VISTA Technologies, Inc.
Radiation Safety Program

PROCEDURE - 16

AIR RADIOLOGICAL SAMPLING

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ABBREVIATIONS AND ACRONYMS

α	-	Alpha
ß	-	Beta
γ	-	Gamma
μ	-	Micro
^{241}Am	-	Americium-241
^{137} Ce	-	Cesium-137
^{234}Pa	-	Protactinium-234
^{210}Pb	-	Lead-210
^{210}Po	-	Polonium-210
^{214}Po	-	Polonium-214
^{218}Po	-	Polonium-218
^{232}Pu	-	Plutonium-232
^{226}Ra	-	Radium-226
^{228}Ra	-	Radium-228
^{219}Rn	-	Radon-219 (Actinium Series)
^{220}Rn	-	Radon-220 (Thorium Series)
^{222}Rn	-	Radon-222 (Uranium Series)
^{89}Sr	-	Strontium-89
^{90}Sr	-	Strontium-90
^{230}Th	-	Thorium-230
^{232}Th	-	Natural Thorium
^{238}U	-	Uranium-238
μCi	-	MicroCurie
μCi/hr	-	MicroCuries per hour
μCi/ml	-	MicroCuries per milliliter
μM	-	Micrometer
μR/hr	-	MicroRoentgen per hour
μg/mg	-	Microgram per milligram
ALARA	-	As low as reasonably achievable
ALI	-	Annual limit on intake
ANSI	-	American National Standards Institute
APR	-	Air-purifying respirator
Bq	-	Becquerel
Bq/m^3	-	Becquerels per cubic meter of air
BZ	-	Breathing Zone
C	-	Coulomb
C/kg	-	Coulombs per kilogram
CDE	-	Committed Dose Equivalent
CEDE	-	Committed Effective Dose Equivalent

CFR	-	Code of Federal Regulations
Ci	-	Curie
CIH	-	Certified Industrial Hygienist
CFM	-	Cubic feet per minute
CLIA	-	Clinical Laboratories Improvement Act
CLP	-	Contract Laboratory Program
cm	-	Centimeter
cm/sec	-	Centimeters per second
cpm	-	Counts per minute
CPR	-	Cardiopulmonary resuscitation
CSE	-	Certified Safety Executive
(D)	-	Duplicate count
DAC	-	Derived air concentration
DAC-h	-	DAC hours
DCA	-	Double Contingency Analysis
DDE	-	Deep Dose Equivalent
DI	-	De-ionized water
DOT	-	U.S. Department of Transportation
dm^2	-	Square Decimeter; one square decimeter equals 100 square centimeters
dpm	-	Disintegrations per minute
dpm/cm^2	-	Disintegrations per minute per square centimeter
dpm/dm^2	-	Disintegrations per minute per square decimeter
dps	-	Disintegrations per second
DRD	-	Direct reading dosimeter
DU	-	Depleted uranium
EPA	-	U.S. Environmental Protection Agency
eV	-	Electronvolt
FE	-	Feces sample
FIDLER	-	Field instrument for detection of low energy radiation
FR	-	Filter ratio
FSP	-	Field Sampling Plan
ft^2	-	Square foot
γ	-	Gamma ray
GA	-	General area
GeLi	-	Germanium - Lithium
G-M	-	Geiger-Mueller
GMC-H	-	Mine Safety Appliances Company, full-facepiece, dual ..combination filter cartridges for an APR
GPD	-	Gaseous Diffusion Plang
h	-	hours
He-3	-	Helium Three (3)

HEPA	-	High efficiency particulate air
HNO_3	-	Nitric acid
HP	-	Health Physics
hr	-	Hour
HS	-	Hot spot (radiation)
HSP	-	Site-specific Health and Safety Plan
HWP	-	Hazardous Work Permit
ICRP	-	International Commission on Radiological Protection
ID	-	Identification
IDLH	-	Immediately dangerous to life or health
IDW	-	Investigation derived waste
IP	-	Ionization potential
IVC	-	Independent verification contractor
keV	-	Kiloelectronvolt
kg	-	Kilogram
LANL	-	Los Alamos National Laboratory
lpm	-	Liters Per Minute
MCA	-	Multi-channel analyzer
MDA	-	Minimum detectable activity
meV	-	Millielectronvolt
m	-	Meter
m^2	-	Squared Meters
m^3	-	Cubic meters
mCi	-	MilliCurie
MSHP	-	Manager, Vista Safety and Health Program
mil	-	1/1000 inch
ml	-	Milliliter
mm	-	Millimeter
mR	-	MilliRoentgen
mR/hr	-	MilliRoentgens per hour
mrem	-	Millirem
mrem/hr	-	Millirems per hour
MSA	-	Mine Safety Appliances Company
MSDS	-	Material Safety Data Sheet
MSHA	-	Mine Safety and Health Administration
NaI	-	Sodium iodide
NCA	-	Nuclear Criticality Analysis
NCS	-	Nuclear Criticality Safety
NCRP	-	National Council on Radiation Protection and Measurements
NEA	-	Nuclear Energy Agency
NIST	-	National Institute of Science and Technology

NIOSH	-	National Institute for Occupational Safety and Health
n. o. s.	-	Not otherwise specified
NPDES	-	National Pollutant Discharge Elimination System
NRC	-	U.S. Nuclear Regulatory Commission
NS	-	Nose swipe
NTIS	-	National Technical Information Service
NVLAP	-	National Voluntary Laboratory Accreditation Program
OHSO	-	On-Site Health and Safety Officer
ORNL	-	Oak Ridge National Laboratory
ORPO	-	On-Site Ionizing Radiation Protection Officer
OSHA	-	U.S. Occupational Safety and Health Administration
pCi	-	PicoCurie
pCi/gm	-	PicoCuries per gram
pCi/l	-	PicoCuries per liter
P.E.	-	Professional Engineer
PF	-	Protection Factor
PIC	-	Pocket Ionization Chamber
PM	-	Project Manager
PMT	-	Photomultiplier Tube
PPE	-	Personal Protective Equipment
PRP	-	Potentially Responsible Party
PRS	-	Portable ratemeter/scaler
PVC	-	Polyvinyl chloride
QA	-	Quality assurance
QC	-	Quality control
R	-	Roentgen
RA	-	Restricted (radiation) area
rad	-	Radiation absorbed dose
RAS-1 -		Kurz air sampling pump flow calibration kit
REM	-	Roentgen equivalent man
RHSC	-	Radiation Health and Safety Committee
RSO	-	VISTA Radiation Safety Officer
RWP	-	Radiation work permit
SAP	-	Sampling and Analysis Plan
SCBA	-	Self-contained breathing apparatus
SRD	-	Self-reading dosimeter
TODE	-	Total Organ Dose Equivalent
TLD	-	Thermoluminescent dosimeter
TWA	-	Time-weighted average

U^{nat}	-	Natural uranium
UR	-	Urine sample
U.S.	-	United States
VISTA	-	Vista Technologies, Inc.
VSHP	-	VISTA Safety and Health Program
VRSP	-	VISTA Radiation Safety Program
WL	-	Working Level
WP	-	Work Plan

1. AIR RADIOLOGICAL SAMPLING

1.1. Scope

This section provides guidelines for the selection, operation, and documentation of the results of air samples performed on Vista field projects. The same basic method is used for both occupational samples (such as high-volume job-related samples and personal air samples), and for fence-line ambient air samples.

1.2. Purpose

The purpose of this procedure is to provide procedural guidance to ensure a) optimum and adequate protection of workers; b) conformance with sound health physics and radiological safety practices; and c) compliance with 10 CFR 20. An additional purpose of this procedure is to provide guidance in the selection of air sampling equipment for monitoring airborne radioactive contamination at Vista project work sites. This procedure also describes the types of equipment used for specific determinations and the documentation requirements.

Air in the work environment is analyzed to determine the types and magnitude of the radiological contaminants present. Airborne sampling for radiological contaminants may also determine the effectiveness of engineering controls to minimize exposure to airborne radiological contaminants. Airborne measurements of radiological contamination are useful for determining if a routine bioassay program is warranted and for determining when non-routine bioassay samples should be collected.

This procedure describes the sampling techniques used in occupational and environmental monitoring of airborne radioactive particulates at Vista project work sites. This procedure also describes the types of equipment used for specific determinations and the documentation requirements therein.

1.3. References

- 10 CFR 20, "Standards for Protection Against Radiation"
- NRC 0041, "Manual of Respiratory Protection Against Airborne Radioactive Materials"
- NRC Regulatory Guide 8.25, "Air Sampling in the Workplace"
- ANSI N13.1, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities"

1.4. Responsibilities

The following sections describe responsibilities of the Vista Project Manager (PM), Vista Radiation Safety Officer (RSO), Vista On-site Radiation Protection Officer (ORPO), and field technical staff.

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

1.4.1. Project Manager

The PM is responsible for:

- Overall Project performance.

1.4.2. Radiation Safety Officer

The Vista RSO is responsible for:

- Implementing this procedure:
- Periodic reviewing of adherence to the requirements of this procedure.
- Periodic reviewing of air sample data to verify effectiveness of engineering controls, and
- Ensuring that the Vista ORPOs are qualified by training and experience to perform the requirements of this procedure:

1.4.3. On-Site Radiation Protection Officer

The Vista ORPOs will be will be responsible for:

- Reviewing and approving documentation generated by the use of this procedure.
- Performing air monitoring and subsequent calculations in accordance with the requirements of this program and 10 CFR 20;
- Performing air monitoring in accordance with procedures for the operation of sampling equipment as outlined in this chapter; and
- Documenting all work performed under this section.

1.4.4. Field Technical Staff

Field technical staff are responsible for:

- Notifying the Vista ORPO prior to the start of any work under an Radiation Work Permit (RWP) requiring respiratory protection: and
- Notifying the Vista ORPO prior to entering any areas posted: "Airborne Radioactivity Area."

Selection of filters and sampling pumps, location of air samplers, measurement of Radon-222 daughters, and passive measurement of Radon-220 (^{220}Rn) and Radon-222 (^{222}Rn) are discussed in the following sections.

2. COMPREHENSIVE AIR SAMPLING PROGRAM

A comprehensive air sampling program is essential to evaluate the hazards associated with work situations involving radioactive materials. In many instances, air sampling data can also provide the basis for development and evaluation of control procedures and can indicate whether or not operational changes are necessary to provide adequate protection for workers. In conjunction with a respiratory protection program, air sampling data is necessary to define the air concentration levels so that the proper respiratory protective equipment can be selected.

Ambient air monitoring will be performed in areas with the potential to exceed 10 percent of a Derived Air Concentration (DAC). Ambient air monitoring may be performed using portable air samplers or air monitoring systems. Ambient air monitoring will be placed in strategic locations to detect and evaluate airborne contamination at work locations. Data obtained from air monitoring will be used for assessing the control of airborne radioactivity in the workplace and may be used to evaluate the dose equivalent to radiation workers from internal contamination.
Air monitoring systems will be routinely calibrated and maintained per Procedure 12 "Operation and Calibration of Instruments" and should be capable of measuring one DAC when averaged over 8 hours.

Since respiratory protection factors vary over several orders of magnitude, it is very important that an initial estimate be made of the air concentration level, relative to specified regulatory limits. Thus, adequate protection can be provided while unnecessary inconvenience to the worker by wearing a respirator is minimized. Air sampling programs may also be designed to estimate the release of contaminants to the general work area and to the outside environment.

An air sampling program directly related to respiratory protection should:

- Provide an estimate of the potential intake of airborne radioactive materials and resulting exposure of the individual worker;
- Provide data to assist in the selection of respiratory protective equipment that would provide adequate protection under exposure conditions;
- Provide data for control of long-term exposure to workers;
- Provide documentation of personnel exposures for legal or regulatory purposes;
- Identify and characterize the contaminants and their sources;
- Provide data for determining the requirements for engineering or administrative controls;
- Indicate the continuing effectiveness of existing controls, and warn of deterioration of control equipment or operating procedures;
- Provide a record of long-term trends showing variations in contaminant levels; and
- Continuously measure the level of airborne contaminants in and above work areas and warn of release of airborne contaminants to the outside environment.

3. CONSIDERATIONS IN AIR SAMPLING

An air sampling program must be designed and operated so that the data obtained are directly and meaningfully related to the problem of concern. As part of a respiratory protection program, the air-sampling procedures must take into account:

- The physical and chemical state of the contaminant;
- Aerodynamic size characteristics of airborne particulates;

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

- Range of contaminant concentration;
- Environmental conditions such as temperature;
- Sampler location relative to the worker and the source of contamination;
- Instrument operating and response characteristics;
- Instrument portability; and
- Sensitivity of the associated analytical procedures relative to the specified concentration limits and quantity of material sampled.

Air may be sampled for various types of radioactive material (particulates, radioiodines, radiogases, or tritium.) Particulates are normally collected on paper filter material. Radioiodines are normally collected by charcoal cartridges. Radiogases are normally collected as a fixed trapped volume of air. Tritium is normally collected by bubbling air through water.

4. TYPES OF AIR SAMPLING

Low volume air samples operate at a flow rate of 1 Cubic Feet Per Minute (CFM) which equals 28.32 Liters Per Minute (LPM) to 5 CFM (141.6 LPM).
High volume air samples operate at a flow rate of 10 CFM (283.2 LPM) to 30 CFM (849.6 LPM).

General Area (GA) airborne surveys provide data representative of the air in an area, building, or room. GA surveys normally provide the data used for determining if an area is an Airborne Radioactivity Area for implementing posting and access controls. Using a low volume air sampler, the minimum volume for GA air samples is $100ft^3$ (2,832 liters). The following are GA air sampling guidelines:

- GA samples are normally taken on a routine basis, including predetermined times and locations;
- GA samples should be taken at between 3 to 6 feet above floor level;
- GA samples may be taken in a period of time varying from an hour up to one or more days, generally known as a "continuous sample;"
- GA samples are normally obtained and analyzed as a minimum for particulates by gross α, ß-γ counting;
- Breathing Zone (BZ) airborne surveys provide data representative of the air that workers would be breathing during a particular task. The minimum volume for BZ air samples is 50 ft^3 (1,416 liters);
- BZ samples are normally taken as a minimum during the time when the highest concentrations of radioactive material are expected to be present;
- BZ samples may be taken at any time to document low, high, and average concentrations of airborne radioactive material;
- BZ samples are normally taken in a position which would be representative of the air which would be breathed by a worker, regardless if a respirator is being worn or not. The samples should be taken within a circumference of 12 inches of the worker's head, if possible; and
- BZ samples are normally analyzed for particulates.

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Grab samples are taken with a high volume sampler. The minimum volume required for grab samples using a high volume sampler is 150ft^3 (4,248 liters). Grab samples represent the concentrations during the relatively short period of sampling time and may be useful to estimate peak concentrations if this type of data is required.

Continuous samples are normally taken with low volume air samplers due to the long run times involved. The minimum volume for continuous air samples is 100ft^3 (2,832 liters). Continuous samples represent the concentrations during the relatively long period of sampling time and are used to estimate average concentrations.

Continuous samples are not normally used where airborne concentrations are expected to vary significantly during the time period of interest. Either grab or continuous samples may be representative of areas where airborne concentrations are not expected to vary significantly over a time period of interest.

4.1. Background Air Samples

Background air sampling should be performed in areas where work activities are not being performed. Consideration should also be made in sampling the work area prior to work starting in the area. The data obtained from these samples should be used as a baseline for work area ambient and breathing zone air samples.

4.2. Sampling and Analysis for Radioactive Noble Gases

Start-up procedures are as follows:

a) Obtain a 500 ml marinelli beaker.
b) Ensure the beaker is free of contamination or that a background count of the beaker has been performed.
c) Ensure petcocks are free to be opened/closed.
d) Fill the beaker with de-ionized water, if available, or tap water, if not, and replace the top.

At the sample location:

a) Remove the marinelli beaker top and pour the water from the beaker.
b) Replace top securely.
c) Ensure petcocks are closed.

The chamber is to be analyzed for gamma isotopic as soon as possible after sampling to minimize error due to noble gas loss by diffusion or decay.

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4.3. Sampling and Analysis for Radioiodines

- Obtain a low volume air sampler with a particulate filter and charcoal cartridge arrangement.
- At the sampling location(s):

  - Start the air sampler.
  - Sample time should be for a minimum volume of $100ft^3$ (2,832 liters).
  - At the end of the sampling period, stop the sampler.
  - Send the filter and charcoal cartridge for gamma isotopic analysis.
  - Request results of the analysis in µCi/ml and percent DAC.

4.4. Sampling and Analysis for Tritium or Carbon 14

- Obtain sample pump and tritium bubbler sampling system.
  - Sampling pump;
  - Midget bubbler with 25 milliliters of de-mineralized water;
  - Filter to remove particulate material from air sample; and
  - Assemble sampling system with filter upstream of bubbler and bubbler upstream of pump.

- At sampling location:
  - Start the pump and if flow rate is adjustable, adjust flow rate as indicated on the sampling pump or for a gentle bubbling action in bubbler.
  - Sample time should be such that a minimum air volume of 10 liters ($0.35\ ft^3$) is sampled.
  - Send the sample to an approved laboratory for analysis.
  - Request a liquid scintillation analysis for Tritium and/or C-14.
  - The results of the analysis are expressed in µCi/ml and percent DAC.

4.5. Sampling and Analysis for Radioactive Particulate Material

- Obtain the air sampler and filter(s) to be used.

  - The filter is to be a F&J FP-47 (Low Volume) and F&J FP-4.0 (High Volume) particulate filter or filter of equivalent efficiency and characteristics.

NOTE: If the sampling head is designed for both a particulate filter and a charcoal cartridge and the sample is for particulate only, a dummy or spacer charcoal cartridge may be required to be inserted into the sampling head to ensure proper fit of the particulate filter and to duplicate calibration conditions. Refer to the samplers calibration documentation for applicability. High volume air samplers will not be used with the spacer cartridge.

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- Install the filter in the sampling head with the "fuzzy side" facing outward.
-

- At the sampling location:
  - Select flow-rate and determine time required for the needed volume of air.
    - High volume 150ft^3
    - Low volume 100ft^3
- Start the air sampler.
  - At the end of the sampling period, stop the sampler.

> NOTE: In the event the required volume of the air sample cannot be taken, the sample, regardless of volume, is still valid.

- Remove the filter at a designated location and identify and package the sample.

5. PARTICULATE SAMPLING TECHNIQUES

Grab samples are taken with a high volume sampler. The minimum volume required for grab samples using a high volume sampler is 150ft^3 (4,248 liters).

Grab samples represent the concentrations during the relatively short period of sampling time and may be useful to estimate peak concentrations if this type of data is required.

Continuous samples are normally taken with low volume air samplers due to the long run times involved. The minimum volume for continuous air samples is 100ft^3 (2,832 liters).

Continuous samples represent the concentrations during the relatively long period of sampling time and are used to estimate average concentrations.

Continuous samples are not normally used where airborne concentrations are expected to vary significantly during the time period of interest.

5.1. Selection of Filters and Sampling Pumps

5.2. Introduction

Air in the work environment is analyzed to determine the types and order of magnitude for the contaminants present. Airborne sampling may also determine the effectiveness of proper engineering controls for minimizing exposure to airborne radioactive contamination. Airborne concentration measurements are useful for determining if a routine bioassay program is warranted and for determining when non-routine bioassay samples should be collected.

5.3. Specific Instructions

Selection of airborne sampling equipment will be based on the types of radioactive contamination present. For Vista project work sites the method used to determine naturally occurring radionuclides present in the work place or at specific sites requires simple procedures. Sampling for specific types of radioactive contamination will be conducted as follows:

- Depleted Uranium

Sampling for Depleted Uranium (DU) will be conducted in areas where the potential of any exposure greater than 10 percent of the DAC exists. Sampling will be conducted by placement of a lapel sampler that has a calibrated flow rate of not less than 2 LPM. The sample medium can be glass fiber or membrane filters and should be at least 25 mm in diameter. Samples will be taken for a period long enough to assure that the sample volume exceeds 1.5×10^5 ml. Samples will be counted as long as required to report a result that is less than the DAC.

All sample results for DU will be entered on "Airborne Contamination Exposure Area Sampling Averages Calculation Data Sheet," shown as Attachment 31, for area averaging of all airborne concentrations.

The established DAC for DU is as follows:

$$2 \times 10^{-11}\ \mu Ci/ml$$

- Natural Uranium

Sampling for natural uranium (U^{nat}) will be conducted in any area where the potential of any exposure greater than 10 percent of the DAC exists. Sampling will be conducted by placement of a lapel sampler that has a calibrated flow rate of not less than 2 liters per minute; flow rates should be less than 13 liters per minute to prevent collapse of the filter described below.
Sample medium can be glass fiber or membrane filters and should be at least 25 mm in diameter. Samples will be taken for a period long enough to assure that the sample volume exceeds 1.5×10^5 ml. Samples will be counted as long as required to report a result that is less than the DAC.

All sample results for U^{nat} will be entered on Attachment 31, for area averaging of all airborne concentrations. The established DAC for U^{nat} is $2 \times 10^{-11}\ \mu Ci/ml$.

- Thorium-232

Sampling for thorium-232 (^{232}Th) will be conducted in any area where the potential of any exposure greater than 10 percent of the DAC exists. Sampling will be conducted by placement of a lapel sampler that has a calibrated flow rate of not less than 2 liters per minute, but less than 13 liters per minute. The sample medium can be glass fiber or membrane filters and should be at least 25 mm in diameter.

Samples will be taken for a long enough time to assure that the sample volume exceeds 3 liters. Samples will be counted as long as required to report a result that is less than the DAC. All sample results for ^{232}Th will be entered on Attachment 31 for area averaging of all airborne concentrations. The established DAC for ^{232}Th is 5×10^{-13} μCi/ml.

- Thorium-230

Sampling for thorium-230 (^{230}Th) will be conducted in any area where the potential of any exposure greater than 10 percent of the DAC exists. Sampling will be conducted by placement of a lapel sampler that has a calibrated flow rate of not less than 2 liters per minute, but less than 13 liters per minute.

Sample medium can be a glass fiber or membrane filter and should be at least 25 mm in diameter. Samples should be taken for a period long enough to assure that the sample volume exceeds 3 liters. Samples will be counted as long as required to report a result that is less than the DAC.

All sample results for ^{230}Th will be entered on Attachment 31 for area averaging of all airborne concentrations. The established DAC for ^{230}Th is 3×10^{-12} μCi/ml.

- Radium-226

Sampling for radium-226 (^{226}Ra) will be conducted in any area where the potential of any exposure greater than 10 percent of the DAC exists. Sampling will be conducted by placement of a lapel sampler that has a calibrated flow rate of not less than 2 liters per minute, but less than 13 liters per minute.

Sample medium will be glass fiber or membrane filter and should be at least 25 mm in diameter. Samples will be taken for a period long enough to assure that the sample volume exceeds 3 liters. Samples will be counted as long as required to report a result that is less than the DAC.

All sample results for ^{226}Ra will be entered on Attachment 31 for area averaging of all airborne concentrations. The established DAC for ^{226}Ra is 3×10^{-10} μCi/ml.

- Radon Daughters

Sampling for radon and thoron daughters will be conducted in areas where the potential for exposure greater than 10 percent of the DAC exists. Sampling will be conducted as per Procedure "Measurement of Radon-222 Daughters," and Procedure "Passive Measurements of Radon-220 and Radon-222 in Ambient Air Using Activated Charcoal Canisters." Sampling results will be documented on the form shown as Attachment 31 for area averaging.

The DAC values for both radon and thoron daughters will be as follows: 0.33 Working Levels (WL). A WL is any combination of short-lived radon daughters in 1 liter of air without regard to the degree of equilibrium that will result in the ultimate emission of 1.3×10^5 MeV of α particle energy.

- Special Nuclear Material

Special Nuclear Material (SNM) is defined in 10 CFR 20.1003 as (1) Plutonium, uranium 235, uranium-233, uranium enriched in the isotope 233 or in isotope 235". Various isotopes of SNM can emit gamma, beta, alpha and neutrons. Some of these isotopes of SNM are physically hot to the touch because of massive alpha emissions. SNM is commonly air sampled using CAM systems. The alpha and beta emissions will set of the CAM alarm. The CAM filter paper will be scanned and analyzed using a Multichannel Analyzer (MCA) system. The MCA system can determine all of the various radioisotopes in the suspected SNM, on the CAM filter paper.

- Californium 252

Californium 252 (Cf-252) emits spontaneous fission neutrons, and is commonly used as a neutron check source to check neutron detectors. Cf-252 also emits gamma rays. Cf-252 is commonly embedded in metallic materials. It could get loose as a solid material or possibly as a particulate in air.

- Americium-241

Americium-241 (Am-241) can be used as a gamma check source, and is readily available from the processing of aging weapons grade plutonium. The alphas emitted from Pu-239 Am-241 built up in aging Plutonium 239 (Pu-239) and the alphas from Pu-239 can boil water. Smear samples suspected with Am-241 contamination can be analyzed using MCA systems and or alpha spectrometers.

- Tritium Gas or Tritium Vapor

Tritium gas is heavy hydrogen. Tritium gas occurs as TH or T_2, and tritium vapor occurs as HTO or as T_2O. Tritium vapor is absorbed extremely fast (25,000 times faster than tritium gas) through the skin. Tritium gas readily combines with organic compounds. Tritium gases can occur around some nuclear warheads. Tritium compounds are also used in some rifle pistol day night vision scopes. Sampling for tritium compounds, gas or vapor is commonly done using Liquid Scintillation Counters (LSC). Suspected contaminated objects and surfaces are swiped, and the swipe dissolved in a LSC liquid then counted in a LSC system.

- Fission Products

Fission products are produced to some extent by some spontaneous fissioning in all fissile materials, and particularly in Weapons Grade (WG) Plutonium (Pu). WG Pu contains some Pu-

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240 that undergoes spontaneous fission. These fission neutrons in turn produce more fissioning in all of the WG Pu and americium isotopes. (Americium 241 will always be produced in almost all WG Pu.). Additional fissioning will also be produced by the (alpha, neutron) reaction in all of the Wg Pu isotopes. Thus, WG Pu will always coexist with fission products (FP). Fission products will be typically radioactive elements across the periodic table, however the predominance of FPs will be located near the center of the periodic table. Therefore, anywhere where WG Pu is manufactured, machined, assembled/disassembled to/from nuclear weapons (NWs), or stored will absolutely have some coexisting FPs. This is particularly true in all of the U.S. DOE nuclear weapons facilities, such as, the Savannah River Site (SRS), Rocky Flats, PANTEX, Los Alamos National Laboratory (LANL), and Hanford facilities. Fission products emit gamma, beta, alpha, and neutron radiation. Thus, depending on how the FPs are contained (and shielded), none, some, or combinations of all of the above nuclear radiation will be emitted from the enclosures (e.g., piping, glove boxes, duct work) where FPs and or WG Pu exists.

- Other Particulate Sampling

Shavings and fines of Uranium and Plutonium always occur in U.S. DOE nuclear weapons manufacturing facilities, such as, Rocky Flats (near Denver, CO.) and the Y-12 Plant (near Oak Ridge, TN). Enriched (and depleted) uranium shavings/fines occur in relatively large quantities at the DOE Y-12 nuclear weapons production plant. These fines and shavings are contained in oils (such as, machining oils) and other chemicals (such as, waste grits). Pu turnings/shavings/fines from Pu machining are embedded in machining oils and waste compounds from glove boxes (where all Pu manufacturing takes place). Some of the waste machining oils are contained in enclosures (such as, plastic bottles) with questionable chemical and nuclear safety. Some of the Pu machining oils (such as, Rocky Flats) have been dumped into nearby topsoil, and covered over with asphalt. Thus, some gamma radiation and a relatively large amount of neutrons will be detected above the asphalt.

Radioactive materials left in the nuclear weapons wet chemistry NW materials production lines is another class of materials to be considered for Decontamination and Disposal (D&D) [2]. These materials are typically solutions of various combinations of uranium nitrate, plutonium nitrate, americium nitrate, and fission products mixed in with various combinations of other hazardous chemicals. (The end products of the production lines are typically dry oxides of the fissile materials (such as, Plutonium oxide (PuO_2)). These solutions exist in various tanks, pipes, mixers, transfer lines, hold up containers (such as, raschg ring tanks), etc. Most of these production lines have not been restarted for around 10 years because of concerns for chemical and nuclear safety (particarly nuclear criticality). Some of the safety concerns are: a) the exact chemistry of these materials (in the production lines) is not always know (or quantified) due to the many oxidation states of the fissile materials, such as, uranium, americium-241, neptunium, plutonium, b) non-continuous surveillance of the materials process equipment, e.g. states of rashig rings, c) uncertain or unknown: precipitations, colloides, sludges, d) uncertainties in the radiolytic decomposition rate of some non-fissile production chemicals (e.g., nitric acid), and, e) uncertain enclosure (e.g., pipes and tanks) holdup, producing material unbalances. These wet chemistry production lines exist at Rocky Flats, Hanford, SRS, Y-12, and (LANL)."

Still another class of radioactive materials to be considered in D&D projects are the materials produced in the stabilization and packaging processes for the residue wastes produced from the manufacture of the nuclear weapons materials [1]. Some of these materials (particularly at Rocky Flats) come from the SALT, ASH, and Wet Combustible (WC) processes. The SALT materials will typically be dry solid, aggregate, slag, and powders resulting from the molten salt (thus the name SALT), electrorefining, and direct oxide reduction manufacturing processes. The ASH residues, will consists of ash (from furnaces), ion-exchange resins, firebrick, sand, slag, and crucible materials. The WC combustible residues typically consist of wet (or damp) filters, sludges, non-leached raschig rings, and grease which have become wet due to the environment that the materials were placed.

For additional information, areas where the potential of airborne radioactive contamination exists will be sampled using low volume air samplers. These samples will be conducted over an extended period to reflect the area exposure potential. These "area" air samples will not be used to determine internal exposure potential unless they were run during work time only.

Any sample that is collected after the normal work schedule will be considered as an information sample only, and noted as such on the form, shown as "Air Particulate Sample Reporting Log Form," Attachment 32. Additionally, information sample results will not be entered on Attachment 32 for area averaging.

5.4. Lapel Sampling

- Attach the sampling apparatus to the user's hip or waist with a belt.
- The sample head is secured in the "lapel" area.
- Secure the tubing and sample head with tape and/or clips.
- At the sampling location turn the sampling pump on.
- Record the following:
  - Name of Wearer and Social Security Number
  - Sampler ID#
  - Date/Time On
  - Instrument Calibration Date
  - Flow Rate CFM/LPM
- At the end of the sampling period turn the sampling pump off.
- Record the following information:
  - Date/Time Off
  - Total Volume Ft^3/Liters

The Vista ORPO will ensure that the worker being issued the sampler is instructed as to follow the requirements below:

- Refrain from tampering with the pump or the sample head.
- Leave the work area if the sampler fails, and note stop time.

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

- Contact the Vista ORPO for assistance at completion of work.

NOTE: Due to the low volume of lapel breathing zone air samples, the Minimum Detectable Activity on gross counting equipment is usually insufficient to determine 10 % DAC for unknown isotopes for screening purposes. In the event it is desired to screen these breathing zone samples, a high volume air sample may be placed within 2 feet of the most restrictive breathing zone (highest expected concentration). This sample may be used to screen the lapel samples.

The following information pertains to air particulate samples:

- Air particulate samples are to be analyzed as a minimum for gross α and β-γ counting using a Ludlum Model-2929 Dual Channel Scalar or equivalent.
- Air particulate samples should be initially counted within fifteen (15) minutes of the end of the sampling period.
- Air particulate samples will be counted for a period of five minutes.
- Place the air sample filter inside the sampling tray with the "fuzzy" side facing up towards the detector.

NOTE: If a high volume air sample filter is to be counted, using a hole punch, cut out the center portion of the filter and place the cut out portion of the filter in the sampling tray with the "fuzzy" side facing up towards the detector.

- Count the sample for a five-minute period.
- Upon completion of the counting period calculate and record the α activity (unless no α counts are present) then calculate the β activity.

NOTE: The following criteria may be used when evaluating air sample results:

- Contamination levels and physical characteristics;
- Work activities in the area/re-suspension probability;
- Historical data/isotopic information; and
- Background air sample data.

If the calculated air activity does not exceed 10% of the DAC value of the radionuclide(s) of concern, no further analysis is required and the sample may be discarded at the discretion of the Vista ORPO. If the calculated air activity exceeds 10% of the DAC value of the radionuclide(s) of concern, do the following:

- Report this information to the Vista ORPO immediately.
- Allow the sample to decay for a 3 hour period (if feasible) and recount the sample.

- Following the 3 hour decay period, if the calculated air activity does not exceed 10% of the DAC value of the radionuclide(s) of concern, no further analysis is required and the sample may be discarded at the discretion of the Vista ORPO.
- If the calculated air activity exceeds 10% of the DAC value of the radionuclide(s) of concern:
  - Report this information to the Vista ORPO immediately.
  - Consideration should be given to isotopic analysis and area access restriction/posting in accordance with 10 CFR 20.
  - Allow the sample to decay for a 20 hour period (if feasible) and recount the sample.
  - Following the 20 hour decay period, if the calculated air activity does not exceed 10% of the DAC value of the radionuclide(s) of concern, no further analysis is required and the sample may be discarded at the discretion of the ORPO.
- If the calculated air activity exceeds 10% of the DAC value of the radionuclide(s) of concern:
  - Report this information to the Vista ORPO immediately; and
  - Consideration should be given to isotopic analysis and area access restriction/posting.
  - If the activity exceeds the established ALARA level, the activity information should be reported to the Vista RSO.

5.5. Location of Air Samplers

The purpose of this procedure is to define the location of air samplers for airborne radioactive contamination and specific techniques therein at Vista project work sites. This procedure describes the methods and equipment for personnel and general air sampling of airborne radionuclides. The procedure also provides detailed instructions for documentation of such sampling data.

5.6. Necessary Supplies

- Filters (as required)
- Air Samplers (as required)
- "Air Particulate Sample Reporting Log Form," shown as Attachment 32
- "Radiological Survey Air Sampling Radon Daughters," shown as Attachment 33
- "Radiological Survey Air Sampling Thoron Daughters Form," shown as Attachment 34
- "Scintillation Cell Radon Sample Form," shown as Attachment 35
- Clipboard and pen.

6. SAMPLING STRATEGY

A single sampling strategy cannot be specific for all airborne monitoring requirements for a given area. Sampling will always be based on field judgment for location and frequency required. Once

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

basic job assignments have been established, the Vista field technical staff may be able to determine a systematic approach for their site-specific needs.

The types of samples may be twofold: time-integrated samples for daily exposure assessments and possibly short-term samples for engineering control or peak concentration assessment. The type and duration will also be site-specific and activity-dependent.

6.1. Specific Instructions

Decide on the type of sample required. There are three basic sample techniques used for most airborne assessments:

- Lapel Samples
  - Personnel sampling may be used to determine air concentrations for any individual by attaching a lapel sampling device directly to the individual's clothing in close proximity to their face. The duration of the sample will be that of the work shift. Individuals whose exposure estimates are determined in this manner are more likely to be accurately assessed with respect to internal exposure potential. This type of sampling is preferred for use in exposure determinations.
  - Lapel samplers with constant flow control will be used.
  - Place the lapel sampler on the individual to be sampled. Turn on sampler and adjust flow rate to the calibrated value required. Record the time started. The Vista field technical staff will calibrate the flow rate of samplers for flow changes due to battery discharge or flow rate reduction. Vista field technical staff will check lapel flow rates at least once every 2 hours and adjust or note changes in flow rate as required.
  - At the end of the sampling period or work shift, Vista field technical staff will retrieve the lapel sampler and check the flow rate to verify constant flow since the last flow rate check. The flow rate will be noted and the sampler will be shut off. Document the stop time and place the filter in the appropriately documented sample container for analyses.

- Short-Term Samples
  - Short-term grab samples may be required to determine the maximum exposure potentials in special areas for the determination of the effectiveness of engineering controls or for determining working condition exposure potential. The following technique is used in taking these types of samples.
  - Make a low-volume air sampler ready for use. Place the sampler at the location in question. Begin the work activity that may create the peak airborne radioactive contamination problem. Start the air sampler for a specific time period, documenting the flow rate, and start and stop time. Place the sample in the sample container for subsequent analysis.

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

- During such experimental sampling, Vista field technical staff and any other individuals will wear suitable PPE.

6.2. Area Sampling

General area sampling, using Continuous Air Monitors (CAMs), has been used to evaluate airborne conditions of rooms, buildings, and so forth. Ideally, this type of sampling would provide area average concentration of airborne radioactive contamination for general working or occupational functions within the structure or work area. Area samples are limited in value for internal exposure assessment if the area being sampled is subject to point-source dust generation.

During work conditions that create uniform airborne radioactive contamination, the use of area samplers will provide sufficient estimates of worker exposure. To conduct area sampling, the following techniques are used:

- Make ready all sampler(s) as required with the proper filter for the contaminant of concern. (Vista area samplers use 47 mm glass fiber). The Vista ORPO will decide the number of area monitors to be used to accurately assess the airborne environment. This may involve several monitors for an exterior remedial action activity or a single monitor for a small interior room.
- Place the area monitor at the sampling location, 3 feet above the ground or floor as required. Start sampler and note flow rate and time started. Sample for the required time. Area samples where the data is to be used to assess exposure will be run only during work activity. Other area samplers may be run for extended periods.
- Area monitors will sample the air at a calibrated flow rate of not less than 2 liters per minute, but will not exceed 13 liters per minute. Flow rates will be checked at least once every hour during sampling.
- At the completion of the sampling period, record the flow rate and shut off time. Place filter in a properly labeled sample container, perform a smear test to assure there is no removable contamination, take a survey meter measurement, assign a transportation index and send the sample to a laboratory for analyses.

6.3. Measurement of Radon-222 Daughters

The purpose of this procedure for the measurement of ^{222}Rn daughters is to establish sampling and analysis techniques for determination of ^{222}Rn daughters in air at Vista project work sites. This procedure also describes how to compute Radon daughter concentrations.

This procedure is used to measure the concentration of ^{222}Rn daughters in air. This "Modified Kusnetz" procedure is used for airborne radon daughter determinations only. The presence of radon and other airborne radionuclides should be determined by other sampling and analysis methods.

Applicable references are:

- Holaday, D. A., Rushing, D. E., Coleman, R. D., Woolrich, P. F., Kusnetz, H. L., and Bale, W. F., "Control of Radon Daughters in Uranium Mines and Calculations on Biological Effects," U. S. Public Service Publication 494.
- R. L. Rock, United States Department of the Interior, "Sampling Mine Atmospheres for Potential Alpha Energy Due to the Presence of Radon Daughters," MSHA, Information Report IR-1015,.
- NCRP Report No. 97, "Measurement of Radon and Radon Daughters in Air,".

The following sections delineate necessary supplies, description, specific sampling instructions, specific Instructions for Attachment 33, "Radiological Survey Air Sampling Radon Daughters," and quality control.

6.4. Necessary Supplies

- Low volume air sampling pump or lapel pump
- 25 mm or 37 mm filter holder
- 0.45 or 0.8 μm mixed cellulose ester filters
- Ludlum Model 3 Survey Meter alpha particle counting system or equivalent
- Tygon tubing, 3/16" inside diameter
- Lapel sampler & bubble tube calibration kit
- Kuznet Flow Calibration Kit or equivalent (RAS-1).
- "Radiological Survey Air Sampling Radon Daughters," shown as Attachment 33
- "Radon Daughter Table Factor Chart," shown as Attachment 36 (Note: Attachment 36 supplied with this document will be the reference used when performing Radon-222 Daughter measurement calculations.)
- Glassine envelopes
- Clipboard and pen.

6.5. Description

In nature, there are three known isotopes of Radon (Rn): Rn-219 [^{219}Rn (Actinium series)], Rn-220 [^{220}Rn (Thorium series)], and Rn-222 [^{222}Rn (Uranium series)]. For sites where ^{238}U is the primary isotope of interest, ^{222}Rn concentrations in air will be measured. ^{222}Rn has a much longer half-life (3.82 days) than either of the other Rn isotopes. In addition, ^{222}Rn's abundance in air is greater than other radon isotopes, and therefore is of greatest interest for human exposures. The short-lived daughter products of ^{222}Rn, particularly Polonium-218 (^{218}Po) and Po-214 (^{214}Po), are highly energetic α particle emitters that provide a significant dose to lung tissue.

^{222}Rn is an inert (noble) gas that decays to daughter products that are particulates. This allows for the collection of the daughter products on filter media when filtering a known volume of air. By counting the α particle activity from the daughter products collected on the filter, exposure from

^{222}Rn daughters can be determined. Working Level (WL) is the common unit for expressing the radon daughter concentration. 1 WL equals 100 pCi/l activity at 100 percent equilibrium among ^{222}Rn and its short-lived daughters. The occupational DAC for ^{222}Rn daughters equals 0.33 WL.

A 10- to 50-liter sample is collected to determine the WL for ^{222}Rn daughters. The filter is counted 40 to 90 minutes after sampling to determine α particle activity using an Ludlum Model 2929, or equivalent. After counting, sample count rates in Counts Per Minute (CPM) are converted to Disintegrations Per Minute (DPM) and the result is divided by the sample volume and the decay factor. The table shown as Attachment 36 shows how to quantify concentrations in WL.
To perform a quick reference check for ^{222}Rn daughter activity, a one minute count of the filter can be done after the filter has decayed for approximately 7.8 minutes. To calculate the WL for the check, a table factor of 213 is used. These checks of this nature are used for informational purposes only.

6.6. Specific Sampling Instructions

The following are specific sampling instructions for Rn-222 daughters:

a) Assemble the RAS-1 or lapel air sampler and calibrate with appropriate calibration kit to determine flow rate in Liters Per minute (LPM). After calibration is completed with the filter type to be used, ^{222}Rn daughter samples can be collected from the specified locations.
b) A 0.45 to 0.8 μm mixed cellulose ester filter is used to collect the sample. The air sampler flow rate will be 2 to 10 LPM.
c) Place sampler at sampling location and collect a 10 to 50 liter sample during a 5-minute sampling period. Because of the short half-life of Rn-222 daughters, a short sampling time is required.
d) Record sample start and stop times on the form shown as "Radiological Survey Air Sampling Radon Daughters," Attachment 33, and on a glassine envelope.
e) Remove sample from filter holder, and mark the side of the filter where sample is collected. Place in glassine envelope with all pertinent sample data recorded on the outside of the envelope.
f) Prior to counting the sample, allow it to decay at least 40 but no more than 90 minutes from stop time.
g) After at least 40 minutes, place sample in α particle counter and count for 5 minutes.

6.7. Specific Instructions for Attachment 33, "Radiological Survey Air Sampling Radon Daughters

The following example is used to illustrate the appropriate way to complete the form shown as Attachment 33.

Example:

A 5-minute air sample is collected in Building X to determine the presence of ^{222}Rn daughter levels in the building. The following information is used to calculate the Working Level (WL) for radon daughters:

Sample volume = 50 liters
Sample start time = 09:05
Sample stop time = 09:10
Count start time = 09:45
Count stop time = 09:50
Gross sample counts = 455
Sample count time = 5 minutes
Background gross counts = 1
Background count time = 50 minutes
SAC-4 counting efficiency = 36 percent
RAS-1 flow rate = 10 l pm

- Enter the sample location.
- Enter the sample start and stop time. Enter the count start and stop time. Use military time designations when entering data onto the form shown as Attachment 33.
- Enter the total sample volume. For this example, 50 liters (10 liters/minute x 5 minutes).
- Calculate the time elapsed (TAS) in minutes from the mean of the sample collection time to the mean of the sample count time.
- TAS equals Count time mean minus Sampling time mean

For this example:

Sampling time mean = 9:07.5
Count time mean = 9:47.5
TAS = 9:47.5 minus :907.5 = 40 minutes

Use the TAS to determine the decay factor (table factor) from the "Radon Daughter Table Factor Chart," Attachment 36.

For this example:

TAS = 40 minutes
Sum of sample and count time = 10 minutes

To put the decay factor into a usable tabular form, the sum of sample and count time is determined to extrapolate the decay factor. The sum is not part of or added to the TAS. For this example, the decay factor equals 146.

The sample gross counts and count time is entered onto the form shown as Attachment 36.

The net sample CPM is calculated using the following equation:

$$\text{Net Sample CPM} = \frac{\text{Sample Gross Counts}}{\text{Sample Count Time}} - \frac{\text{Background Gross Counts}}{\text{Background Count Time}}$$

For this example:

Net Sample = ((455.5) (1.50))

– The WL for ^{222}Rn daughters is determined by using the following equation:

WL = (Net Sample CPM) [(Efficiency) x (Total Sample Volume) x (Table Factor)]

For this example:

WL = (91) [(0.36) x (50) x (146)] = 0.035

The center of the form shown as Attachment 33 pertains to the sample purpose. If the sample was taken for a special purpose, this must be checked and followed by a brief explanation. If corrective action(s) were taken, this must be checked and followed by an explanation of what action was taken.

On the bottom of the form shown as Attachment 36, instrument data pertaining to the α particle counting system along with the air sampling pump must be entered.

6.8. Quality Control

- Perform a Duplicate count for each set of samples collected. The Duplicate count must be performed before the end of the 90-minute time limit.
- The Duplicate count will be recorded on the form shown as Attachment 33 with the original measurements and identified as a (D).

7. PASSIVE MEASUREMENT OF RADON-220 AND RADON-222 IN AMBIENT AIR USING ACTIVATED CHARCOAL CANISTERS

Radon measurements may be made to determine radon concentrations emanating from the soil (referred to as "flux") as well as in ambient air. The procedure describes the method used to determine radon (^{222}Rn and ^{220}Rn) and the associated daughter product concentrations in ambient air using activated charcoal canisters Environmental Protection Agency (EPA model) for occupational and environmental monitoring requirements at Vista project work sites.

This procedure establishes an inexpensive screening method for the presence of radon gas. If elevated radon concentrations are detected by this method, follow-up measurements should be conducted for verification purposes.

Applicable references are:

- EPA, "Interim Protocols for Screening and Follow-up Radon and Radon Decay Products Measurements," EPA-520/1-86-014; and
- EPA, "Standard Operating Procedures for Rn-222 Measurement Using Charcoal Canisters," EPA-520/5-87-005.

The following sections delineate necessary supplies, introduction, pre-deployment considerations, and procedures.

7.1. Necessary Supplies

- Charcoal canister, EPA model
- "Field Sample Collection Form," shown as Attachment 29
- "Radiological Survey Air Sampling Radon Daughters," shown as Attachment 33.
- Clipboard and pen, Map of moitored area,Grimarkers, and Hot Spot Flags.

7.2. Introduction

A charcoal canister is a passive device requiring no power to function. The canister is filled with a measured amount of activated charcoal (approximately 75 grams). The top of the canister is fitted with a wire mesh screen that holds the charcoal in place and allows radon gas to diffused into it. Whenever the canister is not in use, it is covered with an air-tight lid and sealed with adhesive tape.

Canisters are affixed with identification labels in accordance with "Radon Canister Identification Label," shown as Attachment 37, assigned laboratory numbers (Radon Canister No.), weighed, checked to indicate type of measurement (air or flux), and dated before shipping from the vendor.

7.3. Pre-Deployment Considerations

Any structure/house that requires sampling for radon should be closed 72 hours prior to the start of sampling and during the sampling period as much as practical. External doors and windows of the structure should be kept closed during this period although this is not meant to preclude normal structure should be kept closed during this period although this is not meant to preclude normal entry into and exit from the structure. If possible, ventilation systems or heating systems that mix indoor and outdoor air should not be used 12 hours prior to sampling and during the sampling period (fireplaces, dryers, range hoods, attic exhausts, bathroom exhausts).

Closed conditions are necessary to equilibrate radon and it's daughter product concentrations, and to facilitate reproducibility of the measurement. Measurements made under these conditions are generally higher than the average concentrations to which occupants are exposed. It is assumed that the main source of radon in a house/structure is from the underlying soil, therefore screening measurements should be made in the lowest level of the structure normally occupied.

Canisters should be placed at least 1 meter above floor level, and at least 10 cm (approximately 4 inches) from other objects. Canisters should not be placed in direct sunlight, or near drafts caused by either heating, ventilation or air conditioning systems. Because barometric pressure changes can influence results, measurements should not be taken if severe storms or high winds are predicted or have occurred in the previous 12 hours.

7.4. Procedures

a) Record all appropriate information on the canister identification label including the site name or client name, address, sample location, start date, and start time immediately prior to starting the sampling period. Laboratory information will be completed prior to the canister being shipped for analysis.
b) Remove adhesive tape and canister lid. This will allow air and any radon gas (and daughter products) present in the air to diffuse into the canister where it will be absorbed by the activated charcoal.
c) Place the canister, screen-side up, in the desired sampling location as outlined in this section, "Passive Measurements of Radon-220 and Radon-222 In Ambient Air Using Activated Charcoal Canisters," one meter above floor/ground surfaces and approximately 10 cm away from objects.
d) Leave canister in place and undisturbed for 3 days (approximately 72 hours).
e) At the end of the sampling period, remove canister, replace the lid, and seal with adhesive tape to trap radon and daughter products.
f) Record stop date and time on the canister identification label.
g) Complete the "Radiological Survey Air Sampling Radon Daughters," shown as Attachment 33. Specific instructions for completing this form and following the proper chain-of-custody requirements are contained in Procedure 22 "Quality Assurance."
h) Package and ship the canister(s) for analysis along with the "Field Sample Collection Form," shown as Attachment 29, to the vendor within 24 hours of sample completion. Note: The original Field Sample Collection Form must accompany the canisters in each shipping container.

7.5 Precautions and Limitations

- Avoid unnecessary contamination of survey instruments through the use of plastic coverings and care in handling. Do not cover the air intakes or exhausts on air samplers.
- Avoid unnecessary exposure when conducting air monitoring surveys by utilizing good ALARA practices.
- Air samplers will be operated in accordance with Procedure 12 "Operation and Calibration of Instruments."
- Air samplers used in confined spaces may ignite explosive gases. Extreme care will be exercised including prior sampling of the atmosphere for explosive gas and O_2 content.
- Air samples should not be taken in such a manner as to contaminate the sample filter with materials which are not airborne or by sucking up loose contamination from surfaces near the sampling head. Caution should be used to minimize producing airborne material by the exhaust of the sampler.
- The instrument used to screen air samples will be designated by the Vista ORPO.

7.6 Air Sample Packaging Considerations.

- Particulate filters of different air samples should be placed in a separate envelope, poly bag, or other suitable container to ensure no possibility of cross contamination.
- Charcoal cartridges and the upstream particulate filter should be placed in a clear poly bag or equivalent.
- Tritium bubblers should be placed in a clear poly bag or equivalent, and other tritium sampling items placed in another bag.
- Radiogas sample chambers should be placed in a clear poly bag or equivalent.
- During collection and handling of air samples, caution must be used to prevent the samples from being contaminated by other sources of radioactive material.
- Notify the Vista ORPO of any unusual airborne radiological conditions identified, such as dust, smoke or chemicals.

7.7 Survey Documentation

Obtain necessary air sample filter(s) and any other material required to provide the necessary sample data. The following data is normally required for each air sample:

- Type of sample: General Area (GA) or Breathing Zone (BZ);
- Purpose of sample, e.g., routine or non-routine, and special if non-routine;
- A brief description of the task being performed;
- Radiation Work Permit (RWP) number the sample was obtained for;
- Sample location;
- Sampler model and serial or ID number;
- Sample start date and time;
- Sample start flow rate;

Note: For the purposes of this document, Ionizing Radiation includes certain types of Non-Ionizing Radiation

- Sample stop date and time;
- Sample stop flow rate and vacuum, if applicable;
- Sample average flow rate, as Cubic Feet per Minute (CFM) or Liters Per Minute (LPM);
- Total sampling time as days, hours, or minutes as appropriate;
- Any specific sample analysis required (e.g., α or γ isotopic);
- If samples are collected in a sub- atmospheric area, the pressure in pounds per square inch; and
- The name(s) of the individual(s) starting and stopping the sample.

8. CALCULATION OF RADON DAUGHTER PRODUCT ACTIVITY

8.1. Scope

This section provides guidelines for the determination of radon daughters in air.

8.2. Purpose

The purpose of this procedure is to maintain sampling and analysis techniques for determination of radon daughters in air. This procedure also describes the calculation and documentation of radon daughter measurements.

8.3. References

- 10 CFR 20, "Standards for Protection Against Radiation,".
- Procedure 18 "Site Access Control and Radiation Work Permits";
- NUREG 0041, "Manual of Respiratory Protection Against Airborne Radioactive Materials;"
- ANSI N13.1, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities;"
- NRC Regulatory Guide 8.25, "Air Sampling in the Workplace,"
- Procedure 12 "Operation and Calibration of Instruments;" and
- Procedure 16 "Air Radiological Sampling."

8.4. Precautions and Limitations

- Avoid unnecessary contamination of survey instruments through the use of plastic coverings and care in handling. Do not cover the air intakes or exhausts on air samplers.
- Avoid unnecessary exposure when conducting air monitoring surveys by using good ALARA practices.
- Air samplers shall be operated in accordance with their operation and calibration procedures presented in Procedure 12 "Operation and Calibration of Instruments."
- Air samplers used in confined spaces may ignite explosive gases. Extreme care shall be exercised including prior sampling of the atmosphere for explosive gas.

- Samples should not be taken in such a manner as to contaminate the sample filter with materials which are not airborne or by sucking up loose contamination from surfaces near the sampling head. Caution should be used to minimize producing airborne material by the exhaust of the sampler.
- The instrument used to screen air samples shall be designated by the Vista ORPO.

8.5. Description

8.5.1. Radon 222 Daughters

In nature, there are three known isotopes of Radon that are Rn-219 (Actinium series), Rn-220 (Thorium series), and Rn-222 (Uranium series). For sites where U-238 is the primary isotope of interest, Rn-222 concentrations in air will be measured. Rn-222 has a much longer half-life (3.82 days) than either of the other Radon isotopes. In addition, Rn-222 abundance in air is greater, and therefore is of greatest interest for human exposures. The short lived daughter products of Rn-222, particularly Po-218 and Po-214, are highly energetic alpha emitters that are of great concern for dose to lung tissue.

Rn-222 is an inert (noble) gas that decays to daughter products that are particulates. This allows for collection of these daughter products on filter media when filtering a known volume of air. By counting the alpha activity from the daughter products collected on the filter, exposure from Rn-222 can be determined. Working Level (WL) is the common unit for expressing the Radon daughter exposure rate. 1WL=100 pCi/L activity at 100% equilibrium. The hourly Derived Air Concentration (DAC) for Rn-222 daughters = 0.33 WL.

A 10 to 50 liter (0.35 to 1.77 ft^3) or greater sample is collected to determine the WL for Rn-222 daughters. The filter paper is counted 40 to 90 minutes after sampling to determine alpha activity. After counting, sample Counts Per Minute (CPM) and the result is divided by the sample volume and the decay (see table factor chart) to quantify concentrations in WL.

To perform a quick reference check for Rn-222 daughters activity, a one minute count of the filter can be done after the filter has decayed for approximately 7.8 minutes. To calculate the WL for this check, a table factor of 213 is used. Checks of this nature are used for informational purposes only.

8.5.2. Radon 220 Daughters

Thoron (Rn-220) daughter samples are collected by filtering a known volume of air where the presence of Rn-220 daughters are suspected. Concentrations can be determined by the alpha activity measured on these filtered samples. A high volume (50 liter, 1.77 ft^3) or greater sample is analyzed for these determinations. Unlike Rn-222 daughters, buildup and decay of collected thoron daughters do not present a problem during a total sampling time up to one hour. This is due to the 10.6 hour half-life of Pb-212. After sampling, the filtered sample is analyzed for Rn-222 daughters if needed, and left to decay for at least 5 hours. This time allows the Rn-222 daughters to decay, and the Rn-220 daughters (Bi-212) to grow into transient equilibrium with Pb-212 so that the combined alpha counts may be directly correlated. After counting the sample, CPM on the filter paper are converted into Disintegrations Per Minute (DPM), and applying the time factor and sample volume converts the results to "Working Levels" (WL).

8.6. Procedure

- Collect a 50 liter (1.77 ft^3) or greater volume air sample in accordance with Section 6.6 of this procedure.
- Analyze the air sample in accordance with this Procedure.
- Allow the sample to decay 40-90 minutes for Radon 222 daughters or a minimum of 5 hours for Radon 220 daughters. Then count the sample using a Ludlum Model-2929 Dual Channel Scalar (or equivalent) for 5 minutes.
- Complete Attachments 33 or 34. Use Attachment 36 if Radon 222 daughters are of interest. Use Attachment 34 if Radon 220 daughters are of interest. Determine the appropriate factor based on the decay time of the sample and error in the space provided on Attachments 33 or 34.

8.7. Records

The following records will be generated and retained in the permanent project file as a result of using this procedure:

Attachment 33, Radiological Survey Air Sampling Radon Daughters
Attachment 34, Radiological Air Sampling Thoron Daughters.

ATTACHMENTS

Attachment 29

FIELD SAMPLE COLLECTION FORM

SITE ACTIVITY SAMPLES

Site No. | Site Name: | Activity Support (Job) No.: | Samplers:

Sample I.D. No. / Sample Grid Point	Sample Type (1)	Sample Time	Date of Sample	Preservative	Purpose (2)	Depth cm [ ] ft [ ]	Required Analysis	Remarks PERFORM SAMPLE SCAN

Sample Type (1)	Purpose (2)
SS –Surface Soil	RC – Rad Character
BS – Bias Soil	VR – Verification
PS – Profile Soil	QC – Quality Control
SD – Sediment Silt	HS – Hot Spot
OR – Other	RS – Resample
VE – Vegetation	BG – Background
GW – Ground Water	RT – Routine
SW – Surface Water	SP – Special

Note: Scan Samples Prior to Release

"This package conforms to the conditions and limitations specified in 49 CFR 173.421 for excepted radioactive material, limited quantity, n..a., UN 2910"

CHAIN OF CUSTODY

REASON	RELNQ BY	REC'D BY	DATE	TIME

Recorded By: ____________

Date/Time: ____________

No. of sample in box ____________

Total No. of samples in shipment: ____________

Total No. of boxes in shipment: ____________

Attachment 31

AIRBORNE CONTAMINATION EXPOSURE
AREA SAMPLING AVERAGES CALCULATION
DATA SHEET FORM

Site Name: ______________________ Sampling Area: ___________________________ Date: __________

Completed By: ___________________ QC By: ____________________ Contaminant: _________________

Analytical Techniques: ____________ TWA Activity = ____pCi/ml ____pCi/l ____Working Levels (WL)

Results for the month of ___________________________________ MPC = ______________

Sample Date	Sample Identification and Physical Form	Sample Results	Sample Area Average (1x2x3x4) % MPC

Sample Area Averages		Type: L = Lapel Sample A = Area Sample
(1) = Daily	(2) = Weekly	Exposure calculated from these averages
(3) = Monthly	(4) = Quarterly	Note: Transmit a copy of the form with all (1x2x3x4)

Attachment 32

AIR PARTICULATE SAMPLE REPORTING LOG FORM

Site: ____________________ Sample Count Time = ________________ Background Count Time = _______________

Detector Used ________________________ Serial No.: _____________________

SAMPLE DESCRIPTION							COUNTING DATA			RESULTS		
Sample Location/Person	Date	Start	Stop	Sample Time	Flow Rate	Sample Volume	Bkg cpm	Sample cpm	Detector Efficiency	Activity μCi/ml	Standard Deviation	MDA

Recorded By: ______________________________________

Date: _________________________

Checked By: ______________________________________

Date: _________________________

Remarks: ______________________________________

____

____

____

ATTACHMENT 33
RADIOLOGICAL SURVEY AIR SAMPLING
RADON DAUGHTERS

LOCATION: ______________________
DATE: ______________________
SURVEYOR: ______________________

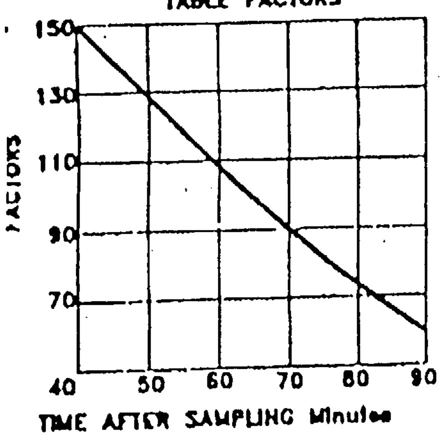
COLLECTION							ANALYSIS									
LOCATION	Time		Total Time (min)	Flow Rate (LPM)		Total Volume (liter)	Sample		Background		Net Count	Eff CPM/DPM	DPM/liter	Net TAS	Table Factor	Working Level
	Start	Stop		Start	Stop		Gross Count Cs+b	Count Time Ts+b	Gross Count Cb	Count Time Tb						

ROUTINE ☐ SPECIAL (If special, indicate reason for initiation of survey below). ☐ CORRECTIVE ACTION TAKEN

____

____

RADON DAUGHTER TIME CORRECTED
TABLE FACTORS



Pump I.D. No. ______________

Cal Date ______________

Cal Error ______________

$$WL = \frac{\left(\frac{Cs}{Ts} - \frac{Cb}{Tb}\right)}{(EFF)(\text{Sample Volume Liters})(\text{Table Factor})}$$

Cs= Gross Counts Sample

Ts= Count Time of Sample

Cb= Gross Counts Background

Tb= Count Time of Background

Eff= Counting Instrument Efficiency

or $\frac{CPM}{DPM}$

1.) Air sample collection duration was exactly five minutes through 0.45 micron membrane fiber at a flow rate of 2–10 lpm.

2.) Analysis performed a minimum of 40 minutes after collection. Count for one minute.

3.) Calibration check using Thorium-230

Standard I.D. No. ______________

Thorium Standard DPM ______________

Gross Counts CPM ______________

$\frac{CPM}{DPM}$ = Efficiency ______________

ATTACHMENT 34
RADIOLOGICAL SURVEY AIR SAMPLING
THORON DAUGHTERS FORM

LOCATION: ____________________
DATE: ____________________
SURVEYOR: ____________________

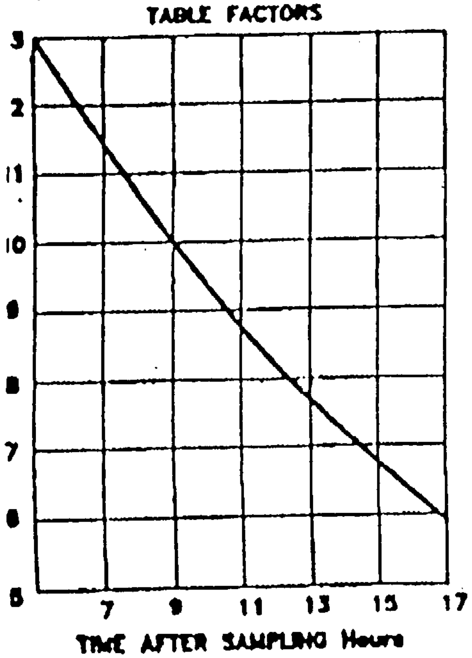
COLLECTION							ANALYSIS									
LOCATION	Time		Total Time (min)	Flow Rate (LPM)		Total Volume (liter)	Sample		Background		Net Count	Eff CPM/DPM	DPM/liter	Net TAS	Table Factor	Working Level
	Start	Stop		Start	Stop		Gross Count Cs	Count Time Ts	Gross Count Cb	Count Time Tb						

UTINE ☐ SPECIAL (If special, indicate reason for initiation of survey below). ☐ CORRECTIVE ACTION TAKEN

____

____

THORON DAUGHTER TIME CORRECTED TABLE FACTORS



$$WL = \frac{\left(\frac{Cs}{Ts} - \frac{Cb}{Tb}\right)}{(EFF)(\text{Sample Volume Liters})(\text{Table Factor})}$$

Cs= Gross Counts Sample

Ts= Count Time of Sample

Cb= Gross Counts Background

Tb= Count Time of Background

Eff= Counting Instrument Efficiency

or $\frac{CPM}{DPM}$

1.) Air sample collection duration was exactly five minutes through .45 micron membrane filter at a flow rate of 2–10 lpm.

2.) Analysis performed a minimum of 40 minutes after collection. Count for one minute.

3.) Calibration Check using Thorium–230

Standard I.D. No. ____________________

Thorium Standard DPM ____________________

Gross Counts CPM ____________________

$\frac{CPM}{DPM}$ = Efficiency ____________________

ATTACHMENT 35

RADIOLOGICAL SURVEY
SCINTILLATION CELL RADON SAMPLE FORM

DATE: ____________

SAMPLE IDENTIFICATION
COLLECTION & CELL DATA
COMPUTED RESULTS
SAMPLE COLLECTION

PREPARED BY:	DETECTOR NO.	JOB SITE	SAMPLE LOCATION	MONTH	DAY	SAMPLE L $\overline{X}$	SCINTILLATION CELL FACTOR cpm/pCi/L	CELL NO.	CELL BKG. Count TIME	CELL BKG. cpm	SAMPLE TO CELL TRANSFER DATE	SAMPLE TO CELL TRANSFER TIME	COUNT TIME $\overline{X}$	HOURS FROM FROM SAMPLE L $\overline{X}$ TO COUNT L $\overline{X}$	DECAY FACTOR	SAMPLE COUNTS/ COUNT TIME	SAMPLE cpm	SAMPLE NET (cpm) (cpm – BKG cpm)	DETECTOR EFFICIENCY	pCi/LITER ±2 SIGMA	(LLD) pCi (Lo) pCi

1. All Scintillation cells calibrated with N.B.S. traceable Ra-226 standard.
2. Results reported with two sigma error factor.

Signed: ____________

Checked: ____________

Attachment 36

RADON DAUGHTER TABLE FACTOR CHART

Decay Time (Min.)	Sum of Sampling & Counting Time (Min.)								
	4	**5**	**6**	**7**	**8**	**10**	**20**	**40**	**60**
40	151	151	150	149	148	146	136	117	99
45	142	141	140	139	138	136	126	107	91
50	132	131	130	129	128	126	117	99	83
55	122	121	120	119	118	116	107	90	75
60	113	112	111	110	109	107	98	82	68
65	103	102	101	101	100	98	89	74	62
70	94	94	93	92	91	89	81	67	56
75	86	85	84	84	83	81	74	61	50
80	78	77	77	76	75	74	67	55	45
85	71	70	69	39	68	67	60	49	41
90	64	63	63	62	61	60	54	44	36

Attachment 37

RADON CANISTER IDENTIFICATION LABEL

____
Radon Canister Number

____
Client Name

____
Address

____
City, State, Zip Code

____
Sample Location

________________________ Start Date	________________________ Start Time
________________________ Stop Date	________________________ Stop Time
____________________ grams Weight Out	____________________ grams ________ Weight In
Rn Air	Rn Flux

____
Date Baked