore by atmospheric conditions or changes in pump flow rates. These minor changes in the water level in the wellbore are the only means to exhaust gases from the production wellhead.

Given the small volume of gas and the low concentration of radon in this gas, the radon released from the production wells is minor when compared to the quantity released from the Main Plant and the Wellhouses. Because the production fluid is the main source of radon measured in the wellhouses, a separate reporting of radon from the production wells will not be included in the release calculations.

A potential source of radon emitted from the wellheads and piping occurs when the wellheads are opened to the atmosphere to depressurize a wellhead that has become pressurized. Because this situation is transient and very short lived, in addition to being highly localized, emissions from this situation will be measured through the use of grab samples collected with scintillation cells. Sampling of at least one well per quarter will be planned to determine the radon concentration in the gases released during depressurization of the wellhead. These samples will be collected in the airstream being vented from the well. Currently, wells are vented at nominally 50 per month. The volume of gas will be calculated based on the casing volume and well pressure. The casing volume will assume the casing diameter and the average length of the casing from ground surface to the top of the screen for each mine unit.

The other potential source of radon release from the wellfields is the unplanned releases of process fluid resulting from spills in the wellfield. The amount of radon released as a result of a spill will be estimated based on the volume of fluid released and an estimate of the radon concentration in that fluid. The concentration of radon in the fluid will be based on the calculations used to determine the radon concentration in production fluid by the program MILDOS. While the quantity of radon released as a result of spills in the wellfields is minor this procedure will represent a conservative estimate of the radon released.

The quantity of radon released from the process facility, wellhouses, well venting, and spills will be summarized on a semi-annual basis and reported in the semiannual report consistent with the requirements of 10 CFR 40.65. If the reported radionuclide emission is significantly greater than that anticipated in the license renewal the cause of the unexpected value will be discussed in the report.

RAI 4:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) for radon releases from the wellfield.

Basis for Request

NUREG-1569, Acceptance Criteria 4.1.3(2) and 5.7.7.3(1) refer, in part, to the ALARA aspects of RG 8.37. RG 8.37 states, in part, "When practicable, releases of airborne radioactive effluents should be from monitored release points (e.g., monitored stacks, discharges, vents) to ensure that the magnitude of such effluents is known with a sufficient degree of confidence to estimate public exposure."

In addition, RG 8.37 states, in part, "If a licensee has release points for which monitoring is not practicable, the licensee should estimate the magnitude of the unmonitored effluents" and "When practicable, unmonitored effluents should not exceed 30% of the total estimated effluent releases."

In its submittal, the licensee stated that the amount of radon released from the production wellheads is minor compared to the quantity released from the main plant and the wellhouses.

Regarding spills, the licensee stated that the radon concentration will be based on an estimate using MILDOS.

The staff requires additional clarification on Cameco's proposed radon monitoring program for the wellfield.

Request for Additional Information

A. Consistent with RG 8.37, please provide an estimate of the radon released from the production wellheads to account for this source.

Crow Butte Response

The release of radon from production wells would be considered to be negligible. The submersible pumps are positioned just above the production zone of the wellfield and approximately 450' to 500' below ground surface with several feet of water above them. These submersible pumps are extracting production fluids containing dissolved radon from the formation and transfer these solutions to the nearest wellhouse through a closed poly pipe line under pressure. This production fluid is the source of the radon measured in the wellhouses.

The stagnant nature of the fluid above the pump lacks the turbulence to release a significant amount of radon gas into the well bore above the fluid surface. The stagnant

water in the well above the pump is raised or lowered within the well bore by atmospheric conditions or changes in pump flow rates. These minor changes in the water level in the wellbore are the only means to exhaust gases from the production wellhead. Given the small volume of gas, the unmonitored effluents would not be expected to exceed 30% of the total estimated effluent releases.

B. Regarding spills, is the assumption that all radon in the spilled production fluid is released (100%) or is a smaller amount assumed?

Crow Butte Response

The assumption will be that all of the radon contained in the spilled fluid is released to the atmosphere.

11.11(B) "Evaluate the member(s) of the public likely to receive the highest exposures from licensed operations consistent with 10 CFR 20.1302".

The Addendum to this document contains a description of MILDOS-Area modelling performed to determine the member of the public likely to receive the maximum dose. In summary, the assessment of receptor doses considered both actual and potential receptors. The actual receptors included local residents, including the nearest resident located approximately 1000 m north-east of the main plant. Potential receptors were members of the public who may be at or near the site for greater than 50 hours per year and included a delivery person and ranchers performing haying or cattle related activities. For the potential receptors an estimate was made of the hours spent at or near the site.

Based on the outputs of this assessment, the member of the public likely to receive the maximum dose is the resident located approximately 1000 m to the north-east of the plant.

This assessment will be updated annually with current meteorological data, and the results compared with the previous year's reported data. If after three years the results are not statistically different, Cameco will request that the analysis be updated on a five year basis.

RAI 5:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criteria 4.1.3(5).

Basis for Request

10 CFR 20.1301(a) requires, in part, that each licensee shall conduct operations so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem in a year.

License Condition 11.2 requires, in part, that a land use survey be submitted with the licensee's analysis of the dose to individual members of the public consistent with 10 CFR 20.1301 and 10 CFR 20.1302.

NUREG-1569, Acceptance Criteria 4.1.3(5) recommends that the application demonstrates that the operations will be conducted so that all airborne effluent releases are ALARA.

In its submittal, the licensee stated that the assessment of the maximally exposed member of the public will be updated annually with current meteorological data and the results compared to the previous year's reported data. In addition, the licensee stated that if there is no statistical difference after 3 years, it will request that the analysis be updated every 5 years.

The NRC staff observes that changes in land use may result in changes to the maximally exposed member of the public.

Request for Additional Information

A. Please describe how a yearly analysis of the maximally exposed member of the public in accordance with 10 CFR 20.1301 would be performed, taking into account potential land use changes, on a proposed five-year update schedule.

Crow Butte Response

A land use survey will be conducted annually in accordance with LC 11.2 and if there is a significant change in public occupation around the permitted area this change will be evaluated to ensure that the dose calculated annually is to the maximally exposed member of the public.

B. Please provide detail on what current meteorological data will be used for the annual updates.

Crow Butte Response

The current met data (data from the year that is represented by the annual report) that is required for the MILDOS calculation will be used.

11.11(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".

In 10 CFR 20.1302 (1), the regulation states that it is acceptable to show compliance to public dose limits by demonstrating by measurement or calculation that the total effective dose equivalent to the individual most likely to receive the highest dose from the licensed operation does not exceed the annual dose limit. In the response to condition 11.11(B), the Edelman resident was identified as the member of the public likely to receive the maximum dose. CBO will show compliance to this requirement for this receptor through one of the following two methods outlined below.

The first method is to perform a dose assessment using measured effluent concentrations at a monitoring location positions 30 m from the residence of the maximum receptor. In regards to radon and radon progeny dose, the dose assessment will be performed using the following equation:

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

Where:

D = annual dose (TEDE) (mrem/year)

DCF = dose conversion factor for Rn-222 with 100% equilibrium factor with its progeny from 10 CRF 20 Appendix B - 500 mrem/hr per pCi Rn/L

C_i = annual average concentration of Rn-222 in air (pCi/L) at the receptor location

F_i = radon equilibrium factor at the receptor

T_i = occupancy factor for the receptor

In the event that a receptor is exposed in multiple locations, e.g. indoors and outdoors, applicable equilibrium and occupancy factors will be used for those locations. For this

receptor, currently all exposure will be assumed to be indoors as this is the most conservative assumption. If multiple exposure locations are to be used in the future, the NRC will be notified prior to this change.

Dose conversion factor was established by taking the 10 CFR 10 Appendix B, Table 2, value for radon with daughters present in air, (1×10^{-10} µCi/mL or 0.1 pCi/L). The annual dose is 50 mrem/year (0.5 mSv/year). Therefore, the dose conversion factor for radon-222 with progeny at 100% equilibrium is determined as 50 mrem/yr (0.5 mSv/year) divided by 0.1 pCi/L, or 500 mrem/year per pCi Rn/L.

The annual radon concentration at the receptor will be determined by calculating the average net radon concentration at the receptor location based on semi-annual radon-222 measurements with track etch cups. As this is a private resident, measurements indoors on private property is not a feasible alternative. In an article published by Shiager (1974), it was shown that buildings immediately adjacent to tailing piles had indoor radon concentration in equilibrium with those found outdoors. In FSME-ISG-01 draft guidance, it is stated as acceptable to assume that the indoor radon concentration due to licensee activities is equal to the outdoor concentration.

The equilibrium factor between radon and radon progeny is assumed to be 50% for indoor exposure. This value is based on Regulatory Guide 3.51 and NCRP 160 and is mentioned in FSME-ISG-01 draft guidance as an acceptable default for indoor equilibrium factor.

The actual occupancy factor for this receptor will be determined based on an assessment of actual residency time.

The alternate method involves use of the MILDOS-Area atmospheric dispersion code. As per the discussion on condition 11.11(A), measurements will be collected and release rates for radon will be determined for each source term. This information can be used as inputs to the MILDOS-Area model in order to determine a dose to this receptor.

RAI 6:

Description of Deficiency

The staff cannot complete its evaluation of the licensee's proposed methodology for factoring in radon-222 (radon) progeny into analyzing potential public dose from operations consistent with 10 CFR 20.1302.

Basis for Request

10 CFR 20.1301(a) requires, in part, that each licensee shall conduct operations so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem in a year.

A year is defined in 10 CFR 20.1003 as the period of time beginning in January used to determine compliance with 10 CFR Part 20.

The licensee state that the annual radon concentration at the receptor will be determined by calculating the average net radon concentration at the receptor location.

Request for Additional Information

Please describe the time period that background concentrations of radon with progeny will be collected to derive average net radon concentrations at the receptor location. If time period for the background measurements of radon with progeny is not concurrent with operational monitoring results, please provide justification for this approach.

Crow Butte Response

Background measurements are made concurrently with receptor measurements. These measurements are made on a semi-annual basis.

RAI 7:

Description of Deficiency

The staff cannot complete its evaluation of the licensee's proposed methodology for factoring in radon-222 (radon) progeny into analyzing potential public dose from operations consistent with 10 CFR 20.1302.

Basis for Request

10 CFR 20.1301(a) requires, in part, that each licensee shall conduct operations so that the total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem in a year.

The licensee stated that an alternate approach to measuring net radon concentrations at ta receptor location is to utilize release rates for radon from the facility, as discussed in its response to LC 11.11(A), and to use this information as input into the MILDOS-AREA atmospheric dispersion code to calculate a dose at a receptor location.

The NRC staff previously determined (NRC, 2014a, 2014b) that using calculations and models with no monitoring results to support either is not sufficient to demonstrate compliance with public dose limits.

In addition, the NRC staff observes that FSME Interim Staff Guidance FSME-ISG-01, *Evaluation of Uranium Recovery Facility Surveys of Radon and Radon Progeny in Air and Demonstrations of Compliance with 10 CFR 20.1301,* Revised Draft Report for Comment (NRC, 2014c) recommends that when radon is measured at release points and a model is used to calculate a dose to a receptor that "...NRC staff should ensure that the licensee has measured (or licensee commits to measuring) radon or radon progeny in air to provide validation that regulatory limits are not exceeded."

Request for Additional Information

Please provide a description of measurements of radon or radon progeny in air to ensure the dose to members of the public do not exceed regulatory limits for this alternate approach.

Crow Butte Response

As mentioned in the submission, generally measurements at or near the maximally exposed member of the public will be used to estimate annual dose. However, if modeling is performed for calculation of dose to the maximally exposed member of the public; measured emissions will be used as an input to the MILDOS-Area model and the outputs compared statistically to the measurements made at the environmental monitoring stations to confirm the reasonableness of the model results.

In response to 11.11(A), Crow Butte indicated that measurements of the radon from tank vents will be performed at a minimum of once a quarter. Samples will be taken during highest predicted concentrations and will be used to determine the effluent of radon from vented tanks. To evaluate the conditions that would represent the highest concentration of radon in the vents, samples will be collected during different stages of the tank's operation. However, measurement of the maximum emission rate is not indicative of actual annual emissions and by definition will overestimate annual emissions; potentially by a significance amount. As such measurements of the maximum emissions rate are not

generally useful for modelling purposes. Field measurements made with a track etch cup are integrated measurements that average the radon concentration over the entire monitoring period. There is a reasonable probability that use of a maximum emission rate as a model input will produce model outputs that are overestimated and cannot be confirmed though measurement because the input will be overestimated.

Crow Butte operation will investigate the impact of using maximum emissions rates in modelling and, prior to use of calculations to determine public dose, will provide NRC with a proposal regarding how the inputs to the model will be determined using actual measurements.

11.11(D) "Discuss how, in accordance with 10 CFR 20.1501, the occupational dose (gaseous and particulate) received throughout the entire License Area from licensed operations will be accounted for, and verified by, survey and/or monitoring".

In accordance with 10 CFR 20.1501 occupational doses will be accounted for, and verified, through monitoring of exposures from (1) radon daughters, (2) airborne particulate radionuclides, and (3) external radiation. The monitoring methods will be in accordance with NRC Regulatory Guide 8.30.

Exposure to Radon and Its Daughters

The method of measurement for radon daughters is the modified Kusnetz method. The modified Kusnetz method samples are collected and analyzed as described in NRC Regulatory Guide 8.30 and at locations and frequencies described in Section 5.8.3.2 of the License Renewal Application (LRA). Inside the Main Plant, monitoring locations are selected based on an air flow study and knowledge of the locations normally occupied by the plant personnel. Additionally, wellhouses and deep disposal well (DDW) buildings will be sampled at least quarterly using the modified Kusnetz method.

Occupancy times for wellhouses and DDW buildings will be estimated from time studies which will be revaluated annually. Concentrations for radon and its daughters in the wellfield as well as outside of the Main Plant will be negligible compared to the dose limits for occupationally exposed workers and therefore it will not be used in the annual occupational dose assessment.

The dose from radon daughters will be calculated from the concentrations measured by the modified Kusnetz method, expressed as working levels and exposure times. The procedures used to calculate these doses and the methods of record keeping are described

more fully in Section 5.8.4 of the LRA and in the Crow Butte Standard Operation Procedures (SOP).

Airborne particulate radionuclide concentrations will be calculated based on routine air sampling of representative Wellhouses, DDW buildings, and Main Plant. Analysis of air sampling filters within the Main Plant and the Wellhouses for U-^{nat}, Th^{230}, Ra^{226}, and Pb^{210} will be performed on a semi-annual basis. Exposures assigned to the individual from particulates will be based on the results of the air particulate sampling program and the occupancy times. Non-routine work will be performed under a Radiation Work Permit (RWP) and based on the circumstances either area air particulate samples or breathing zone samples will be collected. Exposures during non-routine work will be determined from the results of the air particulate samples and the time of exposure. During some activities Personnel Protection Equipment (PPE) will be used to reduce the exposure to the employees and the appropriate protection factor will be used to calculate the actual exposure.

The procedures used to calculate exposures to airborne radionuclides and the methods of record keeping are described more fully in Section 5.8.4 of the LRA and in the Crow SOPs.

External radiation exposure will be determined by personal dosimetry or, if not issued, then as work group dose. Each work group will have at least one person assigned external monitoring dosimetry and high risk work groups, such as plant operators, will have all individuals assigned personal dosimetry. The methods of monitoring exposure to external radiation and the methods of record keeping are described more fully in Section 5.8.4 of the LRA and in the Crow Butte SOPs.

Total occupational dose or Total Effective Dose Equivalent (TEDE) to individuals will be the sum of exposures from (1) radon daughters, (2) airborne particulate radionuclides, and (3) external radiation. Occupancy factors for each area will be assigned for each work group (i.e. operators, wellfield workers, maintenance). Work performed under Radiation Work Permits will be monitored separately from the routine sampling program and the concentrations will be included in the TEDE calculation. Results will be reported to employees on an annual basis as required and summarized in the semi-annual effluent report.

RAI 8:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criterion 5.7.4.3(1) for radon releases from the main plant.

Basis for Request

Regarding the determination of occupational dose, the requirements in 10 CFR 20.1204 specify, in part, that a licensee shall "...take suitable and timely measurements of:

(1) Concentrations of radioactive materials in air in work areas; or
(2) Quantities of radionuclides in the body; or
(3) Quantities of radionuclides excreted from the body; or
(4) Combinations of these measurements.

In addition, the requirements of 10 CFR 20.1501 specify, in part, that a licensee "...shall make or cause to be made, surveys of areas, including the subsurface, that –

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Are reasonable under the circumstances to evaluate –

(i) The magnitude and extent of radiation levels; and
(ii) Concentrations of quantities of residual radioactivity; and
(iii) The potential radiological hazards of the radiation levels and residual radioactivity detected."

In its response to LC 11.11(D), the licensee stated that "Concentrations for radon and its daughters in the wellfield as well as outside of the Main Plant will be negligible compared to the dose limits for occupationally exposed workers and therefore it will not be used in the annual occupational dose assessment."

Request for Additional Information

Please provide measurements of concentrations for radon and its daughters in the wellfield and outside the Main Plant or an analysis to justify disregarding this potential occupational exposure pathway.

Crow Butte Response

All wellfield operations personnel participate in the monitoring program, which includes monitoring for internal and external exposure. The external exposure is monitored with

OSL badges provided by Landauer and exchanged on a quarterly frequency. The badges are worn for an employee's entire shift. Since it is difficult to sample all areas of the wellfield accurately, the internal exposures for the wellfield operations personnel are based on the same plant concentrations at a 100% occupancy factor. Wellfield concentrations of both radon daughters and airborne uranium will be much lower than plant concentrations so this is a very conservative way to assign internal intake.

RAI 9:

Description of Deficiency

The staff cannot complete its evaluation of NUREG-1569, Acceptance Criterion 5.7.4.3(1) for potential particulate releases from the main plant.

Basis for Request

The requirements in 10 CFR 20.1204 provide conditions whereby a licensee may disregard certain radionuclides when a mixture of radionuclides exists in air.

LC 10.8 requires the licensee, in part, to "...conduct isotopic analyses for alpha- and beta- emitting radionuclides on airborne samples at each in-plant air 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)."

In its response to LC 11.11(D), the licensee stated that air sampling filters within the main plant and wellhouses will be analyzed for U-nat, Th-230, Ra-226, and Pb210. The NRC staff observes that the licensee did not provide an analysis on disregarding other potential radionuclides (e.g., Th-234, Po-210) that may exist in equilibrium with other measured radionuclides in order to demonstrate compliance with 10 CFR 20.1204.

Request for Additional Information

Please provide an analysis and justification for disregarding other potential airborne particulate radionuclides that may contribute to occupational dose to demonstrate compliance with 10 CFR 20.1204.

Crow Butte Response

Semi-annually, since 2013 Cameco has been collecting samples from seven locations throughout the main plant for isotopic analysis. This data is analyzed currently for U^{-nat},

Th^{230}, Ra^{226} and Pb^{210}. In 10 CFR 20.1204 (g), it 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 10 CFR 20.1201 and in complying with the monitoring requirements in 10 CFR 20.1502(b), and

b) the concentration of any radionuclide disregarded is less than 10% 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 U^{-nat}, Th^{230}, Ra^{226} and Pb^{210}. The purpose of this sampling was to determine if the concentrations of these radionuclides are below 10% of their respective DACs in the facility and the sum of these percentages for any disregarded radionuclides is below 30%. The DAC for Class W Th^{230} (which is lower than Class Y), is $3x10^{-12}$ µCi/ml. To meet the DAC requirement, Th^{230} must be present at less than a concentration of $3x10^{-13}$ µCi/ml. Similarly, Ra^{226} must be present at concentration less than $3x10^{-11}$ µCi/ml, which is 10% of its DAC of $3x10^{-10}$ µCi/ml, and Pb^{210} 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 U^{-nat} as solubility studies performed for both the Crow Butte and Smith Ranch-Highland operations have demonstrated that the uranium is of class D solubility.

Crow Butte has collected five sample sets, two in each of 2013 and 2014 and one in 2015, consisting of 7 samples each; five from the routine sampling locations and two from additional locations within the plant. Samples were collected using a high-flow pump run for approximately one week, with particulate collected on a 47mm filter. The laboratory data used in this analysis is included in Appendix A.

For each isotope the average concentration was calculated using samples from all in-plant locations. If a value was reported by the laboratory as being below the LLD, a value of one half the LLD was used in the calculation of the average. The background concentration for this time interval for each radionuclide has not been subtracted but is available. Finally, the average was compared with the DAC values from 10 CFR 20. The following table presents the analysis of the in-plant isotopic samples collected at the Crow Butte operation.

Isotopic Analysis of Airborne Dust Samples at Crow Butte

Year	U^{-nat} (µCi/ml)	Th^{230} (µCi/ml)	Ra^{226} (µCi/ml)	Pb^{210} (µCi/ml)
2013	2.57E-13	5.39E-16	1.63E-15	3.51E-14
2014	2.48E-13	8.14E-16	1.76E-15	1.27E-13
2015	7.14E-13	1.29E-16	2.40E-15	3.00E-14
Average	5.00E-10	3.00E-12	3.00E-10	1.00E-10
Percent of DAC	0.071%	0.019%	0.001%	0.073%

As shown in the table, all of the isotopes analyzed were present in concentrations significantly below 10% of their respective DACs. In addition, the sum of the DAC percentage from Th^{230}, Ra^{226} and Pb^{210} combined is significantly less than 1% thus meeting the criteria of being less than 30%. Therefore; these three radionuclides can be disregarded from the determination of internal dose under 10 CFR 20.1204(g).

The NRC staff also raised the question of addressing dose from the decay products of U^{238}, specifically Th^{234} and Po^{210}. Because of the very short half-life of Th^{234}, the need to factor in ingrowth and high LLDs, a lab analysis is not a reasonable option; therefore, a theoretical calculation has been performed assuming equilibrium with its parent U^{238}. U^{238} contributes 49% of the specific activity of U^{-nat} and Th^{234} will be assumed to be in equilibrium at the time of inhalation with U^{238}. The following table shows the calculated U^{238} activity based on the measured average U^{-nat} activity for 2013 through 2015, and a comparison of the Th^{234} activity to the DAC from 10 CFR 20.

Comparison of Th^{234} to the DAC

Year	Average of Uranium (µCi/ml)	Th^{234} Activity (µCi/ml)	DAC (µCi/ml)	Percent of DAC
2013	2.57E-13	1.26E-13	6.00E-08	0.00021%
2014	2.48E-13	1.22E-13	6.00E-08	0.00020%
2015	7.14E-13	3.50E-13	6.00E-08	0.00058%

A similar calculation has been performed for Po^{210}, using Pb^{210} as the parent radionuclide. Full equilibrium between Pb^{210} and Po^{210} has been assumed and as mentioned, the Pb^{210} has not been background corrected, so it is a conservative value.

Comparison of Po^{210} to the DAC

Year	Average of Pb^{210} (µCi/ml)	Po^{210} Activity (µCi/ml)	DAC (µCi/ml)	Percent of DAC
2013	3.51E-14	3.51E-14	3.00E-10	0.01%
2014	1.27E-13	1.27E-13	3.00E-10	0.04%
2015	3.00E-14	3.00E-14	3.00E-10	0.01%

As with the other radionuclides discussed previously, Th^{234} and Po^{210} are below the criteria in 10 CFR 20.1204(g) and can be disregarded. The internal dose from airborne particulates, will continue to be assessed based on the total alpha activity present compared with the DAC and ALI values for natural uranium. Due to the fact Crow Butte is a long running operations and the particulate concentrations are substantially below the criteria in 10 CFR 20.1204(g), Crow Butte proposes that going forward in-plant isotopic analysis be performed only once per license term in order to confirm that no changes have occurred.

Administrative Issues

License Condition 11.11(C)

1. The member of the public likely to receive the maximum dose is referred to as the Edelman resident. In Section 3 of the Addendum to the submittal, the maximum receptor dose is referred to as "#27 (Gibbons)". Please clarify if these receptors are referring to the same resident.

Crow Butte Response

During the 2014 land use survey it was identified that a new residence had been built near the permit area (Edelman). Beginning January 1, 2015 an air monitoring station was located near this residence to begin monitoring for the "nearest residence".

Addendum

2. In Table 2.1-1, the value of 3E-12 (W) is provided for the Thorium-230 entry for "10 CFR 20 Effluent Concentration". However, this appears to be the value for the Derived Air Concentration (DAC) and the correct 10 CFR 20, Appendix B, Table 2, Effluent Concentration value appears to be 2E-14. Please confirm the correct value.

Crow Butte Response

The value in Table 2.1-1 for the Thorium-230 should be 2E-14 (W). A revised page to this addendum is included with this submittal.

3. In Section 2.1, a comparison is made between the airborne particulate concentrations measured at environmental monitoring stations AM1, AM2, and AM3 with the effluent concentration values in 10 CFR 20, Appendix B, Table 2. Please provide a description of how these environmental monitoring station results, located at a distance from the source, are used to infer the vacuum dryer particulate source term.

Crow Butte Response

Below is Table 2.1-1 with AM24 and AM25 data.

Airborne Particulate Concentrations for 2013 Above Background				
	Uranium (µCi/ml)	Radium 226 (µCi/ml)	Lead-210 (µCi/ml)	Thorium-230
AM6 (background)	1E-16	1E-16	2E-14	1E-16
10 CFR 20 Effluent Concentration	9E-14 (D)	9E-13	6E-13	2E-14 (W)
AM1	0	0	0	0
AM2	1E-16	0	0	0
AM3	0	0	0	0
AM24 (200 feet North of Plant)	3E-16	0	0	0
AM25 (200 feet South of Plant)	3E-16	0	0	0

Environmental monitoring stations AM24 and AM25 are located near the central processing plant and show a uranium concentration that is <0.1% below the 10 CFR 20 Effluent Concentration for airborne uranium particulate.

By letter dated May 27, 2015, (received June 10, 2015) the U.S. Nuclear Regulatory Commission (NRC) staff requested Crow Butte's rationale behind not responding to these RAI's earlier than July 1, 2015.

Crow Butte Response

Crow Butte has made numerous attempts over the past several years to resolve these issues with the NRC staff. Knowing that this would be a topic discussed with the uranium mining industry at the National Mining Association meeting held June 8 and 9, 2015, it was Crow Butte's hope that the NRC staff would provide additional information to the industry on how to address these issues.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 122.

Sincerely,

Bob Tiensvold
Mine Manager

Enclosure

cc: Deputy Director
Division of Decommissioning
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T-8F5
11545 Rockville Pike
Two White Flint North, Rockville, MD 20852-2738

CBO- File

ec: CR-Casper

Appendix A

Isotopic Laboratory Data

Inter-Mountain Labs
Your Environmental Monitoring Partner
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Belt Filter Room

Lab ID S1307208-002 **Sample Air Volume: 523187 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	<2		<2E-15		2E-15	1 E-10	Day	0
Radium 226	0.7	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	215		4E-13		1E-16	2 E-11	Year	2.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Dryer Change Room

Lab ID S1307208-001 **Sample Air Volume: 530998 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	<2		<2E-15		2E-15	1 E-10	Day	0
Radium 226	0.4	0.1	7E-16	2E-16	1E-16	3 E-10	Week	0.00023
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	62.7		1E-13		1E-16	2 E-11	Year	0.50

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: R.O. Building

Lab ID S1307208-004 **Sample Air Volume: 585083 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	77.5	5.1	1E-13	9E-15	2E-15	1 E-10	Day	0.10
Radium 226	0.6	0.2	1E-15	3E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.4	0.2	7E-16	3E-16	1E-16	6 E-12	Year	0.012
Uranium	1.4		2E-15		1E-16	2 E-11	Year	0.010

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Tall White Tanks

Lab ID S1307208-003 **Sample Air Volume: 591199 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	55.9	4.5	1E-13	8E-15	2E-15	1 E-10	Day	0.10
Radium 226	1.3	0.2	2E-15	3E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.3	0.2	5E-16	3E-16	1E-16	6 E-12	Year	0.0083
Uranium	643		1E-12		1E-16	2 E-11	Year	5.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Below Thickener Tank

Lab ID S1306269-002 **Sample Air Volume: 617166 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	7.5	2.9	1E-14	5E-15	2E-15	1 E-10	Day	0.010
Radium 226	0.9	0.2	2E-15	3E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	129		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Between IX Trains

Lab ID S1306269-001 **Sample Air Volume: 321651 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	10.7	3.0	3E-14	9E-15	2E-15	1 E-10	Day	0.030
Radium 226	0.8	0.2	3E-15	6E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	22.8		7E-14		1E-16	2 E-11	Year	0.35

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Precip B

Lab ID S1306269-003 **Sample Air Volume: 520605 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	10.8	2.9	2E-14	6E-15	2E-15	1 E-10	Day	0.020
Radium 226	0.8	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.3	0.2	6E-16	4E-16	1E-16	6 E-12	Year	0.010
Uranium	81.3		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Belt filter Room

Lab ID S1312088-003 **Sample Air Volume: 473825.79 Liters**
Sampled 11/4/13 9:04- 11/11/13 8:13 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	16.8	2.9	4E-14	6E-15	2E-15	1 E-10	Day	0.040
Radium 226	1.0	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.6	0.2	1E-15	4E-16	1E-16	6 E-12	Year	0.017
Uranium	474		1E-12		1E-16	2 E-11	Year	5.0

Lab ID S1307208-002 **Sample Air Volume: 523187 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	1.0	2.0	<2E-15		2E-15	1 E-10	Day	0
Radium 226	0.7	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	215		4E-13		1E-16	2 E-11	Year	2.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Dryer Change Room

Lab ID S1312088-002 **Sample Air Volume: 413425.96 Liters**
Sampled 10/29/13 7:35- 11/4/13 8:56 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	7.1	2.3	2E-14	6E-15	2E-15	1 E-10	Day	0.020
Radium 226	<0.3		<1E-16		1E-16	3 E-10	Week	0
Thorium 230	0.2	0.1	5E-16	2E-16	1E-16	6 E-12	Year	0.0083
Uranium	48.9		1E-13		1E-16	2 E-11	Year	0.50

Lab ID S1307208-001 **Sample Air Volume: 530998 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	1.0	2.0	<2E-15		2E-15	1 E-10	Day	0
Radium 226	0.4	0.1	7E-16	2E-16	1E-16	3 E-10	Week	0.00023
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	62.7		1E-13		1E-16	2 E-11	Year	0.50

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: R.O. Building

Lab ID S1312088-005 **Sample Air Volume: 476204.41 Liters**
Sampled 11/18/13 8:36- 11/25/13 7:39 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	24.7	3.1	5E-14	7E-15	2E-15	1 E-10	Day	0.050
Radium 226	1.5	0.2	3E-15	4E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	1.6	0.4	3E-15	8E-16	1E-16	6 E-12	Year	0.050
Uranium	2.6		5E-15		1E-16	2 E-11	Year	0.025

Lab ID S1307208-004 **Sample Air Volume: 585083 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	77.5	5.1	1E-13	9E-15	2E-15	1 E-10	Day	0.10
Radium 226	0.6	0.2	1E-15	3E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.4	0.2	7E-16	3E-16	1E-16	6 E-12	Year	0.012
Uranium	1.4		2E-15		1E-16	2 E-11	Year	0.010

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Precip B

Lab ID S1312088-001 **Sample Air Volume: 482660.665 Liters**

Sampled10/21/13 8:15- 10/28/13 8:05 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	13.0	2.5	3E-14	5E-15	2E-15	1 E-10	Day	0.030
Radium 226	<0.3		<1E-16		1E-16	3 E-10	Week	0
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	39.5		8E-14		1E-16	2 E-11	Year	0.40

Lab ID S1306269-003 **Sample Air Volume: 520605 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	10.8	2.9	2E-14	6E-15	2E-15	1 E-10	Day	0.020
Radium 226	0.8	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.3	0.2	6E-16	4E-16	1E-16	6 E-12	Year	0.010
Uranium	81.3		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Tall White Tanks

Lab ID S1312088-004 **Sample Air Volume: 471305.59 Liters**
Sampled 11/11/13 8:19- 11/18/13 8:06 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	25.9	3.1	6E-14	7E-15	2E-15	1 E-10	Day	0.060
Radium 226	0.7	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	380		8E-13		1E-16	2 E-11	Year	4.0

Lab ID S1307208-003 **Sample Air Volume: 591199 Liters**
First Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	55.9	4.5	1E-13	8E-15	2E-15	1 E-10	Day	0.10
Radium 226	1.3	0.2	2E-15	3E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.3	0.2	5E-16	3E-16	1E-16	6 E-12	Year	0.0083
Uranium	643		1E-12		1E-16	2 E-11	Year	5.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Below Thickener Tank

Lab ID: S1311004-002 **Sample Air Volume: 748839.01 Liters**

Sampled 9/16/13 10:23- 9/23/13 7:39 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	6.9	2.4	9E-15	3E-15	2E-15	1 E-10	Day	0.0090
Radium 226	2.5	0.3	3E-15	4E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	0.2	0.2	3E-16	3E-16	1E-16	6 E-12	Year	0.0050
Uranium	14.2		2E-14		1E-16	2 E-11	Year	0.10

Lab ID: S1306269-002 **Sample Air Volume: 617166 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	7.5	2.9	1E-14	5E-15	2E-15	1 E-10	Day	0.010
Radium 226	0.9	0.2	2E-15	3E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	129		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Between IX Trains

Lab ID: S1311004-001 **Sample Air Volume: 488692.14 Liters**

Sampled 9/16/13 10:23- 9/23/13 7:39 Semi-Annual 2nd Half 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	7.6	2.5	2E-14	5E-15	2E-15	1 E-10	Day	0.020
Radium 226	0.9	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	7.4		2E-14		1E-16	2 E-11	Year	0.10

Lab ID: S1306269-001 **Sample Air Volume: 321651 Liters**

Semi-Annual In Plant Isotopic Air Samples First Half, 2013

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	10.7	3.0	3E-14	9E-15	2E-15	1 E-10	Day	0.030
Radium 226	0.8	0.2	3E-15	6E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	<0.2		4E-16	3E-16	1E-16	6 E-12	Year	0.0067
Uranium	22.8		7E-14		1E-16	2 E-11	Year	0.35

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

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1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Below Thickener Tank

Lab ID S1407191-007 **Sample Air Volume: 398984 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	329	11.6	8E-13	3E-14	2E-15	1 E-10	Day	0.80
Radium 226	0.4	0.1	1E-15	3E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	72.3		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Belt Filter Room #2

Lab ID S1407191-005 **Sample Air Volume: 609973 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	58.3	5.3	1E-13	9E-15	2E-15	1 E-10	Day	0.10
Radium 226	1.9	0.3	3E-15	5E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	1110		2E-12		1E-16	2 E-11	Year	10

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Between IX Trains

Lab ID S1407191-006 **Sample Air Volume: 449247 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	13.4	3.3	3E-14	7E-15	2E-15	1 E-10	Day	0.030
Radium 226	0.5	0.1	1E-15	2E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.4	0.2	9E-16	5E-16	1E-16	6 E-12	Year	0.015
Uranium	26.6		6E-14		1E-16	2 E-11	Year	0.30

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Inside Dryer Change Room

Lab ID S1407191-003 **Sample Air Volume: 489995 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	28.7	4.1	6E-14	8E-15	2E-15	1 E-10	Day	0.060
Radium 226	2.6	0.7	5E-15	1E-15	1E-16	3 E-10	Week	0.0017
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	97.6		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: R.O Building

Lab ID S1407191-004 **Sample Air Volume: 299989 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	12.5	3.4	4E-14	1E-14	2E-15	1 E-10	Day	0.040
Radium 226	1.5	0.4	5E-15	1E-15	1E-16	3 E-10	Week	0.0017
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	1.0		4E-15		1E-16	2 E-11	Year	0.020

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Precip B

Lab ID S1407191-008 **Sample Air Volume: 529610 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	20.9	4.5	4E-14	9E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.7	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.6	0.3	1E-15	6E-16	1E-16	6 E-12	Year	0.017
Uranium	46.9		9E-14		1E-16	2 E-11	Year	0.45

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Tall White Tanks

Lab ID S1407191-002 **Sample Air Volume: 486026 Liters**

Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	203	9.2	4E-13	2E-14	2E-15	1 E-10	Day	0.40
Radium 226	0.6	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	351		7E-13		1E-16	2 E-11	Year	3.5

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Inter-Mountain Labs
Your Environmental Monitoring Partner
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Below Thickener Tank

Lab ID S1412327-006 **Sample Air Volume: 460362 Liters**
Sampled 11/3/2014-11/10/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	24.3	4.2	5E-14	9E-15	2E-15	1 E-10	Day	0.050
Radium 226	0.4	0.1	9E-16	2E-16	1E-16	3 E-10	Week	0.00030
Thorium 230	1.0	1.4	2E-15	3E-15	1E-16	6 E-12	Year	0.033
Uranium	61.8		1E-13		1E-16	2 E-11	Year	0.50

Lab ID S1407191-007 **Sample Air Volume: 398984 Liters**
Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	329	11.6	8E-13	3E-14	2E-15	1 E-10	Day	0.80
Radium 226	0.4	0.1	1E-15	3E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	72.3		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Belt Filter Room

Lab ID S1412327-001 **Sample Air Volume: 461375 Liters**

Sampled 11/24/2014-12/1/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	12.7	4.2	3E-14	9E-15	2E-15	1 E-10	Day	0.030
Radium 226	0.6	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	3.2	2.8	7E-15	6E-15	1E-16	6 E-12	Year	0.12
Uranium	6.5		1E-14		1E-16	2 E-11	Year	0.050

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Between IX Trains

Lab ID S1412327-005 **Sample Air Volume: 429765 Liters**
Sampled 10/27/2014-11/3/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	25.1	4.9	6E-14	1E-14	2E-15	1 E-10	Day	0.060
Radium 226	0.9	0.2	2E-15	5E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.3	0.2	6E-16	5E-16	1E-16	6 E-12	Year	0.010
Uranium	60.1		1E-13		1E-16	2 E-11	Year	0.50

Lab ID S1407191-006 **Sample Air Volume: 449247 Liters**
Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	13.4	3.3	3E-14	7E-15	2E-15	1 E-10	Day	0.030
Radium 226	0.5	0.1	1E-15	2E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.4	0.2	9E-16	5E-16	1E-16	6 E-12	Year	0.015
Uranium	26.6		6E-14		1E-16	2 E-11	Year	0.30

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Inside Dryer Change Room

Lab ID S1412327-003 **Sample Air Volume: 465059 Liters**
Sampled 11/10/2014-11/17/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	29.8	6.3	6E-14	1E-14	2E-15	1 E-10	Day	0.060
Radium 226	0.5	0.1	1E-15	2E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		3E-16	2E-16	1E-16	6 E-12	Year	0.0050
Uranium	52.3		1E-13		1E-16	2 E-11	Year	0.50

Lab ID S1407191-003 **Sample Air Volume: 489995 Liters**
Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	28.7	4.1	6E-14	8E-15	2E-15	1 E-10	Day	0.060
Radium 226	2.6	0.7	5E-15	1E-15	1E-16	3 E-10	Week	0.0017
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	97.6		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: R.O. Building

Lab ID S1412327-004 **Sample Air Volume: 465519 Liters**

Sampled 12/8/2014-12/15/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	17.7	4.2	4E-14	9E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.4	0.1	8E-16	2E-16	1E-16	3 E-10	Week	0.00027
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	<0.3		<1E-16		1E-16	2 E-11	Year	0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Precip B

Lab ID S1412327-007 **Sample Air Volume: 464506 Liters**
Sampled 12/1/2014-12/8/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	13.9	5.5	3E-14	1E-14	2E-15	1 E-10	Day	0.030
Radium 226	0.4	0.1	1E-15	2E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	4.1		9E-15		1E-16	2 E-11	Year	0.045

Lab ID S1407191-008 **Sample Air Volume: 529610 Liters**
Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	20.9	4.5	4E-14	9E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.7	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	0.6	0.3	1E-15	6E-16	1E-16	6 E-12	Year	0.017
Uranium	46.9		9E-14		1E-16	2 E-11	Year	0.45

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Tall White Tanks

Lab ID S1412327-002 **Sample Air Volume: 467499 Liters**
Sampled 11/17/2014-11/24/2014 (Second half 2014)

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	19.6	3.6	4E-14	8E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.4	0.1	9E-16	2E-16	1E-16	3 E-10	Week	0.00030
Thorium 230	<0.2		2E-16	4E-16	1E-16	6 E-12	Year	0.0033
Uranium	187		4E-13		1E-16	2 E-11	Year	2.0

Lab ID S1407191-002 **Sample Air Volume: 486026 Liters**
Sampled 1/1/14 - 6/30/14 Semi-Annual First Half 2014

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	203	9.2	4E-13	2E-14	2E-15	1 E-10	Day	0.40
Radium 226	0.6	0.2	1E-15	4E-16	1E-16	3 E-10	Week	0.00033
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	351		7E-13		1E-16	2 E-11	Year	3.5

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

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Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Below Thickener Tank

Lab ID S1505143-006 **Sample Air Volume: 416566.8 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	23.8	4.5	6E-14	1E-14	2E-15	1 E-10	Day	0.060
Radium 226	2.0	0.3	5E-15	7E-16	1E-16	3 E-10	Week	0.0017
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	66.5		2E-13		1E-16	2 E-11	Year	1.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Belt Filter Room

Lab ID S1505143-001 **Sample Air Volume: 484387.2 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	9.4	3.6	2E-14	7E-15	2E-15	1 E-10	Day	0.020
Radium 226	1.5	0.3	3E-15	6E-16	1E-16	3 E-10	Week	0.0010
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	2080		4E-12		1E-16	2 E-11	Year	20

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Between IX Trains

Lab ID S1505143-005 **Sample Air Volume: 438503.6 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	15.2	4.0	4E-14	9E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.6	0.2	2E-15	5E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	34.4		8E-14		1E-16	2 E-11	Year	0.40

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Inside Dryer Change Room

Lab ID S1505143-003 **Sample Air Volume: 494026.2 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	7.7	3.5	2E-14	7E-15	2E-15	1 E-10	Day	0.020
Radium 226	0.8	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	45.4		9E-14		1E-16	2 E-11	Year	0.45

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: R.O. Building

Lab ID S1505143-004 **Sample Air Volume: 397652.6 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	5.3	3.6	1E-14	9E-15	2E-15	1 E-10	Day	0.010
Radium 226	0.7	0.2	2E-15	5E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	0.2	0.2	6E-16	5E-16	1E-16	6 E-12	Year	0.010
Uranium	0.5		1E-15		1E-16	2 E-11	Year	0.0050

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of Precip B

Lab ID S1505143-007 **Sample Air Volume: 438213.6 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	8.1	3.4	2E-14	8E-15	2E-15	1 E-10	Day	0.020
Radium 226	0.4	0.2	8E-16	5E-16	1E-16	3 E-10	Week	0.00027
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	15.1		3E-14		1E-16	2 E-11	Year	0.15

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Air Filter Summary Report

Client: Cameco Resources, Crow Butte Operation

Client Sampler ID: Top of White Tanks

Lab ID S1505143-002 **Sample Air Volume: 520106.4 Liters**

Semi-Annual In Plant Isotopic Samples 1st half 2015

Analyte	Result pCi/filter	Precision ± pCi/filter	Result µCi/ml	Precision ± µCi/ml	RL	10 CFR Pt 20 Occupational Limit	Effluent Class	% DAC Conc.
Lead 210	20.5	4.7	4E-14	9E-15	2E-15	1 E-10	Day	0.040
Radium 226	0.8	0.2	2E-15	4E-16	1E-16	3 E-10	Week	0.00067
Thorium 230	<0.2		<1E-16		1E-16	6 E-12	Year	0
Uranium	329		6E-13		1E-16	2 E-11	Year	3.0

Effluent Limits are from 10 CFR Part 20 Appendix B Table 2

ND - Not Detected at the Reporting Limit

Tank Vent Locations and Piping

Table 2.1-1 Revision

As with the production down-flow circuit, the majority of the restoration circuit is closed and under pressure, and radon release can only occur at certain points. Opening of bleed valves to remediate pressurized wells is the only potential release mechanism in the wellfields. In the restoration building, radon will periodically be released from the columns when the loaded resin is transferred to the elution columns. Radon will also be released from the RO waste water. The RO waste water will be stored in the deep disposal feed tank before deep injection, during which it will release radon gas.

2.0 Model inputs and assumptions

2.1 General Information

The primary radionuclides of interest from this model are radon gas (Rn-222) and radon progeny (Po-218, Pb-214 and Bi-214), however MILDOS also calculates dose from Pb-210 and Po-210 as well. These radionuclides are part of the U-238 decay series and this decay series is assumed to be the primary source of exposure because the contribution of the U-235 decay series is less than 5% of that from the U-238 series. Primary release mechanisms for radon gas from the circuit have been discussed in the previous section. NRC's recommendation that for modern, low temperature vacuum driers the particulate release is essentially zero, as stated in NUREG 1910 (USNRC 2009), has been adopted for this model. As shown in Table 2.1-1, measurements of airborne particulate collected to date demonstrate that uranium concentrations at our environmental monitoring stations are comparable to or below background concentrations and provide basis for use of this assumption.

Table 2.1- 1: Airborne Particulate Concentrations for 2013 Above Background

	Uranium (µCi/ml)	Radium 226 (µCi/ml)	Lead-210 (µCi/ml)	Thorium-230
AM6 (background)	1E-16	1E-16	2E-14	1E-16
10 CFR 20 Effluent Concentration	9E-14 (D)	9E-13	6E-13	2E-14 (W)
AM1	0	0	0	0
AM2	1E-16	0	0	0
AM3	0	0	0	0

The transport of modelled radiological emissions from the sources is predicted using a sector-averaged Gaussian plume dispersion model. The dispersion model uses the meteorological data provided by the user and also includes mechanisms of dry deposition of particulates, re-suspension, radioactive decay and progeny in-growth and plume reflection. Deposition build-up and in-growth of radioactive progeny are considered in estimating ground concentrations.

2.2 Source Term Calculations

The radionuclide releases from the Crow Butte operation have been determined for each source of emissions. Sources addressed in this model are the wellfields, specifically the emissions from header houses and well heads resulting from venting, up-flow IX columns, down-flow IX columns and the reverse osmosis plant. These sources include emissions from both production and restoration activities. The locations of these sources have been defined within the MILDOS model based on Cartesian

Floor Exhaust Vent Fan

Tank Vent Number

Vent Intake and Duct Work

TANK VENT LOCATIONS

1 - West IX Blower
2 - East IX Blower
3 - Eluant Blower
4 - Waste Blower
5 - Bicarb Mix Tank Blower
6 - Column Drain Blower
7 - Precip Tank Blower
8 - Precip A Tank Blower
9 - Resin Cleaning Blower

Floor Exhaust Vent Fan
Man - Door
Lifting - Doors
PR-1
PR-2
PR-3
TK-001
TK-002
TK-003
TK-004
IX-001
IX-002
IX-003
DEEP WELL RESERVE #2
Plant RO (100 gpm)
CIP Tank
MCC & PLC Panels Pad
Anti -Scalant Skid
RO Pre-Filters Skid
HYDROGEN PEROXIDE
CAUSTIC
SALT
SODIUM BICARB
SODA ASH
BERM
HCL
HCL
Floor Exhaust Vent Fan
Double Doors
Floor Exhaust Vent Fan
Man - Door
IJF #4
IJF #3
IJF #2
IJF #1
BARREN LIX
INJECTION
BICARB STORAGE
WASTE WATER
BARREN
INTER-MEDIATE TANK
HCL SCRUBBER
IP #1
IP #3
IP #2
IP #4
OVER FLOW
YELLOW CAKE STORAGE
DF-1
DF-2
DF-3
DF-4
DF-5
DF-6
D F STORAGE TANK
OVERHEAD DOOR
AIR COMPRESSORS
DDW #1 FILTERS
IX 6
IX 7
IX 3
IX 2
RESIN TRANSFER
PRECIP CELL C
PRECIP CELL B
PRECIP CELL A
THICKENER
FLOC
BELT FILTER & CHANGE
SLURRY
1
2
D F ELUTION
IX 5
IX 8
IX 4
IX 1
DRUM STORAGE
SEA CONTAINER
BEAD TANK
SHAKER TANK
SHAKER DEMISTER
MUNICIPAL RESIN TANK
DRYER CONDENSATE TANK
DRYER ROOM
CHANGE ROOM
COLUMN DRAIN
BACKWASH
DEEP WELL RESERVE
RAW H2O
OVERHEAD DOORS