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September 21, 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 August 18, 2015 (received August 24, 2015), the U.S. Nuclear Regulatory Commission (NRC) staff indicated that by letter dated June 30, 2015, Cameco Resources Crow Butte Operation (Cameco) submitted to the NRC the responses to an April 2, 2015 request for additional information (RAI) (ML 15090A526) addressing License Condition (LC) 11.11 of SUA-1534 providing information on Crow Butte's airborne effluent and environmental monitoring program. During the technical review of these responses, the NRC staff identified certain areas for which additional clarification is requested. Summarized below are Crow Butte's initial submittals for LC 11.11, the June 30, 2015 RAI responses, and the responses to the additional clarification requests.

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

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.

Request for Clarification – Comment 1:

NRC staff comment:

It is not clear to the NRC staff why radon daughter measurements are first converted to radon gas measurements and then the resulting calculated radon concentrations added to the actual radon gas measurements. This proposed method appears to overestimate the radon gas emissions without providing information on the radon daughter activity. It is not clear how this methodology would be used in the compliance with the reporting of effluent monitoring (e.g., 10 CFR 40.65) or for dose estimates (e.g., 10 CFR 20.1302).

In addition, this methodology does not appear to be conservative in its estimate of radon gas. For example, the formula for the radon equilibrium factor, F (refer to Section 4.9.3.2 of NRC, 2014a), is given as:

$$F = \left(\frac{\text{radon progeny concentration (WL)}}{\text{radon concentration (pCi/L)}} \right) \text{X} \left(\frac{\text{100 pCi/L}}{\text{WL}} \right)$$

Where working level, WL, is a measurement of radon progeny in air.

While assuming 100 percent equilibrium (i.e., F = 1) is generally conservative for dose calculations when the concentration of radon gas is known, this is not true for calculating the radon gas from radon daughter working level measurements. For example, if the value of the radon equilibrium factor in the equation is 50 percent (i.e., F = 0.5), the calculated radon concentration will be twice the measured radon progeny concentration.

Please provide the NRC staff with a rationale for converting radon daughter measurements to radon gas concentrations and reporting only radon gas concentrations and how this methodology will be used for compliance purposes. In your response, please justify the use of 100 percent equilibrium (i.e., F = 1) for converting the measurement of radon progeny in air to a radon gas concentration that is not conservative.

<u>Crow Butte Clarification</u>

For clarification, the response cited was answering a question specific to effluent emissions, not dose estimates. Radon daughter doses to workers are calculated according to previously approved, standard methods using radon daughter measurements in working levels.

The rationale behind the conversion from working levels to an activity concentration is that the final required value is a total effluent emission estimate; therefore the unit of the radionuclide concentration must be in a form that can be multiplied by a flow rate to determine the total emissions. It was assumed that the reported unit should be consistent with those listed in 10 CFR 20 Appendix B, (i.e. Ci). The unit of working levels cannot be multiplied directly by a flow rate to give emissions in Ci, therefore the previous submission included conversion of the working level value to an equivalent μCi/ml concentration.

When used to estimate actual radon gas concentrations from a radon progeny measurement, Crow Butte agrees that this conversion factor would not be a conservative measure and would underestimate the concentration. However, the purpose in this case is to convert the radon progeny measurement into an equilibrium equivalent concentration of radon; in other words another way of the expressing the alpha energy of the radon progeny in the air not an estimate of the actual radon. Therefore, in this context, it is an accurate factor to use. The specific description of the equilibrium equivalent concentration and justification for the calculation is provided below.

As stated in the June 30, 2015, submission, Crow Butte is calculating an equivalent concentration to use as an input to a total effluent activity calculation, not inferring the actual radon gas concentration; this follows the method from ICRP 65 (1993). As defined by ICRP 65, the potential alpha energy concentration, Cp, of any mixture of radon progeny in air is the sum of the potential alpha energy of these atoms present per unit volume of air. This can also be expressed, for any mixture of radon progeny in air, in terms of an equilibrium equivalent concentration, Ceq, of the parent nuclide, radon. In other words, Ceq is the concentration of radon in air that would be required to be present in equilibrium with its progeny to give the same alpha energy concentration in air as the non-equilibrium quantity of radon progeny that is actually present. It is not an estimate of radon gas in air, rather a way of stating the alpha energy present in air as a result of the radon progeny. The equilibrium equivalent concentration is the value that is calculated when a working level value is multiplied by the conversion factor of 3E-8 μCi/ml = 0.33 WL.

As a demonstration, equation (1) can be used to show how this conversion factor is calculated and that it is accurate.

Ceq (μCi/ml) = (RnP WL) * (20.8 μJ/m3 per WL) * (180 Bq/m3 per μJ/m3) / (37000 Bq/μCi) / (1E6 ml/m3)

Where:
RnP is the measured radon progeny concentration in working levels
20.8 μJ/m3 per WL = Cp = conversion of WL to an energy concentration in μJ/m3 (ICRP 65)
180 Bq/m3 per μJ/m3 = conversion coefficient between Cp and Ceq (ICRP 65)

If a value of 0.33 WL for RnP was used in this equation, the result would be Ceq = 3E-8 μCi/ml, which is the conversion factor referenced in our submission. Instead of applying the full equation, as a simplification, the previous submission stated that measured working levels would be multiplied by this conversion factor, i.e. Ceq = (measured WL)*(3E-8 μCi/ml per WL) to calculate the equivalent concentration.

As an additional clarification, radon progeny emissions, in Ci, may be added to radon and other particulate emissions from the facility to calculate a total effluent emissions or if required could be reported separately.

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.

Request for Clarification – Comment 2:

NRC staff comments:

The NRC staff observes that the licensee's response to this request included a drawing titled "Tank Vent Locations" that included the configuration of various tank vent intakes and ductwork as well as floor exhausts vent fans. As a separate action, the licensee also submitted a detailed study of the ventilation system at the Crow Butte facility in accordance with LC 11.14 (Cameco, 2014).

The NRC staff reviewed the licensee's responses to NRC staff's Request for Additional Information (Cameco, 2015a) and LC 11.14 (Cameco, 2014), the "Ventilation Report", together in order to understand the proposed methodology for measuring effluents at the Crow Butte facility. There appears to be inconsistencies between the RAI response (Cameco, 2015a) and the Ventilation Report (Cameco, 2014). For example, on the RAI response Figure Tank Vent Locations (Cameco, 2015a), there appears to be nine tank vent sample locations and three floor exhaust fans that discharge to the outside of the facility. On the other hand, Tables 4 and 5 of the Ventilation Report (Cameco, 2014) indicate a total of 10 tank vents, 3 box fans, 2 pipes, 1 room, and 1 unidentified duct that discharge to the outside of the facility.

Please provide clarify the relationship between the identified discharge points in RAI response Figure Tank Vent Locations (Cameco, 2015a) and the discharge points specified in Tables 4 and 5 of the Ventilation Report (Cameco, 2014). The purpose of this clarification request is to understand locations where effluents are being directed from the Crow Butte facility, in order to evaluate the licensee' effluent monitoring plan.

Crow Butte Clarification

Included is a drawing showing the tank vent connections, box fan, and exhaust pipe locations and are labeled as described in Tables 4 and 5 of the Ventilation Report (Cameco, 2014).

All tank vent locations (10) will be assessed as described in Crow Butte's response to RAI 1A.

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.

Request for Clarification

NRC staff comments:

This is a similar issue as accounting for radon from the main plant.

Please see Comment 1 for RAI 1 response for a detailed discussion of the NRC staff's comment.

Please provide the NRC staff with a rationale for converting radon daughter measurements to radon gas concentrations and reporting only radon gas concentrations and how this methodology will be used for compliance purposes. In your response, please justify the use of 100 percent equilibrium (i.e., F = 1) for converting the measurement of radon progeny in air to a radon gas concentration that is not conservative.

Crow Butte Clarification

See response to RAI 1 request for clarification comment 1.

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.

<u>RAI 4:</u>

<u>Description of Deficiency</u>

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.

Request for Clarification

NRC staff comments:

Please clarify the source of the meteorological data (i.e., location of the meteorological station used to collect the data) that will be used for the input to MILDOS for the annual public exposure updates.

Crow Butte Clarification

The meteorological data is collected from the MET station located just inside the front gate at 42° 38' 29" latitude and 103° 21' 48" longitude. Siting of the MET station was done in accordance with the requirements in Reg. Guide 3.63.

A description of the equipment is described in the following table.

Equipment	Description
10-meter tower	Free-standing 10-meter (or 33-foot) aluminum town, which is self-supporting with typical sets of instruments at wind levels up to 110 miles per hour (mph).
Model 034B wind sensor	Model 034B wind sensor combines wind speed and direction measurements into a single sensing unit. The sensor is constructed of aluminum and stainless steel. Specifications: 1. Wind Speed • Range: 0 to 167 mph (0 to 75 meters/second [m/s]) • Starting threshold: 0.9 mph (0.4 m/s) • Accuracy : <22.7 mph (0.25 mph [0.1 m/s]) • Accuracy: >22.7 mph (±1.1 percent of true) 2. Wind Direction • Range: Mechanical: 0 to 360° Electrical: 0 to 356° • Starting threshold: 0.9 mph (0.4 m/s)

Equipment	Description
	• Accuracy: 0.4° • Damping ratio: 0.25 standard (0.4 to 0.6 optional) • Resolution: <0.5° 3. Temperature Range • –30 °C to +70 °C (minimal icing conditions) 4. Output Signal • Wind speed: Pulsed contact closure • Wind direction: Potentiometer output (0 to 10 kohms) 5. Height • 10 meters
Air temperature sensor	Met One Model 062 MP Specifications: 1. General • Sensing element: Multi-stage state thermistor, highly linearized • Time constant: Less than 10 seconds in still air • Self-heating: None 2. Housing: 3/8 in (9.5 mm) x 6 in (152.4 mm) 3. Range: –50 °C to +50 °C 4. Accuracy: <u>+0.05 °C, PSD compliant</u> 5. <u>For a system range of</u>: Maximum Error/Degree of <u>differential temperature:</u> Maximum Error <u>over range:</u> –5 °F to +5 °F — 0.02 °F — 0.05 °F –5 °C to +5 °C — 0.02 °C — 0.05 °C –5 °F to +10 °F — 0.02 °F — 0.1 °F –5 °C to +10 °C — 0.02 °C — 0.1 °C –10 °F to +20 °F — 0.02 °F — 0.2 °F 6. Height • 2 meters • 10 meters
Relative humidity and temperature probes; solar radiation shield	Model HMP45AC Specifications: • Operating temperature range: –40 to +60 °C (–40 to +140 °F) • Storage temperature range: –40 to +80 °C (–40 to +176 °F) • Supply voltage: 7 to 35 VDC • Settling time: 500 m/s • Power consumption: <4 milliamperes (mA)

Equipment	Description
	• Relative humidity: • Measuring range: 0.8 to 100% RH • Output scale: 0 to 100% RH equals 0.1 VDC • Accuracy at +20 °C (+68 °F) (including nonlinearity and hysteresis) against calibration against references: ±1% RH field calibration against references: ±2% RH (0 to 90% RH) ±3% RH (90 to 100% RH) • Typical long-term stability: <1% RH/year • Temperature dependence: ±0.05% RH/°C (±0.03% RH/°F) • Response time (90% at +20 °C): 10 seconds with membrane filter • Humidity sensor: HUMICAP 180 7. Temperature • Measurement range: –39.2 to +60 °C (–32 to +140 °F) • Output scale: –40 to +60 °C (–40 to +140 °F) equals 0 to 1 VDC • Accuracy at +20 °C (+68 °F) 8. Height • 2 meters
Solar radiation	LiCor 200 Pyranometer Designed for field measurement if global solar radiation. Specifications: 1. Sensitivity: Typically 90 microamperes (μA) per 1000 W m^{-2} 2. Linearity: maximum deviation of 1% up to 3000 W m^{-2} 3. Stability: <± 2% change over a 1-year period 4. Response time: 10 microseconds (μs) 5. Temperature dependence: 0.15% per °C maximum 6. Cosine correction: cosine corrected up to 80° angle of incidence 7. Azimuth: <±1% error over 360° at 45° elevation 8. Operating temperature: –40 to 65 °C 9. Relative humidity: 0 to 100% 10. Height: 1.3 meters
Datalogger	Campbell Scientific CR 1000 programmable control and data acquisition system Provides direct communications and telecommunications, reduces data, controls external devices, and stores data and programs in on-board, non-volatile storage. Sensor data can be directly downloaded from the datalogger.

Equipment	Description
	Specifications: 1. Analog inputs: 16 single-ended or 8 differential, individually configured 2. Pulse counters: 2 3. Switched voltage excitations: 3 4. Control/digital ports: 8 5. RS-232 port: 1 6. CS I/O port: 1 7. Scan rate: 100 Hz 8. Burst mode: 1500 HZ 9. Programming: CR Basic 10. Data storage: Table
Tipping bucket rain gage	Texas Electronics TE525WS tipping bucket rain gage Specifications: 1.Orifice diameter: 8 inches (20.3 cm) 2.Rainfall per tip: 0.01 inch (0.254 mm) 3.Accuracy: • Up to 1 inch/hr: ±1% • 1 to 2 inches/hr: +0, –2.5% • 2 to 3 inches/hr: +0, –3.5% 4. Temperature: 0 °C to +50 °C 5. Resolution: 1 tip 6. Magnetic reed switch 7. Height: .91 meters

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 modelling 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 modeling 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.

Request for Clarification

NRC staff comments:
As the NRC staff presented in RAI 7, it previously determined (NRC, 2014b, 2014c) that using calculations and models with no monitoring results to support either is not sufficient to demonstrate compliance with public dose limits as well as using measurements made at the point of an actual individual receptor as the primary means of compliance. Therefore, it is unclear to the NRC staff why the licensee is proposing the

use of modelling for the calculation of dose to the maximally exposed member of the public. Specifically, the conditions under which the licensee would use the alternate approach of modelling as a primary means of compliance are vague and the NRC staff does not know when "generally measurements at or near the maximally exposed member of the public" will not be used by the licensee.

In addition, the licensee proposed comparing the results of MILDOS calculations with measurements made at the environmental monitoring stations to confirm the reasonableness of the model results. Although the NRC staff presented this methodology as an option to the uranium recovery industry (NRC, 2011), the licensee neither provided sufficient information for the NRC staff to enable it to make a determination that MILDOS is "calibrated: for the Crow Butte site nor did it request the NRC staff to make this determination.

Please provide the NRC staff with a more definitive description of the program for performing measurements of radon or radon progeny in air to ensure the dose to members of the public do not exceed regulatory limits, or provide the NRC staff with a specific request to review an alternate program with sufficient information for it to make a regulatory decision.

<u>Crow Butte Clarification</u>

Crow Butte has previously submitted evidence showing that the outputs of the model are a statistically significant fit to measurements at the environmental stations and preliminary measurements demonstrating that the calculated source terms were also accurate. The purpose behind the proposal for modelling is to have a reliable and accurate method to estimate public dose when there are issues with the track etch monitors, such as contamination or failures, which have occurred in the past. Further, as discussed on numerous occasions with the NRC staff, monitoring at concentrations comparable to background are inherently uncertain and prone to either false positives or negatives. Even though the model has produced results that are statistically comparable to actual measurements over the entire mine site, given the difficulty of pursuing this option, Crow Butte is withdrawing the modelling proposal at this time. Crow Butte will continue to maintain the model and collect the data for future consideration.

As per the previous submission, Crow Butte will show compliance to this requirement for this receptor through the method outlined below. 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/yr)
- DCF = dose conversion factor for Rn-222 with 100% equilibrium factor with its progeny from 10 CRF 20 Appendix B - 500 mrem/yr 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

To attempt to mitigate the uncertainty in the measurement method and potential for mishandling or damaged equipment, Crow Butte will increase the number of track etch cups at the background and maximum receptor location to six.

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 $U\text{-}^{nat}$, 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.

Request for Clarification

NRC staff comments:

The licensee's approach appears reasonable. However, the NRC staff requires pertinent monitoring information on which to base an evaluation.

The licensee previously submitted historical data on in-plant radon daughter monitoring results for the years 1994-2006 (refer to Table 5.8-1 of Cameco, 2009). Please provide the NRC staff with updated in-plant radon daughter monitoring results (i.e., from 2007 to present).

In addition, the licensee previously submitted a monitoring plan for the Crow Butte facility that included radon and radon daughter monitors placed on all sides of the Crow Butte central processing plant (refer to the Crow Butte Sampling Plan and associated figures in the attachments to Cameco, 2011). Please provide the NRC staff with available data from these monitoring efforts.

Crow Butte Clarification

The requested data is attached at the end of this submittal.

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 Pb^{210}. 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 3×10^{-12} μCi/ml. To meet the DAC requirement, Th^{230} must be present at less than a concentration of 3×10^{-13} μCi/ml. Similarly, Ra^{226} must be present at concentration less than 3×10^{-11} μCi/ml, which is 10% of its DAC of 3×10^{-10} μCi/ml, and Pb^{210} must be present at concentration less than 1×10^{-11} μCi/ml, which is 10% of its DAC of 1×10^{-10} μCi/ml. A DAC of 5×10^{-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.

Request for Clarification

NRC staff comments:

The requirements that specify when a licensee may disregard certain radionuclides in a mixture when determining internal exposure are found in 10 CFR 20.1204(g). NRC guidance on 10 CFR 20.1204(g) can be found in NUREG-1736 (NRC, 2001). NUREG-1736 presents several examples of calculations using mixtures of radionuclides.

The following questions and answers on the NRC website may also be helpful in addressing mixtures of radionuclides and when certain radionuclides may be disregarded when assessing internal dose:

Q121: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/qa121.html

Q403: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/qa403.html

Q453: http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/qa453.html

In particular, question Q403 addresses disregarding the contribution of a radionuclide for recording and reporting purposes if it is less than 10% of the CEDE.

The licensee's proposed method of assessing mixtures of radionuclides does not meet the requirement of 10 CFR 20.1204(g)(1) and is not consistent with the guidance provided above for this regulation. Specifically, while the licensee measured or calculated the activity of the radionuclides and compared the activity to their respective DACs as indicated in the statement above, the licensee did not account for the activity of those radionuclides it disregarded based on the DAC analysis. For example, the licensee calculated the following activities for Th^{234}, based on U^{238} activity:

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%

Based on the DAC analysis, the licensee disregarded Th^{234} altogether. However, the correct application of 10 CFR 20.1204(g)(1) is to add the activity of Th^{234} to the U^{238} activity. This methodology is also correct for any other radionuclides that are in equilibrium with its parent.

Please provide the NRC staff with a proposed method of assessing mixtures of radionuclides that meets the requirement of 10 CFR 20.1204(g)(1) and is consistent with the guidance provided above for this regulation.

<u>Crow Butte Clarification</u>

Based on a better understanding of NRC guidance, a more thorough description of the assessment of dose from radionuclides has been provided. A critical point to re-state is that all alpha emitting radionuclides present in the air are included in the activity measurement used for calculation of dose to workers; the activity of these radionuclides have not been excluded for dosimetry purposes and are summed and compared to the ALI and DAC of U^{Nat}.

One very important factor that was stated in the June 30, 2015, submittal is that in section 3.3.1 of ICRP 30, daughter products produced in the body after intake of a specified radionuclide are taken into account in the ALI specified by ICRP 30. This means that the ALI for uranium in ICRP 30 and 10 CFR 20 Appendix B already includes the dose from Th^{234} and Pa^{234m} that is produced as a result of radioactive decay after the intake of U^{238}. Therefore, the only dose that could be considered in addition is from decay products present at the time of inhalation. Given the half-lives of these short-lived daughter products, 24.1 days for Th^{234} and 1.17 minutes for Pa^{234m}, less than 1% of the total activity potentially inhaled at the time of an intake remains after 6 months meaning any potential dose is extremely low and decreasing over that time period. Specifically, if Th^{234} is present in full equilibrium with U^{238}, it would contribute a dose that was at most 0.25% of that from U^{Nat}. Using the average estimated Th^{234} concentration in air from the 2015 sample, 3.5E-13 µCi/ml, and assuming a 2000 hour per year exposure, this would result in a 0.00001 rem dose. This is a negligible dose and well below any measurable or reportable quantity. As a side note, Pa^{234m} does not have an ALI in Appendix B of 10

CFR 20, therefore a dose cannot be calculated for this radionuclide independently, but as stated, it is included in the ALI of U^{Nat}.

Further, as stated in the June 30, 2015 submittal, internal dosimetry from airborne radionuclides is based on the total alpha activity present on the filters used for sample collection. This means that all alpha emitting radionuclides are explicitly measured and included in the total activity measurements which are then compared to the U^{Nat} ALI for dose calculations. Therefore, the activity from all alpha emitting radionuclides (U^{Nat}, Th^{230}, Ra^{226}, Pb^{210} and Po^{210}) are already included in the total airborne activity measurements and should not be added again as independent radionuclides. The only other beta emitters that may be present are Pb^{210} and its daughter Bi^{210}. Using the estimated average Pb^{210} and Bi^{210} concentrations in air from the 2015 sample, 2.0E-14 µCi/ml, and assuming a 2000 hour per year exposure, this would result in a 0.001 rem and 0.00001 rem doses, respectively, or 0.02% of the dose limit.

In conclusion, because Crow Butte measures all alpha activity on the sample filters, all alpha emitters present are included in the total activity and dosimetry calculations. For the beta emitters discussed above, even the reasonable maximum total dose from these emitters, assuming 2000 hours/year exposure, is only approximately 0.001 rem per year. For most workers, the dose would be significantly less than this amount and not reportable within the reported significant figures of the dose calculations. Because of the extremely small potential dose and the administrative complexity of trying to include this dose into the calculations, Crow Butte is requesting an exemption from including the dose from these beta emitting radionuclides in the dose calculations. All alpha emitters, however, will continue to be included in dose calculations.

<u>Administrative Issues</u>

<u>License Condition 11.11(C)</u>

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.

<u>Crow Butte Response</u>

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.

Request for Clarification

NRC staff comments:

The NRC staff observes that the response to Administrative Issue 3 did not answer the original question. In its original response (Cameco, 2015b), the licensee compared the results of distant monitoring stations to the 10 CFR 20, Appendix B, Table 2, effluent concentration value for uranium in an attempt to demonstrate that the vacuum dryer used to dry yellowcake releases no particulates.

For example, the licensee indicated that AM1 is located approximately 900 meters (m) (0.56 miles (mi)) from the plant, AM2 is approximately 1,210 m (0.75 mi) from the plant and AM3 is approximately 2,060 m (1.28 mi) from the plant (refer to Table 3.0-1 of Cameco, 2015b). At these distances, it is not clear to the NRC staff how measurements can be utilized to construct a source term for the vacuum dryer or confirm the lack of particulate release. In any case, the licensee included two additional monitoring stations in its response to Administrative Issue 3, AM24 and AM5, which are closer to the yellowcake dryer source (61 m (200 feet) north and south of the plant, respectively) (Cameco, 2015a). The NRC staff observes that, although the monitoring results from these locations could potentially be used for other compliance purposes, these close-in measurements are not taken at the point of release and that, as the NRC has previously evaluated (NRC, 2014d), only a portion of the source term will be measured at these two locations.

Please clarify for the NRC staff if any measurements, other than general environmental monitoring, have been taken to specifically characterize the vacuum dryer effluent.

Crow Butte Clarification

The type of dryer used in the Crow Butte process facility is a vacuum dryer. With this dryer, the yellowcake is dried in a heating chamber that is maintained at negative pressure. Airflow in a vacuum dryer is minimal and is from the outside of the drying chamber into the chamber. Any particulate that may be released goes to a bag filter, with the moisture-laden air going to a closed loop condenser where the water condenses and entrains any remaining particulate, with the vacuum source being a liquid ring vacuum pump acting as a final filter against any particulate escape. The water is periodically transferred to the yellowcake thickener. With a vacuum dryer, there is no release of particulate by way of a stack since there is no positive airflow. During packaging, the drum is sealed via a gasket to the dryer discharge. As the dryer is operating under vacuum, any leaks around this gasket result in air being drawn into the drum during the packaging of yellowcake, thus no contaminants are released. The air that may enter the discharge to the drum is also routed to the condenser system described above.

As part of Crow Butte's routine in-plant air sampling, monthly uranium and semi-annual isotopic samples are collected in the dryer change room as well as at the other pre-defined sample locations. Because the only pathway for the air is through the main plant, any particulate that is released from the dryer must pass through the plant and is therefore included in these in-plant air samples. As described in the previous submission, the plant particulate emissions (including those from the dryer) represent an extremely small effluent source term, on the order of 0.001 Ci/yr and 0.00001% of the total emissions.

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

Sincerely,

Bob Tiensvold

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
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Two White Flint North, Rockville, MD 20852-2738

CBO- File

ec: CR-Casper

Additional Requested Laboratory Data

Radon Progeny Monitoring using Personal Alpha Dosimeter (PAD)

Location	Feb & Mar 2013	Apr & May 2013	Jun 2013	Jul 2013	Aug 2013	Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014
AM-6 - background station	**NA**	**0.001**	**0.0011**	**0**	**0.0002**	**0.0013**	**0.0003**	**0.0012**	**0.0017**	**0.0003**
TE-1	NA	NA	-0.0002	0.0007	0.0016	0.0001	0.0007	0.0011	NA	0.0001
TE-2	0.0006	0.0003	-0.0002	0.0008	0.0009	0	-0.0001	0.0012	0.0007	NA
TE-3	0.0007	0.0003	0.0006	0.0006	0.0006	-0.0003	NA	0.0004	0.0012	0.0015
TE-4	-0.0002	0.0001	0.0005	0.0007	0.0011	0.0001	NA	0.0007	0.0011	0.0012

NA = Failure of the Personal Alpha Dosimeter (PAD)

Note: Background unit failed in Feb & Mar 2013 - used background measurement for Apr & May 2013

Units = Working Levels (WL)

In-plant Airborne Uranium Monitoring Results

Airborne Uranium Monitoring (Calendar Year)	Annual Average Airborne Activity μCi/Ml Gross α	(% Dac)[1]	Maximum Monthly Average Airborne Activity μCi/Ml Gross α	(%Dac)[1]
1994	3.22 E-12	0.6	6.07 E-12	1.2
1995	3.8E-12	0.8	9.36E-12	1.9
1996	1.28E-12	0.3	4.71Ee-12	0.9
1997	2.77 E-12	0.6	5.43 E-12	1.1
1998	3.06 E-12	0.6	5.36 E-12	1.1
1999	2.87 E-12	0.6	4.44 E-12	0.9
2000	2.63 E-12	0.5	5.84 E-12	1.2
2001	3.30 E-12	0.7	7.05 E-12	1.4
2002	2.25 E-12	0.5	3.70 E-12	0.7
2003	4.02 E-12	0.8	2.33 E-12	0.5
2004	1.65 E-12	0.3	5.99 E-12	1.2
2005	3.80 E-12	0.8	5.03 E-12	1.0
2006	3.86E-12	0.8	4.87E-12	1.0
2007	2.50E-12	0.5	4.53E-12	0.9
2008	2.48E-12	0.5	5.33E-12	1.1
2009	2.95E-12	0.6	6.76E-12	1.4
2010	2.90E-12	0.6	5.05E-12	1.0
2011	2.51E-12	0.5	6.20E-12	1.2
2012	2.79E-12	0.6	3.84E-12	0.8
2013	1.93E-12	0.4	3.61E-12	0.7
2014	3.05E-12	0.6	4.00E-12	0.8

Note: [1] Samples compared to the DAC where DAC=5E-10 μCi/ml (10 CFR §§ 20.1001-2401 App B)

Results include dryer room samples

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: January 2, 2013 to April 1, 2013

Air Monitoring Station ID	Gross Count	Average Radon Concentration ($x\ 10^{-9}\ \mu Ci/ml$)	Accuracy ($x\ 10^{-9}\ \mu Ci/ml$)	Percent Effluent Concentration
1-TE	273.0	0.9	0.05	9.0%
2-TE	265.0	0.8	0.05	8.0%
3-TE	422.0	1.7	0.08	17.0%
4-TE	234.0	0.6	0.04	6.0%

LLD ($x\ 10^{-9}\ \mu Ci/ml$)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: April 1, 2013 to July 1, 2013

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} µCi/ml)	Accuracy (x 10^{-9} µCi/ml)	Percent Effluent Concentration
1-TE	432.0	1.6	0.08	16.0%
2-TE	277.0	0.6	0.04	6.0%
3-TE	410.0	1.4	0.07	14.0%
4-TE	408.0	1.4	0.07	14.0%

LLD (x 10^{-9} µCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: July 1, 2013 to September 30, 2013

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} µCi/ml)	Accuracy (x 10^{-9} µCi/ml)	Percent Effluent Concentration
1-TE	645.0	2.7	0.11	27.0%
2-TE	298.0	0.6	0.03	6.0%
3-TE	325.0	0.8	0.04	8.0%
4-TE	560.0	2.2	0.09	22.0%

LLD (x 10^{-9} µCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: September 30, 2013 to January 2, 2014

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} μCi/ml)	Accuracy (x 10^{-9} μCi/ml)	Percent Effluent Concentration
1-TE	385.0	1.0	0.05	10.0%
2-TE	337.0	0.7	0.04	7.0%
3-TE	438.0	1.3	0.06	13.0%
4-TE	381.0	1.0	0.05	10.0%

LLD (x 10^{-9} μCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: January 2, 2014 to July 2, 2014

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} µCi/ml)	Accuracy (x 10^{-9} µCi/ml)	Percent Effluent Concentration
1-TE A	402.0	1.6	0.08	16.0%
1-TE B	346.0	1.3	0.07	13.0%
1-TE C	334.0	1.3	0.07	13.0%
2-TE A	282.0	1.0	0.06	10.0%
2-TE B	247.0	0.8	0.05	8.0%
2-TE C	287.0	1.0	0.06	10.0%
3-TE A	523.0	2.2	0.10	22.0%
3-TE B	504.0	2.1	0.09	21.0%
3-TE C	475.0	2.0	0.09	20.0%
4-TE A	410.0	1.6	0.08	16.0%
4-TE B	437.0	1.8	0.09	18.0%
4-TE C	504.0	2.1	0.09	21.0%

LLD (x 10^{-9} µCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

Period: July 2, 2014 to January 2, 2015

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} µCi/ml)	Accuracy (x 10^{-9} µCi/ml)	Percent Effluent Concentration
1-TE A	594.0	2.8	0.11	28.0%
1-TE B	572.0	2.7	0.11	27.0%
1-TE C	619.0	2.9	0.12	29.0%
2-TE A	352.0	1.6	0.09	16.0%
2-TE B	324.0	1.5	0.08	15.0%
2-TE C	311.0	1.4	0.08	14.0%
3-TE A	500.0	2.3	0.10	23.0%
3-TE B	553.0	2.6	0.11	26.0%
3-TE C	553.0	2.6	0.11	26.0%
4-TE A	509.0	2.4	0.10	24.0%
4-TE B	561.0	2.6	0.11	26.0%
4-TE C	555.0	2.6	0.11	26.0%

LLD (x 10^{-9} µCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Crow Butte Resources, Inc.
Crow Butte Uranium Project

Track Etch Cup Ambient Radon Concentrations

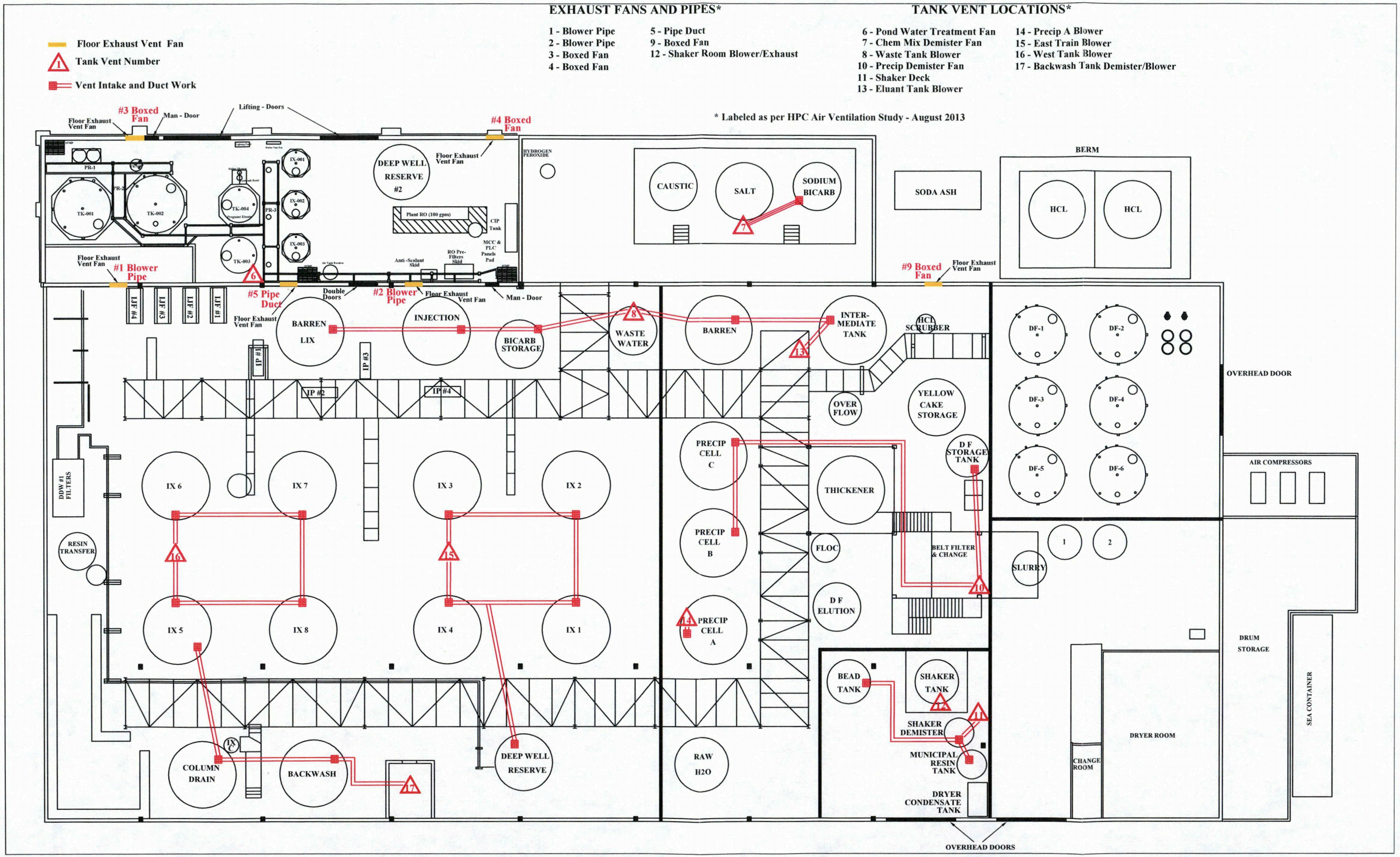
Period: January 1, 2015 to July 1, 2015

Air Monitoring Station ID	Gross Count	Average Radon Concentration (x 10^{-9} µCi/ml)	Accuracy (x 10^{-9} µCi/ml)	Percent Effluent Concentration
1-TE A	454.0	2.1	0.10	21.0%
1-TE B	428.0	2.0	0.10	20.0%
1-TE C	475.0	2.2	0.10	22.0%
2-TE A	251.0	1.0	0.06	10.0%
2-TE B	343.0	1.5	0.08	15.0%
2-TE C	255.0	1.0	0.06	10.0%
3-TE A	437.0	2	0.10	20.0%
3-TE B	493.0	2.3	0.10	23.0%
3-TE C	421.0	1.9	0.09	19.0%
4-TE A	458.0	2.1	0.10	21.0%
4-TE B	456.0	2.1	0.10	21.0%
4-TE C	471.0	2.2	0.10	22.0%

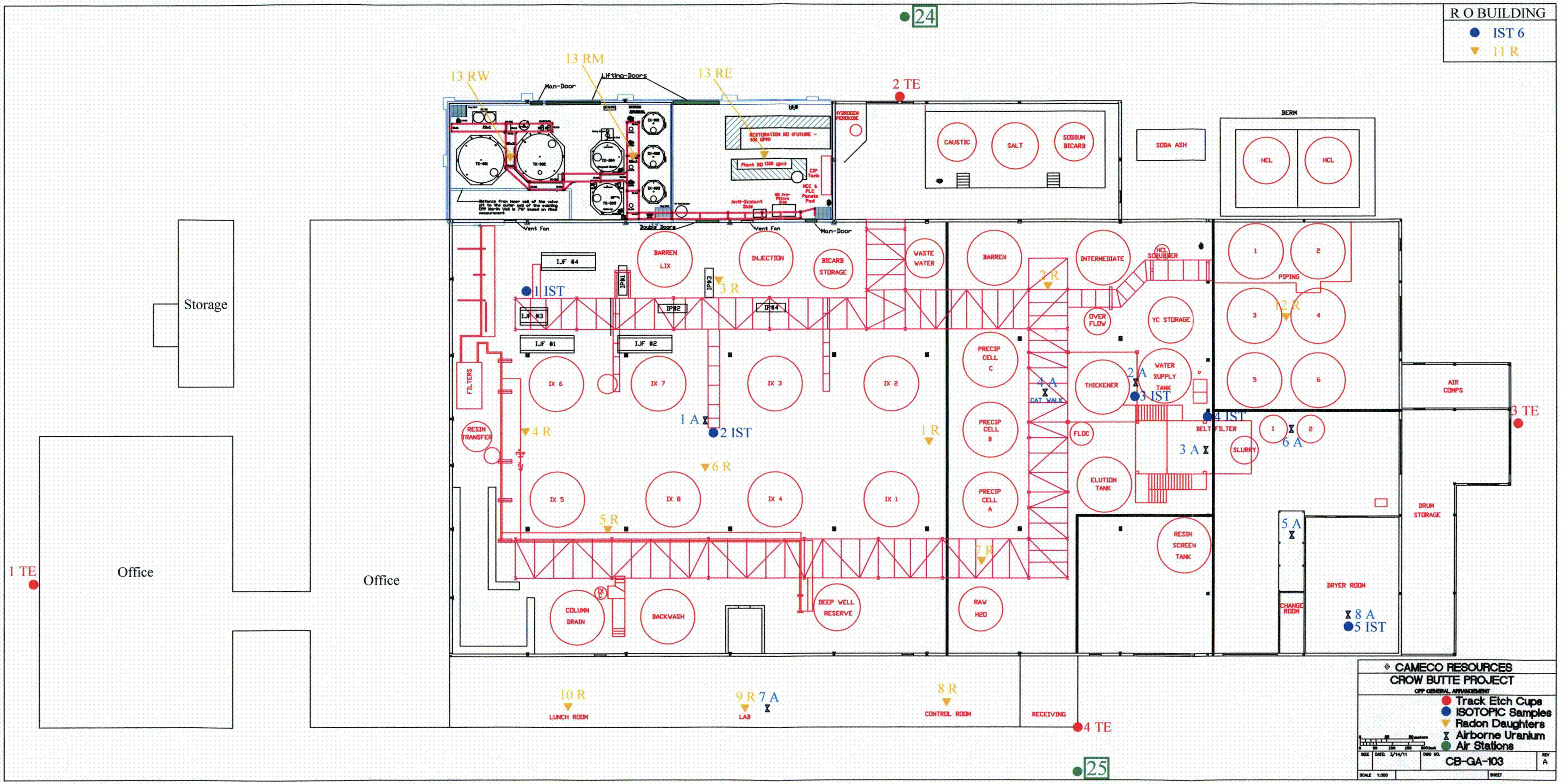
LLD (x 10^{-9} µCi/ml)	0.2
Effluent Concentration Limit, 10 CFR 20 App B Column 2:	10

Tank Vent Locations and Piping
Revised Figure

Track Etch (TE) Locations



EXHAUST FANS AND PIPES*
1 - Blower Pipe
2 - Blower Pipe
3 - Boxed Fan
4 - Boxed Fan
5 - Pipe Duct
9 - Boxed Fan
12 - Shaker Room Blower/Exhaust
TANK VENT LOCATIONS*
6 - Pond Water Treatment Fan
7 - Chem Mix Demister Fan
8 - Waste Tank Blower
10 - Precip Demister Fan
11 - Shaker Deck
13 - Eluant Tank Blower
14 - Precip A Blower
15 - East Train Blower
16 - West Tank Blower
17 - Backwash Tank Demister/Blower
* Labeled as per HPC Air Ventilation Study - August 2013
Floor Exhaust Vent Fan
Tank Vent Number
Vent Intake and Duct Work
#3 Boxed Fan
Man - Door
Lifting - Doors
#4 Boxed Fan
Floor Exhaust Vent Fan
#1 Blower Pipe
#5 Pipe Duct
#2 Blower Pipe
#9 Boxed Fan
Double Doors
PR-1
TK-001
TK-002
TK-004
TK-003
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
LJF #4
LJF #3
LJF #2
LJF #1
BARREN LIX
INJECTION
BICARB STORAGE
WASTE WATER
BARREN
INTER-MEDIATE TANK
HCL SCRUBBER
DF-1
DF-2
DF-3
DF-4
DF-5
DF-6
OVERHEAD DOOR
IP #1
IP #2
IP #3
IP #4
OVER FLOW
YELLOW CAKE STORAGE
PRECIP CELL C
D F STORAGE TANK
THICKENER
AIR COMPRESSORS
DDW #1 FILTERS
IX 6
IX 7
IX 3
IX 2
PRECIP CELL B
FLOC
BELT FILTER & CHANGE
SLURRY
RESIN TRANSFER
IX 5
IX 8
IX 4
IX 1
D F ELUTION
PRECIP CELL A
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



R O BUILDING
IST 6
11 R
24
25
13 RW
13 RM
13 RE
2 TE
1 TE
3 TE
4 TE
Storage
Office
Office
BERM
CAUSTIC
SALT
SODIUM BICARB
SODA ASH
HCL
HCL
BARREN LIX
INJECTION
BICARB STORAGE
WASTE WATER
BARREN
INTERMEDIATE
HCL SCRUBBER
PIPING
OVER FLOW
YC STORAGE
WATER SUPPLY TANK
THICKENER
PRECIP CELL C
PRECIP CELL B
PRECIP CELL A
CAT WALK
FLOC
ELUTION TANK
BELT FILTER
SLURRY
AIR COMPS
DRUM STORAGE
RESIN SCREEN TANK
DRYER ROOM
CHANGE ROOM
IX 6
IX 7
IX 3
IX 2
IX 5
IX 8
IX 4
IX 1
IJF #4
IJF #3
IJF #1
IJF #2
FILTERS
RESIN TRANSFER
COLUMN DRAIN
BACKWASH
DEEP WELL RESERVE
RAW H2O
LUNCH ROOM
LAB
CONTROL ROOM
RECEIVING
Man-Door
Lifting-Doors
Vent Fan
Double Doors
Vent Fan
Man-Door
1 IST
2 IST
3 IST
4 IST
5 IST
1 A
2 A
3 A
4 A
5 A
6 A
7 A
8 A
1 R
2 R
3 R
4 R
5 R
6 R
7 R
8 R
9 R
10 R
12 R
CAMECO RESOURCES
CROW BUTTE PROJECT
CPP GENERAL ARRANGEMENT
Track Etch Cups
ISOTOPIC Samples
Radon Daughters
Airborne Uranium
Air Stations
DATE 3/14/11
CB-GA-103
REV A
SCALE 1:300