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WCAP-14497

FORT ST. VRAIN TECHNICAL BASIS DOCUMENTS FOR PIPING SURVEY INSTRUMENTATION

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ABSTRACT

Public Service Company of Colorado has requested NRC approval of three changes to the Fort St. Vrain (FSV) Final Survey Plan for Site Release. These changes are associated with piping systems and suspect affected survey units, as outlined in Public Service Company's letter no. P-95077 dated October 12, 1995 (Fisher to Weber). In that letter, Public Service Company committed to provide Technical Basis Documents for piping survey instrumentation. This information is presented herein as WCAP-14496 (Proprietary) and WCAP-14497 (Non-Proprietary). Each version of the WCAP contains two Technical Basis Documents. Both documents are specific to the Fort St. Vrain decommissioning program.

USE OF [ ]^{a,c,f} TO ASSESS INTERNAL CONTAMINATION IN PIPING

1.0 OBJECTIVE

This document presents the technical basis for performance of contamination surveys of the internal surfaces of system piping with [ ]^{a,c,f} This basis includes the justification for the [ ]^{a,c,f} design utilized, calibration methodology, and data analysis performed to relate beta dose measured by [ ]^{a,c,f} while in system piping to a contamination level, including uncertainty and sensitivity of the process. Also included are the survey results performed on Equipment Storage Well (ESW) embedded piping (i.e., 1" and 2" diameter piping runs embedded in concrete) for which the first full-scale testing of the [ ]^{a,c,f} survey method was conducted.

2.0 REFERENCES & COMMITMENTS

2.1 References

2.1.1 [ ]^{a,c,e,f}

2.1.2 [ ]^{a,c,e,f}

2.1.3 FSV-FRS-TBD-201, "Site Specific Guideline Values For Surface Activity"

2.1.4 [ ]^{a,c}

2.1.5 Final Survey Plan, Fort St. Vrain Nuclear Station

2.1.6 Kocher, D.C., "Radioactive Decay Data Tables - A Handbook of Decay Data For Application To Radiation Dosimetry and Radiological Assessments", U.S. Department of Energy, Washington, DC, 1981

2.2 Commitments

None

3.0 DISCUSSION

Assessment of internal contamination in piping is most easily accomplished by using real-time measuring instruments (e.g., [ ]^{a,c,f} However, when dealing with [ ]^{a} in concrete, situations can be encountered where use of conventional equipment is not practical (and in some cases not possible). This is especially true for small diameter [ ]^{a} (e.g., ≤ 2") that includes multiple bends. In these situations, surface contamination levels on the inside of piping can be measured by [ ]^{a,c,f} In this process, [ ]^{a,c,e}

The beta dose measured by [ ]^{a,c,f} in system piping is defined by this document and is not intended to be equivalent to other similar values typically determined by [ ]^{a,c,f} in personnel exposure situations (e.g., shallow-dose or lens of the eye dose). Rather, [ ]^{a}

This is a new application for [ ]^{a,c,f} and has therefore not been addressed by any industry guide or standard. Therefore, the implementation of this method is as described and governed by this document.

To survey a given pipe segment, a [ ]^{a,c,e,f} Construction, installation, and removal of the [ ]^{a,c,e,f} are governed by an approved procedure [2.1.1].

4.0 [ ]^{a,c,f} CONSTRUCTION

4.1 [ ]^{a,c,f} and Shielding

The [ ]^{a,c,f} are constructed with [ ]^{a,c,f}

[ ]^{a,c,f}

Figure 1 - [ ]^{a,c,f}

[ ]^{a,c,e,f} the construction process.

[ ]^{a,c,e,f}

Figure 2 - [ ]^{a,c,f}

4.2 [ ]^{a,c,f}

[

]^{a,c,e,f}

[ ]^{a,c,e}

Figure 3 - [ ]^{a,c,f} Construction

[

]^{a,c,e}

[

]^{a,c,e,f}

5.0 CALIBRATION OF [ ]^{a,c,f}

5.1 Calibration Source

The radionuclide selected for calibration of the [ ]^{a,c,f} has an average beta energy similar to that anticipated at the measurement location, with a reasonably long half-life (although the latter is only necessary from a cost/replacement perspective). In some piping systems, particularly liquid drains, additional contaminants may have been introduced as a result of decommissioning activities. In fact, Eu-152 and Eu-154, which is found in activated concrete (FSV Prestressed Concrete Reactor Vessel), has been identified in some samples obtained within these drain systems.

Attachment 8.1, "Average Beta Energy (Ebar) for Detectable Plant Contamination At Fort St. Vrain", presents the calculation performed to determine Ebar using 10CFR61 data which may be relevant to plant systems. This provides an indication that the average beta energy (Ebar) expected in "detectable" plant contamination, (i.e., excluding hard to detect nuclides such as Fe-55 and H-3 that are addressed by reducing the Site Guideline Values, SGLV [2.1.3]) at Fort St. Vrain is 113.6 keV.

[

]^{a,c,e}

[

]^{a,c,e}

a,c,e,f

Figure 4 - 1" Pipe Jig, Source and [ ]^{a,c,f} Configuration

a,c,e,f

Figure 5 - 2" Pipe Jig, Source and [ ]^{a,c,f} Configuration

5.2 Calibration Methodology

5.2.1 General Discussion

Calibration is accomplished [

]^{a,c,e,f}

The TLDs are calibrated to a [

]^{a,c,e} however, based on the knowledge of the radionuclides present on the internal surfaces of piping and in contamination found outside of pipes.

Many factors will affect the [

]^{a,c,e,f} is rapidly diminished outside the defined area due to the limited beta range.

[

]^{a,c,e} and gain a more complete understanding of the response capabilities of the [ ]^{a,c,f} arrangement.

5.2.2 Calibration Procedure

To calibrate [

]^{a,c,e}

The value [

]^{a,c,e}

NOTE

[

]^{a,c,e}

[

]^{a,e,c} Attachments 8.2 and 8.3 contain the plots and spreadsheets of calibration data obtained during ESW embedded pipe testing. Attachment 8.2 includes [

]^{a,e,c}

a,c,e

In addition to the initial testing performed with the ESW piping and as the method is used in the future, the technique will be better defined regarding the range of element response.

5.3 LINEAR RESPONSE TESTING

Published literature for [

]^{a,c,e}

5.4 [ ]^{a,c,e} PROCESSING

NOTE

[

]^{a,c}

[

]^{a,c,e}

Upon removal of [

]^{a,c}

6.0 DATA ANALYSIS

6.1 Contamination Level Determination:

The contamination level measured at a given survey location [

]^{a,c,e,f}

[

]^{a,c,e,f}

[ ]^{a,c,e,f}

This type of calculation is performed for both element types with the average contamination level used as the result for the [ ]^{a,c,f} location.

6.2 Error Analysis

For a set of measurements taken (e.g., a set of measurements in a given pipe segment [

]^{a,c,e,f}

[ ]^{a,c,e,f}

To determine the acceptability of a pipe or survey unit's average contamination level, uncertainty of the average value must be determined. To perform this determination, the sample standard deviation (SD) of the set of measurements taken is calculated. The equation used to calculate the standard deviation is as follows:

$$SD = \sqrt{\frac{\sum_{1}^{N} (X_i - \overline{X})^2}{N-1}}$$

Uncertainty of the average contamination level is then determined for 95% confidence by using Student's t equation as previously shown:

$$95\%\ \text{Confidence Interval} = \frac{t_{0.95,N-1} * SD}{\sqrt{N}}$$

Upon adding the uncertainty to the average value, an upper limit is then obtained which represents (with 95% confidence) the maximum value of the average contamination level of the pipe or survey unit.

6.3 Sensitivity Analysis (MDA)

To ensure a [

]a,c,e,f

a,c,e,f

a,c,e,f

[ ]^{a,c,e,f}

Critical level is calculated for reference purposes only. The acceptability of a given pipe or collection of pipes is determined by the criteria of Section 6.4.

6.4 Acceptability of Results

To determine if a given pipe or collection of pipes is acceptable for unrestricted use, the average contamination level plus 95% confidence interval (one-sided) is compared to the SGLV. [ ]^{a,c,e,f} if the following is true:

[ ]^{a,c,e,f}

[ ]^{a,c,e,f}

6.5 ESW Test Results

Attachments 8.4 and 8.5 contain results from ESW embedded pipe testing. In these attachments are plots for each pipe segment surveyed, that indicate the measured contamination level at various positions in the pipe, and spreadsheets containing the test data for each pipe. Attachment 8.4 contains [ ]^{a,c,e,f}

The SGLV for affected plant systems at FSV is established at 4,000 dpm/100cm^2. Therefore, ESW piping is acceptable for unrestricted use provided the mean [ ]^{a,c,e,f} dpm/100cm^2. When evaluating each ESW pipe separately using the data collected with [ ]^{a,c,f} 11 of the 20 pipes surveyed yielded results less than the SGLV. The other 9 pipes will require further evaluation or decontamination.

6.6 Comparison Testing Results

[

$]^{a,c,e,f}$

Compared data for line L1414 is considered very good. Both methods produced the same approximate contamination profile in the pipe. [

$]^{a,c,e,f}$ This was evidenced by the average results for L1414 where 4.4 kdpm/100cm^2 and 4.2 kdpm/100cm^2 were determined for the SN-050-4K assembly and [$]^{a,c,f}$ respectively.

L1416 data was also in good agreement. In this pipe both methods indicated that the pipe was clean (i.e., all measurements < 12 kdpm/100cm^2, and average < 4 kdpm/100cm^2). The [

$]^{a,c,e,f}$ The average contamination levels determined by each method are in acceptable agreement considering that MDAs for both methods were approximately 2 kdpm/100cm^2.

7.0 SUMMARY

Using [ ]^{a,c,f} to survey internal surfaces of plant system piping is a feasible method for providing reasonable estimates of surface contamination in piping. The method is a new application for [ ]^{a,c,f} and has therefore not been addressed by any guide or standard.

Although attempts were made to be as accurate as possible in the initial testing, [

]^{a,c,e,f}

While use of [

]^{a,c,e,f} of the method is provided.

Major Advantages and Disadvantages of [ ]^{a,c,f} Survey Method

[

]^{a,c,e,f}

The principal application of the [ ]^{a,c,f} survey method is [

]^{a,c}

8.0 ATTACHMENTS

8.1 Average Beta Energy (Ebar) for Detectable Plant Contamination at Fort St. Vrain

8.2 Calibration Data and Results for 1" Piping [ ]^{a,c,f} (collected during ESW testing)

8.3 Calibration Data and Results for 2" Piping [ ]^{a,c,f} (collected during ESW testing)

8.4 ESW 1" Piping [ ]^{a,c,f} Survey Data and Results

8.5 ESW 2" Piping [ ]^{a,c,f} Survey Data and Results

8.6 SN-050-4K vs. [ ]^{a,c,f} Survey Comparison Test Results

ATTACHMENT 8.1

AVERAGE BETA ENERGY (EBAR) FOR DETECTABLE PLANT CONTAMINATION AT FORT ST. VRAIN

Table 1 below presents the relative radionuclide composition of various samples and smears taken at Fort St. Vrain for the "detectable" radionuclides. These particular samples, which are decay corrected to 1/1/96, are the ones used to determine the Site Specific Guideline Values (SGLV). Also presented in the table, is the average radionuclide composition that is determined by assigning equal weight to each of the individual samples. Only the "detectable" (i.e., readily detectable) nuclides are included in the calculation because the hard to detect nuclides and alpha emitters are accounted for by reducing the SGLV.

Table 1 - Relative Radionuclide Composition of Fort St. Vrain Samples/Smears

	Co-60	Sr-90	Cs-134	Cs-137	Eu-152	Eu-154	Tc-99
PCRV Smear	7.25E-1	3.75E-3	3.28E-3	1.02E-1	1.56E-1	1.03E-2	
HSF Smear	9.87E-1	2.75E-4		1.24E-2			
FHM Smear	9.38E-1	4.93E-3	1.30E-3	5.58E-2			
Liquid Waste Resin	3.44E-2	1.39E-3	4.72E-2	9.17E-1			
PCRV Concrete	1.17E-1		4.53E-3		8.08E-1	5.66E-2	1.34E-2
Graphite Dust	3.22E-1	9.15E-5			6.27E-1	5.12E-2	
PCRV Access Flange	9.78E-1	2.26E-3	1.51E-3	1.77E-2			
PCRV Shield Plug	8.56E-1	6.01E-3	1.85E-3	1.36E-1			
Average Fraction	6.20E-1	2.34E-3	7.46E-3	1.55E-1	1.99E-1	1.48E-2	1.68E-3

To determine Ebar for the average radionuclide composition, Ebar for each radionuclide is determined using published tabulations [2.1.6]. In the individual nuclide Ebar calculation, electrons from internal conversion, auger electron emission as well as beta decay are considered "beta particles" because each electron of a given energy (without regard to its decay source) has the same probability of interacting with a detector. In addition, any daughter nuclides that can be assumed to be in equilibrium with the parent are factored into the calculation (e.g., the Sr-90 daughter Y-90 and the Cs-137 daughter Ba-137m).

The equation used to calculate Ebar for a given radionuclide is as follows:

$$\text{Ebar} = \frac{\sum_{1}^{N} (\text{Abundance} * \text{BetaEnergy})}{\sum_{1}^{N} (\text{Abundance})}$$

where N is the number of individual branches of the radionuclide (i.e., each auger, conversion, or beta decay electron and its associated energy)

The Ebar calculation for each individual radionuclide uses all electron energies, including low energy auger electrons. This was done to ensure a consistent approach is followed with each nuclide and the range of its electron emissions. Most auger electrons and some of the beta decay electrons (which are emitted with an energy spectrum from zero to a characteristic maximum) are unable to reach the detector due to their low energy. To be consistent in omitting electron energies not expected to be detected would require correcting for all low energy electrons, including beta decay. Consequently, the consistent approach of using all energies emitted by a given radionuclide is followed. A summary of the Ebar values for each radionuclide that are used in the overall average Ebar calculation is provided in Table 2 below:

Table 2 - Ebar Data Summary

	Co-60	**Sr-90**	**Cs-134**	**Cs-137**	**Eu-152**	**Eu-154**	**Tc-99**
Average Fraction	6.20E-1	2.34E-3	7.46E-3	1.55E-1	1.99E-1	1.48E-2	1.68E-3
Ebar (keV)	95.8	565.3[2]	159.6[1]	196.8[1,2]	87.2[1]	149.2[1]	84.6
Beta Abundance[3]	1.000	2.000[2]	1.015[1]	1.174[1,2]	1.424[1]	1.838[1]	1.000

NOTES:
[1] Data include contributions from conversion and auger electrons
[2] Data include contributions from daughter
[3] Beta Abundance is the average number of beta particles emitted per decay

To determine the overall Ebar for the average radionuclide composition, the following equation is used:

$$\text{Ebar} = \frac{\sum_{1}^{N} (\text{AverageFraction} * \text{Abundance} * \text{BetaEnergy})}{\sum_{1}^{N} (\text{AverageFraction} * \text{Abundance})}$$

where N is the number of detectable radionuclides in the average composition. Using the preceding equation and data from Table 2, the results of Table 3 are obtained.

Note: The denominator of this equation is the beta abundance (i.e., average number of beta particles emitted per decay) for average radionuclide composition at FSV.

Using the preceding equation and data from Table 2, the results of Table 3 are obtained.

TABLE 3 - Ebar Results For Radionuclide Composition

Ebar (keV)	113.6	**Beta Abundance**	1.126

ATTACHMENT 8.2
CALIBRATION DATA AND RESULTS FOR 1" PIPING [ ]^{a,c,f}

(collected during ESW testing)

ATTACHMENT 8.2
CALIBRATION DATA AND RESULTS FOR 1" PIPING [$]^{a,c,f}$ (collected during ESW testing)

[$]^{a,c}$ 1" Pipe Calibration Data

a,b,c,f

ATTACHMENT 8.2
CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

[ ]^{a,c} 1" Pipe Calibration Data

a,b,c,e,f

ATTACHMENT 8.2
CALIBRATION DATA AND RESULTS FOR 1" PIPING [ ]^{a,c,f} (collected during ESW testing)

[ ]^{a,b,c,e,f}

ATTACHMENT 8.2

CALIBRATION DATA AND RESULTS FOR 1" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.2

CALIBRATION DATA AND RESULTS FOR 1" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.2

CALIBRATION DATA AND RESULTS FOR 1" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.3
CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]a,c,f
(collected during ESW testing)

ATTACHMENT 8.3

CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

[ ]^{a,c} 2" Pipe Calibration Data

a,b,c,e,f

ATTACHMENT 8.3
CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

[ ]^{a,c} 2" Pipe Calibration Data

ATTACHMENT 8.3

CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.3
CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.3
CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]^{a,c,f} (collected during ESW testing)

[ ]^{a,b,c,e,f}

ATTACHMENT 8.3

CALIBRATION DATA AND RESULTS FOR 2" PIPING [ ]a,c,f (collected during ESW testing)

a,b,c,e,f

ATTACHMENT 8.4
ESW 1" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

ATTACHMENT 8.4
ESW 1" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]a,b,c,e,f

ATTACHMENT 8.4
ESW 1" PIPING [$]^{a,c,f}$ SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.4
ESW 1" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

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ATTACHMENT 8.4
ESW 1" PIPING [ ]^{a,c,e,f} SURVEY DATA AND RESULTS

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ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

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ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

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ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

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ATTACHMENT 8.5
ESW 2" PIPING [$]^{a,c,f}$ SURVEY DATA AND RESULTS

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ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]^{a,b,c,e,f}

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5

ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]^{a,b,c,e,f}

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

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ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

[ ]

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

[ ]^{a,b,c,e,f}

ATTACHMENT 8.5
ESW 2" PIPING [ ]^{a,c,f} SURVEY DATA AND RESULTS

a,b,c,e,f

ATTACHMENT 8.6

SN-050-4K VS. [ ]^{a,c,f} SURVEY COMPARISON TEST RESULTS

a,b,c,e,f

ATTACHMENT 8.6
SN-050-4K VS. [ ]^{a,c,f} SURVEY COMPARISON TEST RESULTS

a,b,c,e,f

Methods to Evaluate the Final Condition of Plant System Piping Internal Surface

1.0 PURPOSE

This document provides the technical basis by which the measurement of total surface activity on the internal surfaces of plant system piping are performed at Fort St. Vrain (FSV). The protocols and instruments detailed in this document may also be used for other plant system internal surfaces as applicable. Included in this document are descriptions of available instrumentation, calibration methods, testing performed, and the survey techniques to be used. [

]^{a,c,f}

2.0 REFERENCES & COMMITMENTS

2.1 References

2.1.1 Final Survey Plan, Fort St. Vrain Nuclear Station.

2.1.2 Kocher, D.C., "Radioactive Decay Data Tables- A Handbook of Decay Data For Application To Radiation Dosimetry and Radiological Assessments", U.S. Department of Energy, Washington, DC, 1981.

2.1.3 Lederer and Shirley, et al., Table of Isotopes, 7th edition, John Wiley & Sons, New York, 1978.

2.1.4 Friedlander, et at., Nuclear and Radiochemistry, 3rd edition, John Wiley & Sons, New York, 1981.

2.1.5 Krane, K.S., Introductory Nuclear Physics, John Wiley & Sons, New York, 1988.

2.1.6 [ ]^{a,c}

2.1.7 [ ]^{a,c,f}

2.2 Commitments

None

3.0 DISCUSSION

The assessment of total surface activity on internal surfaces of piping is accomplished by using an assortment of detector sizes and types. [

]^{a,c}

are each used in applicable situations. Each detector is used with a [ ]^{a,c} Data Logger to provide bias voltage to the detector(s) and measurement recording.

To correct field measurements to meaningful results, the efficiency of a detector must be known. [ ]^{a,c} The [ ]^{a,c,f} are calibrated with disc sources, including a multiple source position jig for the larger area [ ]^{a,c,f} detector. The [ ]^{a,c} encountered during field measurements.

Based on desired sensitivity, the performance of total surface activity measurements with a given detector requires the determination of appropriate count times and/or scanning rates. Specifically, a Minimum Detectable Activity (MDA) of 1,250 dpm/100 cm^2 for unaffected systems and 3,000 dpm/100 cm^2 for affected systems is required for total surface activity measurements. With the specialized detectors that are often required to survey inside piping or other non-standard survey surfaces encountered in plant systems, [ ]^{a,c} However, fixed point measurements can be performed with any detector and by collecting a sufficient number of measurements (and scanning when possible), plant systems can be adequately surveyed.

4.0 DESCRIPTION OF INSTRUMENTATION

NOTE

Attachment 8.9, Piping Instrumentation Figures, contains figures of each detector described in this section.

4.1 [ ]^{a,c} Pipe Detectors

The [ ]^{a,c} Two different models are available to survey plant system piping at FSV. These are the [ ]^{a,c} This detector is considered to be appropriate for making measurements in straight run piping with an inside diameter up to 2 inches. The [ ]^{a,c} and is used in up to

3 inch diameter straight run piping. [

]^{a,c}

4.2 [ ]^{a,c} Detector

The [

]^{a,c}

[

]^{a,c} Possible applications include, tanks, sumps, wells, and other large bore (i.e., 7 inch diameter and larger) piping and components.

4.3 [ ]^{a,c} Assemblies

4.3.1 General

In cases where piping cannot be surveyed with [ ]^{a,c} (i.e., the piping contains bends or is too large for [ ]^{a,c} but not large enough for the [

]^{a,c}

To identify each type of [

]^{a,c} Each of the assemblies developed to date are described in the following sections.

4.3.2 Model SP-175-3M Assembly

The Model SP-175-3M assembly consists of [

]^{a,c}

[

]^{a,c} Applications include surveying piping (or components) with an inside diameter from 4 to 12 inches, although typical use is for 4 to 6 inch piping.

4.3.3 Model SP-113-3 Assemblies

The SP-113-3 assemblies (which include the SP-113-3M and SP-113-3T) consist of [

]^{a,c}

The design of the SP-113-3M assembly [

]^{a,c} This assembly was especially designed to survey gas bottles by entering the bottle through an end opening and expanding out to the inside surface of the bottle. This assembly is [

]^{a,c,f} for surveying 3 to 6 inch diameter straight run piping.

With the SP-113-3T assembly, [

]^{a,c} includes the ability to pass through 90 degree piping bends. The assembly is applicable for surveying long runs of piping, including piping with bends, with an inside diameter from 3 to 6 inches.

4.3.4 Model SN-113-3 Assemblies

The SN-113-3 assemblies (which include the SN-113-3C and SN-113-3T) consist of [

]^{a,c}

The housing design for the SN-113-3C assembly [

]^{a,c} This assembly is applicable for 3 or 4 inch diameter piping with bends.

Detector position control for the SN-113-3T [

]^{a,c} to survey 3 inch piping with bends.

4.3.5 Model SN-050-4K Assembly

The SN-050-4K assembly [

]^{a,c}

4.3.6 Model SN-050-6K Assembly

The SN-050-6K assembly [

]^{a,c}

4.4 Special Use [ ]^{a,c}

Specialty [

]^{a,c} and lengths from 3 to 7 inches. The detectors are used with the M2350 Data Logger to supply the necessary bias voltage and ability to log the measurement result.

5.0 CALIBRATION METHODOLOGIES

5.1 Calibration Sources

The radionuclide selected for calibration of the detectors used in plant system piping is Tc-99. Tc-99 is a pure beta emitter with an average beta energy of 84.6 keV and a long half-life of 2.13E5 years. The Average Beta Energy (Ebar) expected in "detectable" plant contamination, (i.e., excluding hard to detect nuclides such as Fe-55 and H-3 that are addressed by reducing the Site Guideline Values, SGLV) at Fort St. Vrain is 113.6 keV. Attachment 8.1, Average Beta Energy (Ebar) for Detectable Plant Contamination at Fort St. Vrain, presents the calculation performed to determine Ebar, which is based on the same samples used to determine the SGLVs. Therefore, a conservative estimate of piping contamination can be made with a Tc-99 calibrated detector.

[

]^{a,c}

5.2 Calibration Procedures

5.2.1 [ ]^{a,c} Detectors

The operating voltage for the pipe detectors [ ]^{a,c} is determined by generating a response vs. voltage curve and selecting a point on the "plateau" region of the curve. Typical operating voltages for these detectors are approximately 1600 volts. Example plateaus are provided in Attachment 8.2, Plateau Data for [ ]^{a,c} Detectors.

Efficiencies for the pipe detectors are established by determining the detector's response to a source while centered in a calibration jig [

]^{a,c}

The Tc-99 sources used with the piping detectors are approximately [

]^{a,c} During calibration, an initial response ± 20% tolerance band is calculated to which all subsequent source checks are compared to verify operation of the detectors.

5.2.2 [ ]^{a,c} Detector

When surveying tanks or very large wells or piping (i.e., ≥30 inch diameter) the [

]^{a,c,f}

If the detector will be used to survey wells, piping or components whose diameter is <30 inches (and at least 7 inches as is necessary for accessibility of the detector), an additional [

]^{a,c}

5.2.3 [$]^{a,c}$ Assemblies and Special Use [$]^{a,c}$

Operating voltages for the [$]^{a,c}$ are as specified by the [$]^{a,c}$ manufacturer. When a batch of [$]^{a,c}$ are received, initial screening tests are conducted on the tubes to verify their operation. These tests include background and source response checks to verify each tube operates as expected for the given [$]^{a,c}$ design. Additionally, plateaus are generated on a sampling of the purchased [$]^{a,c}$ to confirm that rated voltages are appropriate. Dead time corrections use the value stated by manufacturer. At the count rates these detectors are used (i.e., final survey measurements), dead time corrections will be insignificant.

Efficiencies are determined by taking measurements with a source whose diameter is approximately the same as the detector window. [

$]^{a,c,e}$

6.0 PERFORMANCE TESTING

6.1 LMI Pipe Detectors

6.1.1 Linearity Testing

To examine the linear operation of the cylindrical gas flow pipe detectors, the response of the detectors was checked with different source strengths. Specifically, the response of the [$]^{a,c,e}$ Linearity Test Results for [$]^{a,c}$ contains the test results. As indicated by the results, the test data was linear within the allowed tolerance band for both the [$]^{a,c}$

6.1.2 Uniformity Testing

The [$]^{a,c}$ detectors were designed to achieve an [$]^{a,c,e}$ Nonetheless, this was investigated by performing response checks with the detectors [ ]^{a,c,e} source measurements.

[ ]^{a,c} Uniformity Test Results for [ ]^{a,c} Detectors, contains the test results. As indicated by the results, the test data was within the allowed tolerance band at each [ ]^{a,c,e}

6.1.3 [ ]^{a,c} Testing

The degree of [ ]^{a,c} amplification within a [ ]^{a,c} is dependant on the [ ]^{a,c} within the detector and therefore can vary with [ ]^{a,c} rate. [ ]^{a,c,e} As indicated by the results, the detectors were very consistent over this flow rate range.

6.2 [ ]^{a,c} Assemblies

6.2.1 Comparison Study with [ ]^{a,c,f} Survey Method

To evaluate the measurement method of [ ]^{a,c} assemblies, a comparison study was performed with the SN-050-4K assembly and [ ]^{a,c,e} (i.e., lines L1414 and L1416). Measurements were taken at regular intervals in each pipe by both survey methods. Attachment 8.7, SN-050-4K vs. [ ]^{a,c} Comparison Test Results, contains plots of the measurement results.

Compared data for line L1414 is considered very good. Both methods produced the same approximate contamination profile in the pipe. Two localized spots (i.e., at 0 feet and 50 feet) yielded different values by each method as can be expected [

$]^{a,c,e}$

Such inherent [$]^{a,c,e}$ determination of the average contamination in a given pipe. This was evidenced by the average results for L1414 where 4.4 kdpm/100 cm^2 and 4.2 kdpm/100 cm^2 were determined for the SN-050-4K assembly and [$]^{a,c,e}$ respectively.

L1416 data was also in good agreement. In this pipe both methods indicated that the pipe was clean (i.e., all measurements <12 kdpm/100 cm^2, and average <4 kdpm/100 cm^2). The [$]^{a,c,e}$ did indicate one outlying result of 8.6 kdpm/100 cm^2 that was not detected by the SN-050-4K. However, due to the long count times required for the SN-050-4K, measurements were taken at 40 inch intervals in this pipe while [$]^{a,c,e}$ This elevated reading was located at a pipe position not monitored by the SN-050-4K; therefore, the [$]^{a,c}$ assembly could not be expected to detect this spot. The average contamination levels determined by each method are in acceptable agreement considering that MDAs for both methods were approximately 2 kdpm/100 cm^2.

Additional comparison testing is planned with other [$]^{a,c,f}$ detectors and will be included in a later revision of this document.

6.2.2 Comparison Study with [$]^{a,c}$ Pipe Detectors

Testing is underway to compare the [$]^{a,c,f}$ detector assemblies and [$]^{a,c,e}$ and will be included in a later revision of this document

7.0 SURVEY TECHNIQUES

7.1 Detector Sensitivity (MDA)

The sensitivity of detectors used to measure total surface activity in plant system piping is quantified by determining a MDA. Counting sensitivity, or MDA, is targeted to meet action levels as defined in the final survey plan for both unaffected and affected plant system survey units. From the target MDAs, count times for stationary (i.e., fixed point) measurements are calculated.

Fixed point measurements in unaffected plant systems are counted for a sufficient time to achieve a MDA of 1,250 dpm/100 cm^2. This MDA is based on the reclassification action level of 25% of 5,000 dpm/100 cm^2 (i.e., the controlling limit for unaffected plant systems). For affected plant systems, fixed point measurements are counted to achieve an MDA of 3,000 dpm/100 cm^2. This value corresponds to 75% of 4,000 dpm/100 cm^2 (i.e., SGLV for affected plant systems), which is the investigation action level for affected plant systems; however, a MDA of 2,000 dpm/100 cm^2 will be targeted when appropriate (i.e., for detectors with higher sensitivities).

The equation used to calculate MDA is as follows:

$$MDA = \frac{\dfrac{2.71}{t_s} + 3.29\sqrt{\dfrac{R_b}{t_s} + \dfrac{R_b}{t_b}}}{(Efficiency)\left(\dfrac{A}{100}\right)}$$

where t_s is the sample count time (min),

t_b is the background count time (min),

R_b is the background count rate (cpm), and

A is the detection area in cm^2.

For flat-surfaced detectors, the area of detection is equal to the area of the detector window. With the [ ]^{a,c} piping detectors, the area of detection is equal to the inside surface area of the pipe over the active length of the detector. For 1 inch diameter and greater piping, this area is greater than 100 cm^2 for the [ ]^{a,c} detectors (which have an active length of approximately 6 inches). However, it is assumed that the detectors response originates from contamination that is distributed over only 100 cm^2.

[ ]^{a,c,f}

Scanning for surface activity has traditionally been performed at an approximate rate of 2 inches/sec. With this scan rate, standard detectors (e.g., HP-210 "frisker" probes or rectangular gas flow detectors such as the [ ]^{a,c} can achieve reasonably low MDAs. However, the specialized detectors that are necessary to survey internal surfaces of plant system piping have lower efficiencies and detection areas, both of which limit their sensitivity. Therefore, scanning, in the conventional sense, is considered to be impractical for many of these detectors, but will be performed when measurement locations allow the use of standard detectors or specialized detectors that can meet or exceed the sensitivity of standard detectors.

7.2 Background Measurements

To determine the net count rate at a given survey location, the background count rate must be known. This is determined by [

]^{a,c,e} Attachment 8.8, Shielding Detectable Contamination at Fort St. Vrain, presents the calculation performed to evaluate the shielding used for background measurements.

Generally speaking, [

]^{a,c,e}

Plant system internal surfaces are almost exclusively metal, which, for the metals typically used to construct plant systems, contain insignificant natural beta radioactivity. Accordingly, additional corrections (i.e., background subtractions) to the net survey results are not performed. Should survey surfaces be found or expected to contain natural surface activity (e.g., wall and floor penetrations without steel sleeves), evaluations will be performed to determine the appropriate background subtract values to be applied to plant system survey data so the results reflect only licensed material.

7.3 Surface Activity Measurements

Specific survey instructions and procedures will be used to control the survey and data analysis process for plant system survey units. The basic process will involve scanning at the location (if possible), and the collection of fixed and removable measurements.

Scanning for surface activity (i.e., for those detectors capable of performing scans) in plant system piping is performed by slowly (2 inches/sec or less) moving the probe through or across the pipe or other survey surface. The fixed point measurement is then typically performed at the specific point yielding the highest audible response. If no increase in count rate is noticeable, a biased location is chosen for the fixed point measurement (e.g., at pipe welds, in open valves, etc.). The fixed point measurement is performed by taking an unshielded and shielded reading. Following the collection of fixed point readings, samples for removable surface activity are collected for laboratory analysis.

To verify the proper operation of the detectors used to perform Final Survey of plant system piping, a pre-use and post-use response check is performed. These checks are performed with the source jigs used to determine the detectors initial response and calibration and are required to be within ±20% of the value observed at time of calibration.

7.4 Summary of Piping Instrumentation Capabilities

Table 1 below summarizes the piping instrumentation developed to date for FSV. Included in the table are the basic parameters, advantages, disadvantages, and applications of the various detector types and assemblies available to survey plant system internal surfaces. The efficiency and background values represent average results from past measurements.

The count times in the table are based on using the same count time for both background and sample measurements and are rounded up to convenient values. The selection of appropriate detectors and specific count times to be used for a given plant system survey unit are identified in specific survey instructions that are prepared in accordance with an approved procedure. The detectors that are considered capable of performing scans (i.e., at 2 inches/sec) include the [

]^{a,c,f}

TABLE 1 - SUMMARY OF PLANT SYSTEM SURVEY DETECTORS

a,c,f

8.0 ATTACHMENTS

8.1 Average Beta Energy (Ebar) for Detectable Plant Contamination at Fort St. Vrain

8.2 Plateau Data for LMI Gas Flow Pipe Detectors

8.3 Effective Survey Distance in Large Diameter Piping

8.4 Linearity Test Results for [ ]^{a,c} Detectors

8.5 Uniformity Test Results for [ ]^{a,c} Detectors

8.6 Gas Flow Test Results for [ ]^{a,c} Detectors

8.7 SN-050-4K vs. [ ]^{a,c,f} Survey Comparison Test Results

8.8 Shielding Detectable Contamination at Fort St. Vrain

8.9 Piping Instrumentation Figures

ATTACHMENT 8.1
AVERAGE BETA ENERGY (EBAR) FOR DETECTABLE PLANT CONTAMINATION AT FORT ST. VRAIN

Table 1 below presents the relative radionuclide composition of various samples and smears taken at Fort St. Vrain for the "detectable" radionuclides. These particular samples, which are decay corrected to January 1, 1996, are the ones used to determine the Site Specific Guideline Values (SGLV). Also presented in the table, is the average radionuclide composition that is determined by assigning equal weight to each of the individual samples. Only the "detectable" (i.e., readily detectable) nuclides are included in the calculation because the hard to detect nuclides and alpha emitters are accounted for by reducing the SGLV.

TABLE 1 - RELATIVE RADIONUCLIDE COMPOSITION OF FORT ST. VRAIN SAMPLES/SMEARS

	Co-60	Sr-90	Cs-134	Cs-137	Eu-152	Eu-154	Tc-99
PCRV Smear	7.25E-1	3.75E-3	3.28E-3	1.02E-1	1.56E-1	1.03E-2	
HSF Smear	9.87E-1	2.75E-4		1.24E-2			
FHM Smear	9.33E-1	4.93E-3	1.30E-3	5.58E-2			
Liquid Waste Resin	3.44E-2	1.39E-3	4.72E-2	9.17E-1			
PCRV Concrete	1.17E-1		4.53E-3		8.08E-1	5.66E-2	1.34E-2
Graphite Dust	3.22E-1	9.15E-5			6.27E-1	5.12E-2	
PCRV Access Flange	9.78E-1	2.26E-3	1.51E-3	1.77E-2			
PCRV Shield Plug	8.56E-1	6.01E-3	1.85E-3	1.36E-1			
Average Fraction	6.20E-1	2.34E-3	7.46E-3	1.55E-1	1.99E-1	1.48E-2	1.68E-3

To determine Ebar for the average radionuclide composition, Ebar for each radionuclide is determined using published tabulations. In the individual nuclide Ebar calculation, electrons from internal conversion, auger electron emission as well as beta decay are considered "beta particles" because each electron of a given energy (without regard to its decay source) has the same probability of interacting with a detector. In addition, any daughter nuclides that can be assumed to be in equilibrium with the parent are factored into the calculation (e.g., the Sr-90 daughter Y-90 and the Cs-137 daughter Ba-137m).

The equation used to calculate Ebar for a given radionuclide is as follows:

$$Ebar = \frac{\sum_{1}^{N} (Abundance * BetaEnergy)}{\sum_{1}^{N} (Abundance)}$$

where N is the number of individual branches of the radionuclide (i.e., each auger, conversion, or beta decay electron and its associated energy)

The Ebar calculation for each individual radionuclide uses all electron energies, including low energy auger electrons. This was done to ensure a consistent approach is followed with each nuclide and the range of its electron emissions. Most auger electrons and some of the beta decay electrons (which are emitted with an energy spectrum from zero to a characteristic maximum) are unable to reach the detector due to their low energy. To be consistent in omitting electron energies not expected to be detected would require correcting for all low energy electrons, including beta decay. Consequently, the consistent approach of using all energies emitted by a given radionuclide is followed. A summary of the Ebar values for each radionuclide that are used in the overall average Ebar calculation is provided in Table 2 below:

TABLE 2 - EBAR DATA SUMMARY

	Co-60	Sr-90	Cs-134	Cs-137	Eu-152	Eu-154	Tc-99
Average Fraction	6.20E-1	2.34E-3	7.46E-3	1.55E-1	1.99E-1	1.48E-2	1.68E-3
Ebar (keV)	95.8	565.3[2]	159.6[1]	196.8[1,2]	87.2[1]	149.2[1]	84.6
Beta Abundance[3]	1.000	2.000[2]	1.015[1]	1.174[1,2]	1.424[1]	1.838[1]	1.000

NOTES:

[1] Data include contributions from conversion and auger electrons

[2] Data include contributions from daughter

[3] Beta Abundance is the average number of beta particles emitted per decay

To determine overall Ebar for the average radionuclide composition, the following equation is used:

$$Ebar = \frac{\sum_{1}^{N} (AverageFraction * Abundance * BetaEnergy)}{\sum_{1}^{N} (AverageFraction * Abundance)}$$

where N is the number of detectable radionuclides in the average composition. Using the preceding equation and data from Table 2, the results of Table 3 are obtained.

Note: The denominator of this equation is the beta abundance (i.e., average number of beta particles emitted per decay) for average radionuclide composition at FSV.

Using the preceding equation and data from Table 2, the results of Table 3 are obtained.

TABLE 3 - EBAR RESULTS FOR RADIONUCLIDE COMPOSITION

Ebar (keV)	Beta Abundance
113.6	1.126

ATTACHMENT 8.2
PLATEAU DATA FOR [ ]^{a,c} PIPE DETECTORS

[ ]^{a,b,c}

ATTACHMENT 8.2
PLATEAU DATA FOR [ ]^{a,c} PIPE DETECTORS

[ ]^{a,b,c}

[ ]c

c

[ ]^{c}

ATTACHMENT 8.4
LINEARITY TEST RESULTS FOR [ ]^{a,c} DETECTORS

a,b,c

[ ]

ATTACHMENT 8.4

LINEARITY TEST RESULTS FOR [ ]a,c DETECTORS

a,b,c

ATTACHMENT 8.5
UNIFORMITY TEST RESULTS FOR [ ]^{a,c} DETECTORS

[ ]^{a,b,c}

ATTACHMENT 8.5
UNIFORMITY TEST RESULTS FOR [ ]^{a,c} DETECTORS

[ ]^{a,b,c}

ATTACHMENT 8.6
[$]^{a,c}$ TEST RESULTS FOR [$]^{a,c}$ DETECTORS

a,b,c

ATTACHMENT 8.6

[ ]^{a,c} TEST RESULTS FOR [ ]^{a,c} DETECTORS

[ ]^{a,b,c}

ATTACHMENT 8.7

SN-050-4K VS. [ ]^{a,c,f} COMPARISON TEST RESULTS

a,b,c,f

ATTACHMENT 8.7
SN-050-4K VS. [ ]^{a,c,f} COMPARISON TEST RESULTS

a,b,c,f

ATTACHMENT 8.8
SHIELDING DETECTABLE CONTAMINATION AT FORT ST. VRAIN

a,c,f

a,c,f

a,c,f

a,c,f

FIGURE 1: [ ]^{a,c}

FIGURE 2: [ ]^{a,c}

ATTACHMENT 8.9
PIPING INSTRUMENTATION FIGURES

a,b,c

Figure 3 [ ]^{a,c}

a,f

a,f

a,f

a,f

a,f