Contamination Control and Workplace Monitoring

Module Objectives

- Recognize considerations necessary to properly control and assess airborne contamination.
- Recognize considerations necessary to properly detect, control, and assess surface contamination.
- Identify personnel contamination hazards.
- Understand the fundamentals of radon and its effect on contamination monitoring.

Air Sampling Uses

- Air sampling in the workplace might be performed for the following reasons:
  - To measure the concentrations of radioactive material.
  - To determine posting requirements.
  - To determine effectiveness of engineered controls.

Air Sampling Uses, con't

- To select appropriate protective equipment and measures.
- To provide warnings of significantly elevated levels of airborne radioactive materials.
- To estimate intake of radioactive materials by workers.
- To meet regulatory requirements.

Primary Dose Limits

Population	Dose Limit
Adult Worker	5 rem TEDE 50 rem TODE 15 rem eye dose equivalent
Minor Worker	500 mrem TEDE 5 rem TODE 1.5 rem eye dose equivalent
Member of the Public	100 mrem, with only 10 mrem from airborne emissions
Embryo/fetus of Declared Pregnant Worker	500 mrem during gestation period

Secondary Derived Limits

- The dose limits on the previous slide are the primary dose limits.
- There are two secondary derived limits that are useful for individual dose control and determining compliance with primary dose limits.
  - ALI
  - DAC

Secondary Derived Limits

- The Annual Limit on Intake (ALI) is the amount of a single radionuclide that would deliver a CEDE of 5 rem (50 mSv), called the SALI, or a CDE 50 rem (500 mSv), called the NALI.
- "The" ALI is the smaller of the SALI and the NALI
- It is useful as a benchmark figure for controlling dose.

Secondary Derived Limits

- Values of ALIs are listed in:
  - NRC regulations: 10 CFR 20, Appendix B.
  - ICRP 30.
  - Federal Guidance Report No. 11.
- Values of ALIs based on a different limit (2 rem effective dose) are given in
  - ICRP 78
  - IAEA Basic Safety Standards

Secondary Derived Limits

- The Derived Air Concentration (DAC) is the concentration of a single radionuclide in air that if breathed by reference man for a full working year (2000 hours), would result in an intake of one ALI.

Secondary Derived Limits

- It is also very useful as a benchmark figure for controlling dose since measured concentrations of radionuclides in air are easy to obtain from air sampling results.

Secondary Derived Limits

- Tables of DACs can be found in:
  - NRC regulations: 10 CFR 20, Appendix B.
  - ICRP 30.
  - Federal Guidance Report No. 11.
- As with ALIs, DACs based on newer ICRP guidance are different

Atomic No.	Radionuclide	Class	Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Relase to Sewers
			Col 1.	Col 2.	Col 3.	Col 1.	Col 2.	
				Inhalation				
			Oral Ingestion ALI (µCi)	ALI (µCi)	DAC (µCi/ml)	Air (µCi/ml)	Water (µCi/ml)	Monthly Average Concentration (µCi/ml)
92	U-238	D	1E+1 Bone Surface (2E+1)	1E+0 Bone Surface (2E+0)	6.E-10	3.E-12	3.E-07	3.E-06
		W	-	8.E-01	3.E-10	1.E-12	-	-
		Y	-	4.E-02	2.E-11	6.E-14	-	-

Secondary Derived Limits

- **DAC and ALI values may be used to determine the individual's dose and to demonstrate compliance with the occupational dose limits. 20.1201(d)**

Secondary Derived Limits

- The *DAC fraction,* or percent of the DAC, is used to control and assess dose.
- It is calculated by the following formula:

$$\text{DAC Fraction} = \frac{\text{measured airborne concentration}}{\text{appendix B DAC}}$$

Secondary Derived Limits

- A useful operational quantity is DAC-hours, the product of the DAC fraction and the exposure (stay) time in hours.

Secondary Derived Limits

- Dose is easily determined by multiplying DAC-hrs by a dose conversion factor of 2.5 mrem/DAC-hr for a stochastic DAC value or 25 mrem/DAC-hr for a nonstochastic DAC value.

Secondary Derived Limits

- In other words, a worker can breathe 2000 DAC-hours in a year without exceeding the more restrictive of the primary dose limits.

Secondary Derived Limits

- **The following formula represents the dose calculation for a stochastic DAC.**

$$\text{Dose} = \left(\frac{\text{airborne concentration}}{\text{appendixB DAC}}\right)\left(\frac{\text{stay time (hrs)}}{1}\right)\left(\frac{2.5\ \text{mrem}}{1\ \text{DAC} - \text{hr}}\right)$$

Determining the Need for Air Sampling

- Monitoring of a worker's intake is required if the intake is likely to exceed 10% of the ALI. (10 CFR 20.1502).
- For many workers, intakes will never approach 10% of the ALI.

Determining the Need for Air Sampling

- **But to meet this requirement, licensees will have to estimate whether projected airborne concentrations may be high enough that workers are likely to exceed 10% of an ALI.**

Determining the Need for Air Sampling

- Reg. Guide 8.25 and NUREG 1400 recommend a method to determine the need for air sampling.
- First the total quantity Q of radioactive material is estimated.

Determining the Need for Air Sampling

- All potential radionuclides and amounts that may be used are to be considered in the estimate.
- If more than one radionuclide is present, the "sum of fractions" method can be used.

Determining the Need for Air Sampling

- Reg. Guide 8.25 recommends that licensees who handle quantities of unsealed radioactive materials > 10,000 times the ALI for inhalation evaluate the need for air sampling.

Determining the Need for Air Sampling

- The next step is to estimate the potential intake by a particular worker or group of workers.
- NUREG 1400 suggests that the potential intake be estimated at one millionth ($1x10^{-6}$) of the amount of unencapsulated radioactive material in the work location during 1 year.

Determining the Need for Air Sampling

- **Once the fractional intake is known, then Table 1 of Reg Guide 8.25 can be used to determine if air sampling is necessary.**

Air Sampling Recommendations Based on Estimated Intakes and Airborne Concentrations		
Worker's estimated annual intake as a fraction of the ALI	Estimated airborne concentrations as a fraction of DAC	Air Sampling Recommendations
<0.1	<0.01	Air sampling is generally not necessary. However, monthly or quarterly grab samples or some other measurement may be appropriate to confirm that airborne levels are indeed low.

From Reg Guide 8.25, pg. 3

Determining the Need for Air Sampling

- The potential intake can be modified by factors such as:
  - The release fraction R based on the physical form and use.
  - The type of confinement C for the material.
  - The dispersibility D of the material.

Determining the Need for Air Sampling

- The modified potential intake I_p will then be:

$$I_p = \left(Q\,x\,10^{-6}\right)\left(R\right)\left(C\right)\left(D\right)$$

- A table of release fractions is on the next slide.

Determining the Need for Air Sampling

Release Fractions (NUREG 1400)	
Physical Form	Release Fractions
Gases or volatile material	1.00
Non volatile powders	0.01
Solids (uranium fuel pellets, cobalt, or iridium metal)	0.001
Liquids	0.01
Encapsulated material	0

Determining the Need for Air Sampling

- The confinement factor C takes into consideration whether the material is within an isolated volume of some sort while a worker is present or whether it is actually handled in the open.

Determining the Need for Air Sampling

Confinement Factors (NUREG 1400)	
Type of confinement	Confinement Factors
Glovebox	0.01
Well-ventilated hood	0.1
Open work area	1.0

Determining the Need for Air Sampling

- **A dispersibility factor D of 10 can be applied to the calculation if operations likely to produce airborne contamination, such as cutting, grinding, heating, or chemical reactions are performed.**

Determining the Need for Air Sampling

- Therefore, the potential intake for a nonvolatile powder ($R = 10^{-2}$) that is being ground ($D = 10$) in a glovebox ($C = 10^{-2}$) would be:

$$I_p = Q \, x \, 10^{-6} \, x \, 10^{-2} \, x \, 10^{-2} \, x \, 10$$

Determining the Need for Air Sampling

- **Example:**
- **In the manufacturing of uranium fuel, sintered pellets of UO_2 are ground to a uniform diameter. The grinding is mostly an automated dry process. The apparatus is contained in a well-ventilated shroud, but not glovebox tight.**

Determining the Need for Air Sampling

- The annual throughput for a grinding station is 170 Ci.
- The ALI is 0.04×10^{-6} Ci.
- $R = 10^{-3}$ (solid fuel pellets)
- $C = 10^{-1}$ (hood value)
- D = 10 (grinding)

Determining the Need for Air Sampling

- **Therefore, the modified potential intake as a fraction of the ALI is:**

$$I_f = \frac{170\ Ci\ x\ 10^{-6}\ x\ 10^{-3}\ x\ 10^{-1}\ x\ 10}{0.04\ x\ 10^{-6}\ Ci}$$

$$I_f = 4.25$$

Air Sampling Recommendations Based on Estimated Intakes and Airborne Concentrations		
Worker's estimated annual intake as a fraction of the ALI	Estimated airborne concentrations as a fraction of DAC	Air Sampling Recommendations
>0.1	>0.3	Monitoring of intake by air sampling or bioassay is required by 10 CFR 20.1502(b). A demonstration that the air samples are representative of the breathing zone air is appropriate if (1) intakes of record will be based on air sampling and (2) concentrations are likely to exceed 0.3 DAC averaged over 40 hours.

Location of Air Samplers

- The purpose of the air sample and airflow patterns will dictate the location of the air sampler.
- In general, air samples should be collected in airflow pathways downstream of release points, i.e., between the release point and the worker.

Location of Air Samplers

- **To verify the effectiveness of confinement or to provide warning of elevated concentrations, the sampling point should be located in the airflow near the release point, between the source and worker.**
- **More than one sampler may be necessary.**

Location of Air Samplers

- To determine release of material outside the laboratory, the sampler should be located near the exhaust point.

Location of Air Samplers

- **Fixed air samplers may be installed slightly above head height and in front of the worker on the front face of a hood.**

Purpose of Sampling	General Placement of Sampler
Estimate worker's intake	Sampler in BZ
Identify area needing confinement control	Sampler in airflow pathway near release
Provide early warning	CAM between workers and release
Test for leakage from sealed confinement	Samplers downstream of confinement
Determine total concentration from many release points	Downstream at exhaust point
Determine airborne radioactivity area	Samplers at workers' locations
Special purpose (particle size)	Case by case, depending on airflow

Using Air Concentrations

- If air sampling is to be used to assess worker intakes, then each frequently occupied work location should have its own air sampler.

Using Air Concentrations

- The air samplers should be placed as close to the breathing zone (BZ) of the worker as practical.
- The breathing zone is the area about 12 inches around the head.

Using Air Concentrations

- ***When air sampling results will be used to determine the intake and dose of record, the licensee may have to demonstrate that the sampled air represents the worker's BZ air.***

  Reg Guide 8.25.

Using Air Concentrations

- If :
  - Monitoring for intakes is required and
  - Intake is based on air sampling

- Then:
  - the licensee must demonstrate that the sampled air is representative of the BZ air, i.e., the air actually inhaled by the worker(s)

Using Air Concentrations

- Assume exposure is in an airborne radioactivity area (>12 DAC-hours/wk), and
- Lapel samplers are not used.

Using Air Concentrations

- Representativeness can be demonstrated by comparing air sampling results with:
  - Lapel sampler results.
  - Bioassay results.
  - Multiple air samples near the BZ.
  - Quantitative air flow studies.

Using Air Concentrations

- If results show that the sampled air is not representative of the worker's BZ, the licensee may need to:
  - Relocate samplers.
  - Switch to lapel sampling.
  - Use bioassay to assess intake.

Using Air Concentrations

- When sampled air is not representative of the worker's BZ, the licensee should correct intake estimates made within the last year and subsequent to the previous demonstration of representativeness. Reg Guide 8.25.

Using Air Concentrations

- The licensee may use the specific physical and biochemical properties of the radionuclides taken into the body to calculate CEDE, but shall document that information in the individual's dose record. 20.1204 (c).

Using Air Concentrations

- The licensee may request (prior) approval from the NRC to adjust ALI and DAC values to reflect actual physical and chemical characteristics of airborne radioactive material (e.g. aerosol size distribution, solubility class) 20.1204 (c)(2).

Types of Air Samplers

- Lapel samplers are worn by the worker, with the filter holder worn on or near the shirt collar and the battery powered vacuum pump worn on the belt.

Buck Basic 1
75 to 600 cc/min

Buck Basic 5
0.6 – 5 LPM / 5-600 cc/min

Buck Basic 12
10-Liters/min.

From F&J Specialty Products

Types of Air Samples

- **Lapel samplers may be the best method of estimating breathing zone concentrations because they are located close to the worker's nose and mouth.**

Types of Air Samples

- A primary problem with BZ samplers is that they have a low flow rate (2 L/min), which may make them unsuitable for some airborne radioactivity areas, e.g., a radionuclide with a very low DAC.

Types of Air Samples

- The low flow rate problem can be overcome by:
  - Collecting the sample for a longer time.
  - Using a more sensitive counting system.

Types of Air Samples

- Other problems with lapel samplers are:
  - They may become contaminated and give higher readings.
  - They are expensive.
  - Require worker acceptance (some workers find them uncomfortable).
- In spite of the problems, lapel samplers still may be the best method for determining intakes.

Types of Air Samples

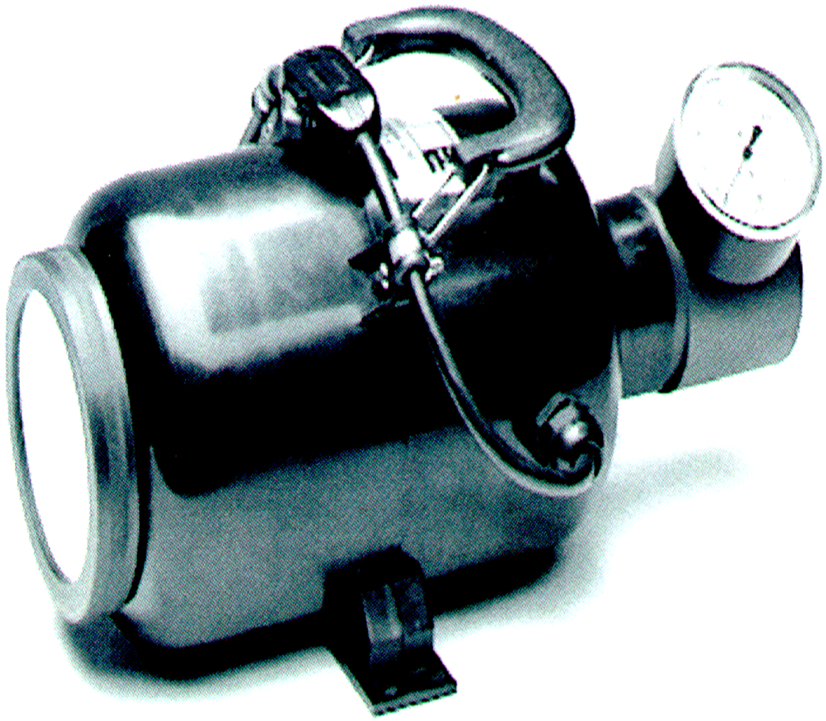
- Portable air samplers are usually used in facilities where the location of airborne radioactivity changes frequently, such as nuclear power plants.
- Because they are portable, they can be located close to the worker.

Types of Air Samples

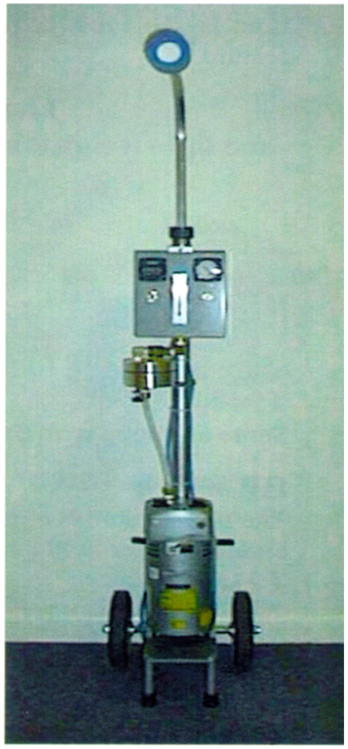
- Portable air samplers are available as:
  - Rugged AC samplers.
  - Battery powered air samplers with air volume totalizers.
  - Constant airflow samplers on goosenecks.

Types of Air Samples

- Portable samplers are categorized by their airflow rates as low-volume or high volume samplers.



Types of Air Samples



LV-14M
Breathing Zone Air
Samplers

- For breathing zone sampling, low-volume samplers are used, with flow rates from 28 to 56 L/min.

Types of Air Samples

- **Fixed location samplers or general air samplers are used for various purposes (detect releases, estimate intakes) and can be used to collect continuous or grab samples.**

Types of Air Samples

- Air monitors are designed to prevent worker exposure to higher than expected levels of airborne radioactive materials.

Types of Air Samples

- The early warning is provided by:
  - Prompt sample analysis.
  - Continuous monitoring in real time.
  - Alarm often triggered by rate of increase in counting rate.

Types of Air Samples

- Air sampling may be continuous or intermittent (grab samples).
- Continuous samples are typically exchanged on a weekly basis.

Types of Air Samples

- Grab sampling for continuous processes may be collected on a weekly basis, or less frequently if concentrations are extremely low.
- Grab sampling is also performed for intermittent processes.

Types of Filters

- There are different types of filters with different characteristics.
- The desirable characteristics of an ideal filter media are:
  - High collection efficiency
  - Low flow resistance
  - Low deposition of non-respirable particulates

Types of Filters

- Cellulose filters
  - Moderate flow resistance
  - Poor collection efficiency
  - Low surface collection
  - High burial loss
- Cellulose Ester Membrane filters
  - High flow resistance
  - High collection efficiency
  - High surface collection
  - Low burial loss

Types of Filters

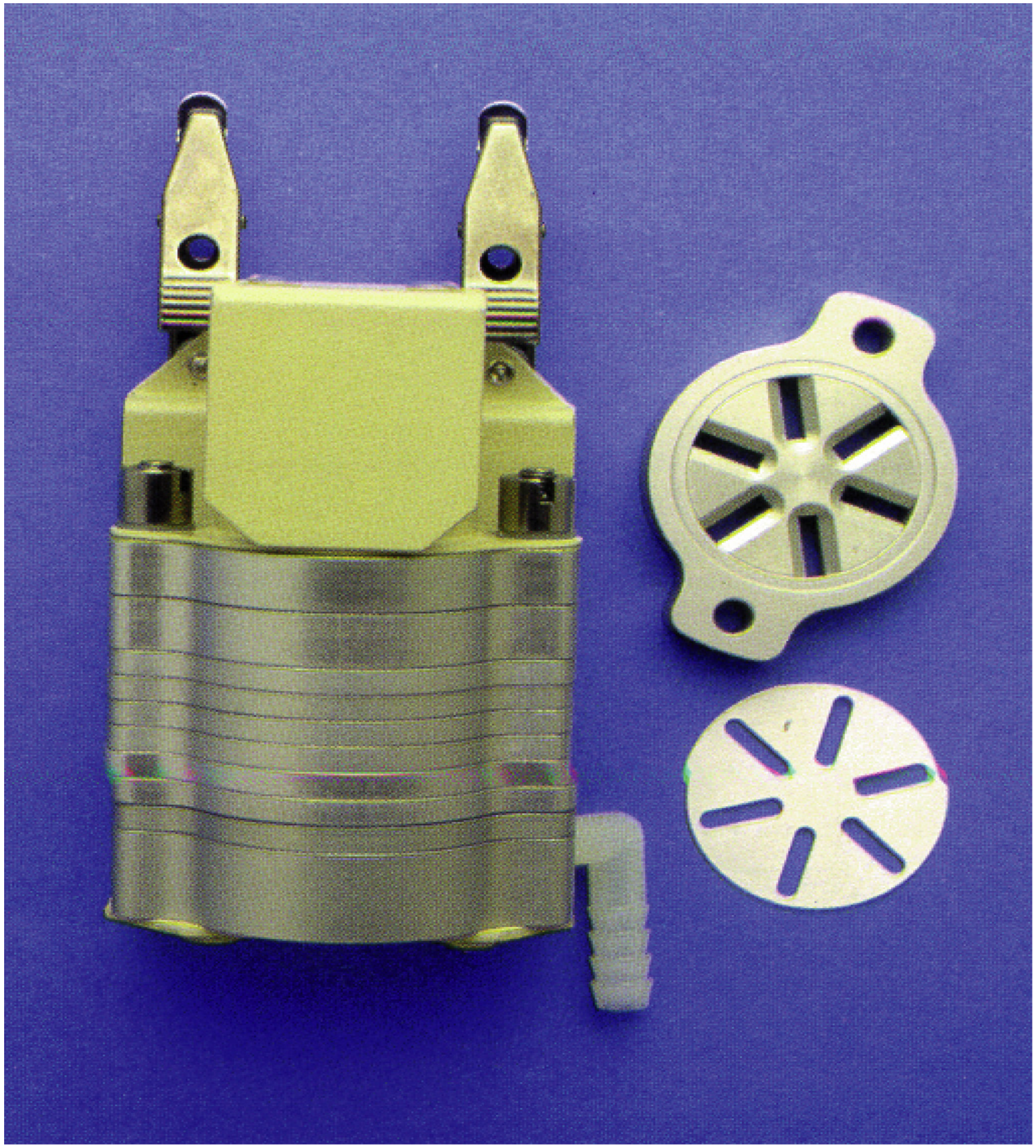
- Glass Fiber filters
  - Moderate flow resistance
  - High collection efficiency
  - Moderate surface collection
  - Low burial loss
  - Not advised if destructive analysis will be done

Size Selective Devices

- Two categories
  - Particle size devices
  - Respirable fraction devices

Size Selection Devices

- Particle sizing devices
- Collects all particles based on particle size
- Known as cascade impactor
- Used to determine the distribution of particle sizes and to correct dose for larger or smaller particle size.



Size Selection Devices

- Respirable-Fraction sampler
- The most commonly used is the cyclone separator
- Rated at a specific flow rate usually 1.7 lpm.
- Separates out all particles bigger than 10 um and 50% of particles 4 um.
- Collects smaller respirable particles on the filter.

Personal Cyclone Sampler

Sample Activity Measurement

- Gross alpha or beta measurement
  - May need to be corrected for “burial loss” in the filter
- Direct Spectroscopy
  - Alpha, and gamma spec, but again for alpha spec “burial loss” could interfere with spectrum
- Destructive analysis
  - Chemical processing then analysis, but glass fiber filters difficult to chemically digest (need to use HF)

Calculation of Exposure

- Once activity is known then calculation can be performed to determine airborne concentration in µCi/mL, and then compare to DAC to get potential intake and dose.

$$\frac{cpm}{eff\left(\frac{cpm}{dpm}\right) * 2.22E6\left(\frac{dpm}{uCi}\right) * flow\left(\frac{L}{m}\right) * 1000\left(\frac{mL}{L}\right) * time(m) * filter\ eff}$$

Example

- You are conducting air sampling in an area that contains U-235 contamination in a chemical form that is solubility class Y. A worker in the area wears a personal air sampler with a flow rate of 2 L/m for 6 hours of work in the area. The sampler uses a glass fiber filter with a collection efficiency of 1 and a surface efficiency of 0.9. The filter is removed and counted and has a count rate of 10 cpm. What is the dose to this worker?
- And by the way, which dose is it?

Given:

count rate is 10 cpm

Efficiency of counter 30 %

Glass fiber filter collection eff iciency is 100%

Surface efficiency is 90%

Flow rate of sampler is 2 L/min

Sampling time is 6 hours (360 minutes)

DAC value for class Y U-235 is 2E-11 µCi/ml

Calculation

$$\frac{10\ cpm}{0.30\left(\frac{cpm}{dpm}\right) * 2.22E6\left(\frac{dpm}{uCi}\right) * 2\left(\frac{L}{m}\right) * 1000\ (mL/L)\ * 360(m) * 0.9} = 2.3E\text{-}11\ uCi/ml$$

$$D = \frac{2.3E-11uCi/ml}{2E-11uCi/ml} * 6\ hours * \frac{2.5\ mrem}{DAC-Hr} = 17.25\ mrem$$

Calculation, continued

- The dose is 17.25 mrem, but which dose is this?
- You have to determine when you look up the DAC if it is based on the SALI or the NALI
- In this case (class Y uranium), it is based on the SALI
- So the 17.25 mrem is CEDE.

Radon and Air Sampling

- When collecting an air sample the radon gas passes through the filter but the decay product are collected.
- The decay products begin to decay into other decay products so an equilibrium is eventually established as long as the air sample is being collected.
- Once air sampling is stopped the decay products will continue to decay and the activity due to the decay products will decrease over time.

Radon and Air Sampling

- This is important when using continuous air monitors
- When a new filter is placed in the CAM the activity will increase rapidly as the equilibrium of decay products is established; this could result in an alarm if the CAM is not properly set up.
- Fluctuations of radon throughout the day or evening can also cause CAM alarms.
- Some CAMs are now equipped with a radon rejection algorithm.

Radon and air sampling

- When conducting air sampling using stationary or lapel air samplers, radon decay products can cause a misinterpretation if you assume all activity on a filter is from the radionuclide of interest.
- The usual method of dealing with this is to conduct an initial count of the filter, then hold the filter for seven days and do another count after the radon daughters have decayed.

Measurement of Radon Decay Products

- The two measurement methods for radon decay products that are described here are very similar: the Kusnetz and the Thomas-Tsivoglou techniques.
- They are not particularly sensitive, that is, they would not be used for most environmental measurements.
- Both methods were developed for use in the uranium industry about 50 years ago.
- They share one important advantage: there is no need to calibrate the instrumentation in an atmosphere with a known decay product concentration.

Measurement of Radon Decay Products

- Kusnetz Method
  - An air sample is collected on a surface-loading filter for a 5 minute sampling time. Between 40 and 90 minutes after sampling ,the total alpha activity on the filter is measured with a 10 minute count.
  - This technique is widely used because of its simplicity.
  - An important advantage of this method: it is not necessary to calibrate this system in a radon/radon daughter chamber. All that is needed is the counting efficiency for the alpha detector.

Measurement of Radon Decay Products

- Kusnetz Method
- The working level concentration is determined with the following formula:

$$PAEC = \frac{R}{K\ V\ E}$$

PAEC is the potential alpha energy concentration in working levels

R is the net count rate in cpm

V is the volume of air sampled in liters

K is a correction factor taken from the table in the next slide

Measurement of Radon Decay Products

Time (min)	K
40	150
42	146
44	142
46	138
48	134
50	130
52	126
54	122
56	118

Time (min)	K
58	114
60	110
62	106
64	102
66	98
68	94
70	90
72	87
74	84

Time (min)	K
76	82
78	78
80	75
82	73
84	69
86	66
88	63
90	60

Measurement of Radon Decay Products

- Thomas-Tsivoglou Method
- This is a more sensitive technique than the Kusnetz method and it provides information about the concentrations of the individual radon daughters.
- Like the Kusnetz Method, a 5 minute sampling time is usually used. However, three alpha counts, rather than one, are performed; one from 2-5 minutes, the second from 6-20 minutes and the third from 21-30 minutes after sampling.
- The formulae on the next slide are used to calculate the concentrations of the individual radon daughters:

Measurement of Radon Decay Products

$$Concentration\ of\ Po-218\ in\ pCi/l:$$

$$C_{Po-218} = \frac{1}{F\ E}(0.16746G_1 - 0.0813G_2 + 0.0769G_3 - 0.0566R)$$

$$Concentration\ of\ Pb-214\ in\ pCi/l:$$

$$C_{Pb-214} = \frac{1}{F\ E}(0.00184G_1 - 0.0209G_2 + 0.0494G_3 - 0.1575R)$$

$$Concentration\ of\ Bi-214\ in\ pCi/l:$$

$$C_{Bi-214} = \frac{1}{F\ E}(-0.0235G_1 + 0.0337G_2 - 0.0382G_3 - 0.0576R)$$

Measurement of Radon Decay Products

- F is the flow rate in L/min
- E is the counting efficiency in cpm/dpm
- R is the background count rate in cpm
- G_1 is the gross count from 2-5 minutes after sampling (a three minute count)
- G_2 is the gross count from 6-20 minutes after sampling (a 14 minute count)
- G_3 is the gross count from 21-30 minutes after sampling (a 9 minute count)

Measurement of Radon Decay Products

- Thomas-Tsivoglou Method
  - The Potential Alpha Energy Concentration (in working levels) is then determined with the following formula:
  - PAEC (WL) = 0.00105 $C_{Po\text{-}218}$ + 0.00508 $C_{Pb\text{-}214}$ + 0.00373 $C_{Bi\text{-}214}$
  - The Thomas-Tsivoglou method might be considered "better“ than the Kusnetz method.
  - Nevertheless, it is less widely used because the math and counting are more complicated and because of the inconvenience of having to start the first count exactly two minutes after sampling.

Surface Contamination Control

- Uranium contamination on surfaces such as floors and walls does not usually present a significant risk to personnel unless the uranium becomes airborne by resuspension and is inhaled.
- The probability of resuspension of uranium as a result of normal operations is low.
- This is a function of the chemical and physical properties of the uranium compound(s) in the workplace.
- Even if the probability of resuspension is low, surface contamination on floors can result in contamination of shoes, and thereby result in tracking of contamination into uncontrolled areas.

Surface Contamination Control

- A program of contamination monitoring can be used to accomplish several other objectives such as:
  - The program can be designed to provide information to detect containment failures or departures from good operating practices.
  - It can provide information that will assist in the design of personnel monitoring programs.
  - It can provide information to establish operating zones, guidelines and constraints for radiation protection and operating procedures.
  - It can provide assurance that contamination is kept within controlled areas.

Surface Contamination Control

- Contamination control of work surfaces such as tools, equipment to be worked on, desks, tables in process areas, etc. is a greater concern than contamination on floors.
- The likelihood of personnel contamination, ingestion of material through hand contamination, or inhalation through work activities represents a significant potential for exposure of personnel.
- Job-specific monitoring is required to establish protection requirements as a function of surface contamination.

Reporting and Documenting Contamination Levels

- When conducting contamination surveys, maps with sufficient detail to permit identification of original survey locations should be maintained.
- Records shall contain sufficient detail to be meaningful even after the originator is no longer available.

Reporting and Documenting Contamination Levels

- Contamination surveys should be recorded on appropriate standard forms and include the following common elements:
  - Date, time, and purpose of the survey,
  - General and specific location of the survey
  - Name and signature of the surveyor
  - Pertinent information needed to interpret the survey results
  - Reference to a specific radiological work permit if the survey is performed to support the permit.

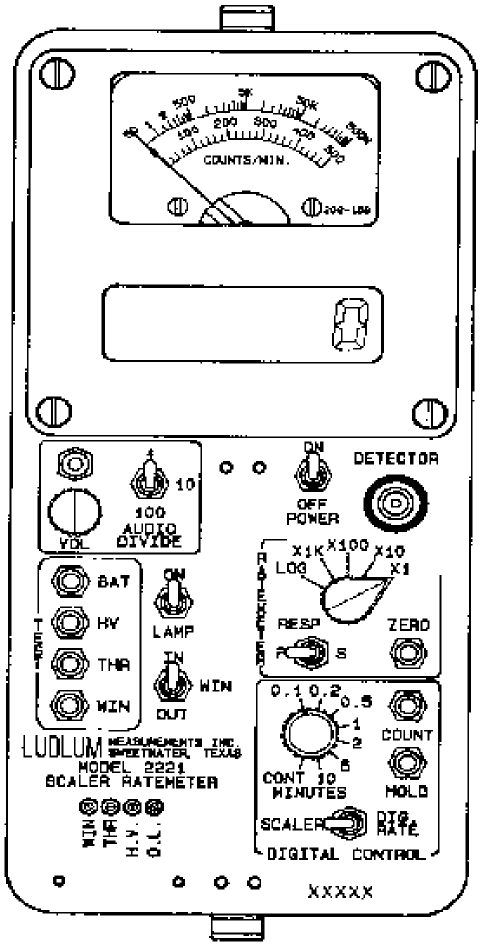
Reporting and Documenting Contamination Levels

- In addition, records of contamination surveys should include, at a minimum, the following information:
  - Model and serial number of counting equipment
  - Contamination levels and appropriate supporting parameters, including counting efficiency, counting time, correction factors, type of radiation, and whether the contamination was fixed or removable.
  - Locations found to contain contamination
  - Follow-up survey results for decontamination processes, cross-referenced to the original survey.

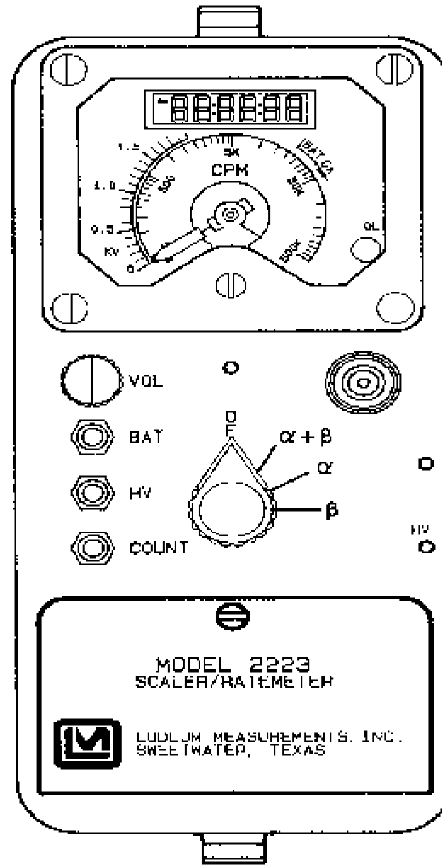
Survey Instrumentaton

- Common field survey instruments:
  - Gas proportional
    - Alpha-only (using voltage setting)
    - Beta-only (using Mylar thickness)
    - Alpha plus Beta
  - GM (measures primarily beta)
  - ZnS (alpha measurements)
  - Dual phosphor (alpha and beta, cross talk)

Ratemeter vs. Scaler



Combination ratemeter-scaler



Combination ratemeter-scaler. Employs logar
analog scale. Dual channel capability for alpha
beta discrimination.

Types of Detectors

- alpha and beta detectors
- alpha only detectors
- beta only detectors
- gamma detectors

Detectors (General)

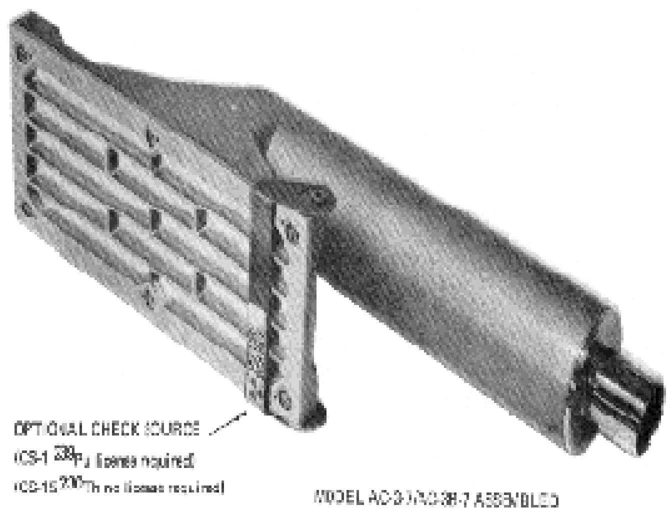
- Large area detectors
  - advantages
    - faster coverage
    - greater sensitivity (esp. large sources)
  - disadvantages
    - efficiency varies across face
    - accessing small areas
    - portability
    - easier to damage
    - higher backgrounds (esp. beta-gamma)

Alpha and Beta Detectors

- charged particles vs. gamma rays
  - efficiency
- alpha vs. beta detection
  - limits
  - attenuation
  - background
  - effects of gamma fields
  - efficiency as a function of energy
- Cross talk

Alpha Scintillators (ZnS)

- only responds to alphas
- no gas supply
- large window areas
- light leaks
- fragile window



Combined Alpha and Beta Scintillators

- can distinguish alphas and betas
- no gas supply required
- large window areas
- beta efficiency can be relatively poor
- light leaks

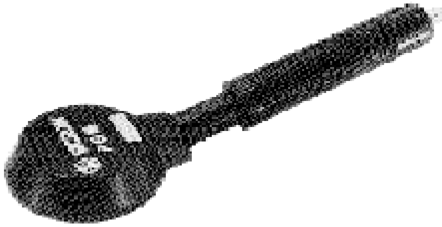
Sealed Proportional Counters

- can distinguish alphas and betas
- no gas supply required
- larger areas have thicker windows
- window not repairable

Beta Detectors

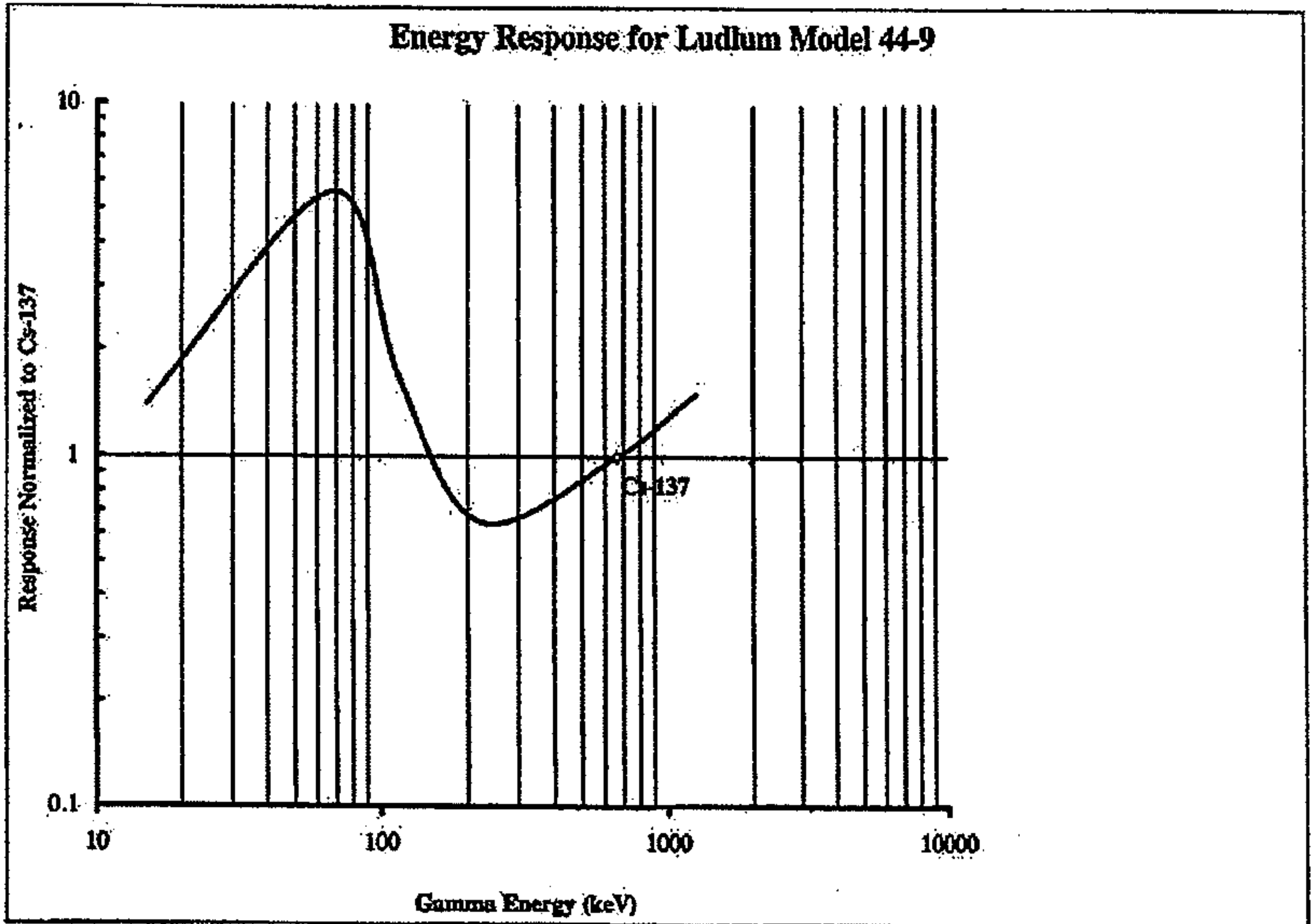
- respond to gammas
- increased size, increased background
- efficiency
  - window thickness
  - beta energy

Pancake GM



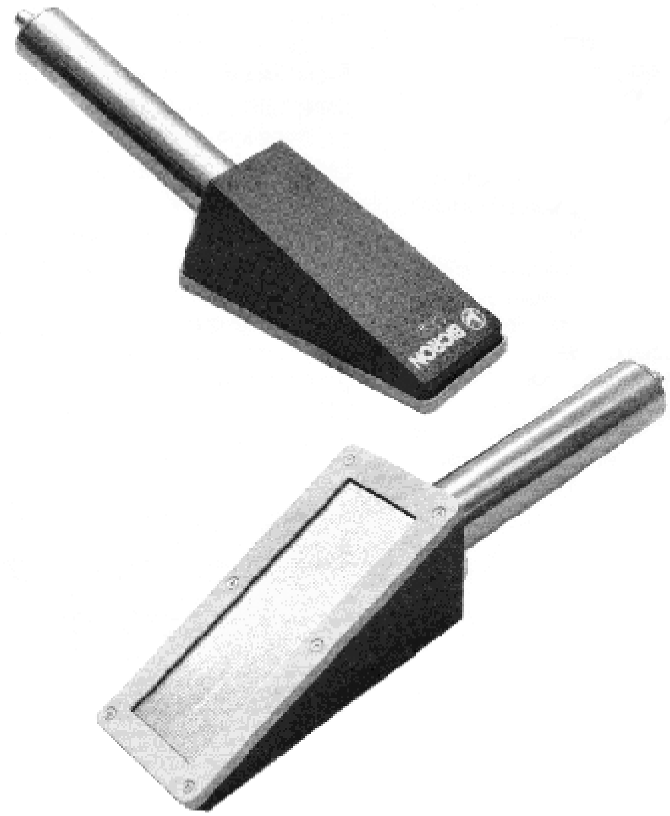
- responds to alphas, betas and gammas

- small window
- shielded versions available
- rugged


Energy Response for Ludlum Model 44-9
10
1
0.1
Response Normalized to Cs-137
Cs-137
10
100
1000
10000
Gamma Energy (keV)

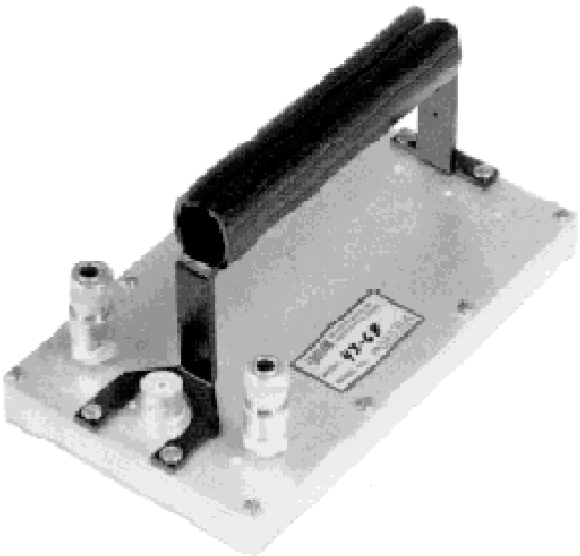
Beta Scintallators

- large thin windows
- no gas supply
- light leaks
- sensitive to voltage



Gas Flow Proportional Counters

- Can distinguish alphas and betas
- P-10 gas needed
- large windows
- very thin window
- problems with counting gas

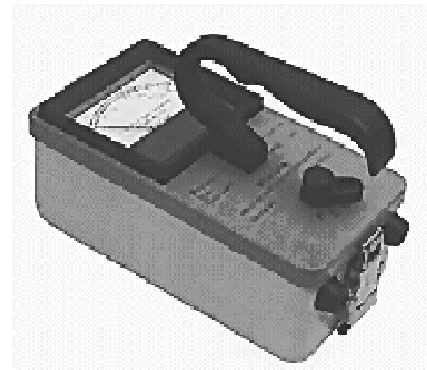


Gamma and X-Ray Measurements

- Gamma and X-Ray Measurements might be performed to:
  - Identify gross radiation levels
  - Search for, and possibly quantify, surface contaminants that do no emit readily detectable charged particles
  - Search for, and possibly quantify, contaminants in a matrix that would attenuate charged particles (painted, dirty surfaces)

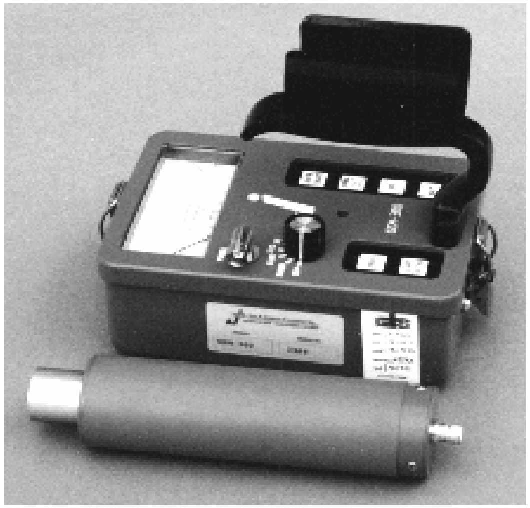
Pressurized Ion Chambers

- sealed pressurized chambers
- measure in μR/h range
- less accurate than μR (NaI) or μrem (plastic) meters at background
- not recommended to substitute for large volume high pressure Reuter Stokes PICs



Plastic Scintillators

- easily measures background (µR/h or µrem/h)
- lighter and more rugged than NaI
- energy independent

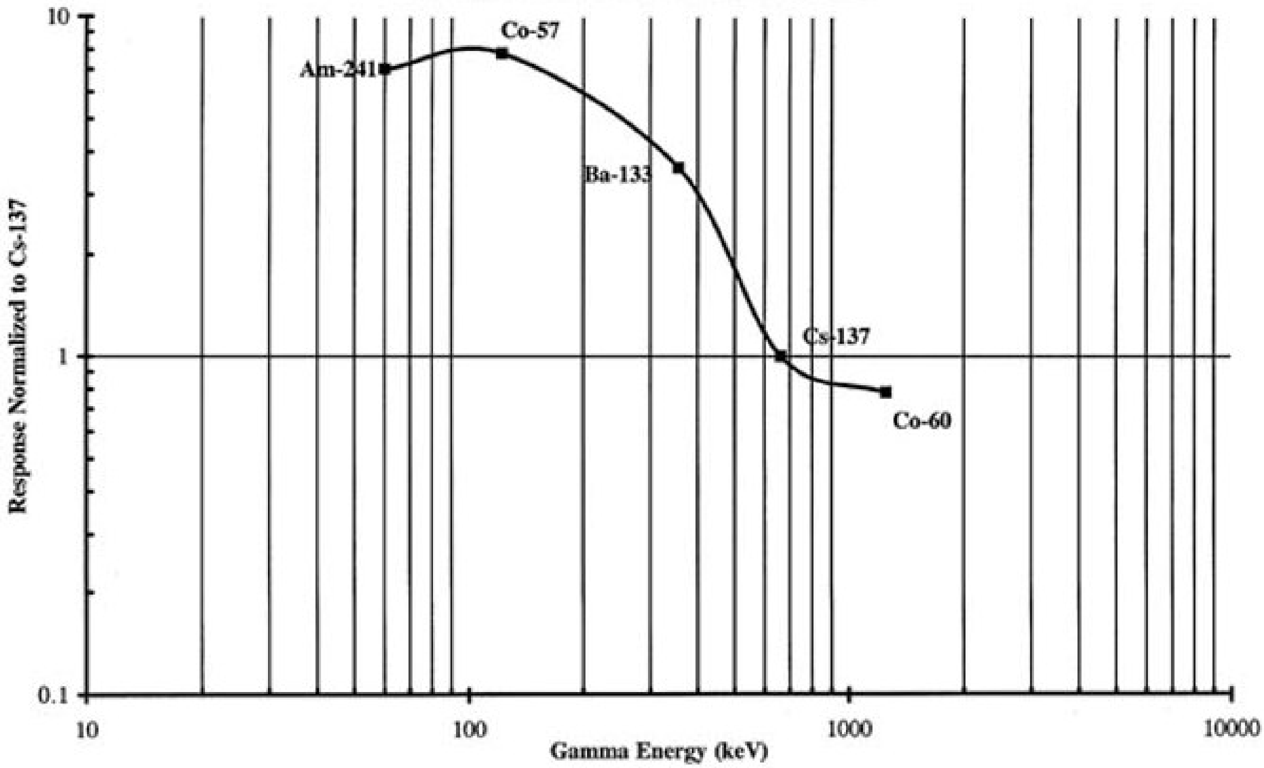


NaI micro R meters

- Contains a small NaI detector
- Very energy dependent

NaI micro R meters

Energy Response for Ludlum Model 19



Reporting and Documenting Contamination Levels

- Records for the release of material and equipment from radiological areas to uncontrolled areas should:
  - Describe the property and contain:
  - The date of the release survey
  - The identity of the individual performing the survey
  - The type and serial number of the instrument used
  - The results of the survey

Reporting and Documenting Contamination Levels

- All skin and personal property contamination should be documented and evaluated to help improve the contamination control program.
- Documentation should include:
  - Person's name and work group
  - Location, amount, and type of skin contamination
  - Results of decontaminaiton
  - Description of the circumstances involved in the occurance, radiation work permit number, and protective clothing required

Workplace Monitoring

- Monitoring of the workplace is an essential element of every routine surveillance program.
- The rigor with which all of the various elements of a radiation monitoring program are applied should be tailored to meet the needs of the individual work areas.
- Each program should be designed to meet existing needs, but also should be flexible to allow for incorporation of the possible advantages to be provided by the various available monitoring practices.

Workplace Monitoring

- Monitoring practices include but are not limited to the following:
  - Contamination surveys of the workplace
  - Release surveys
  - External exposure surveys
  - Airborne contamination surveys
  - Routine surveillance monitoring

Contamination Surveys of the Workplace

- The results of contamination surveys should be reported in activity per unit area, e.g., dpm/100 cm^2
- This permits interpretation of results without the need to know instrument efficiency and geometry.
- All workplaces should be monitored on a regularly scheduled basis.
- RegGuide 8.30 "Health Physics Surveys in Uranium Recovery Facilities" gives suggested survey frequencies.

Type of Survey	Type of Area	Survey Frequency	Lower Limit of Detection
1. Uranium ore dust	Airborne radioactivity areas Other indoor process areas Outdoor areas	Weekly grab samples Monthly grab samples Quarterly grab samples	5×10^{-12} μCi/ml (uranium)
2. Yellowcake	Airborne radioactivity areas Other indoor process areas Special maintenance involving high airborne concentrations of yellowcake	Weekly grab samples Monthly grab samples Extra breathing zone grab samples	1×10^{-11} μCi/ml
3. Radon daughters	Areas that exceed 0.08 working level Areas that exceed 0.03 working level Areas below 0.03 working level	Weekly radon daughter grab samples Monthly radon daughter grab samples Quarterly radon daughter grab samples	0.03 WL
4. External radiation: Gamma Beta	Throughout UR facility Radiation areas Where workers are in close contact with yellowcake	Semiannually Quarterly Survey by operation done once plus whenever procedures change	0.1 mrad/hr 1 mrem/hr
5. Surface contamination	Yellowcake areas Eating rooms, change rooms, control rooms, offices	Daily Weekly	Visual 500 dpm alpha per 100 cm^2
6. Skin and personal clothing	Yellowcake workers who shower Yellowcake workers who do not shower	Quarterly Each day before leaving	500 dpm alpha per 100 cm^2
7. Equipment to be released	Equipment to be released that may be contaminated	Once before release	500 dpm alpha per 100 cm^2
8. Package containing yellowcake	Packages	Spot check before release	500 dpm alpha per 100 cm^2
9. Ventilation	All areas with airborne radioactivity	Daily	Not applicable
10. Respirators	Respirator face pieces and hoods	Before reuse	100 dpm alpha per 100 cm^2

Surface Contamination Limits

Surface Contamination Levels for Uranium and Daughters on Equipment To Be Released for Unrestricted Use, on Clothing, and on Nonoperating Areas of UR Facilities*

Average**	5,000 dpm alpha per 100 cm^2	Average over no more than $1 m^2$
Maximum**	15,000 dpm alpha per 100 cm^2	Applies to an area of not more than 100 cm^2
Removable	1,000 dpm alpha per 100 cm^2	Determined by smearing with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the smear

* These values are taken from Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors" (Ref. 23), and from "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source. or Special Nuclear Material," Division of Fuel Cycle and Material Safety, USNRC, Washington, DC 20555, August 1987 (Ref. 24). Available in NRC Public Document Room for inspection and copying for a fee.

** The value includes both fixed and removable contamination.

(The contamination levels in Table 2 are given in units of dpm/100 cm^2 because this is the minimum area typically surveyed. When performing a smear or wipe test, the area should roughly approximate 100 cm^2. However, there is no need to be precise about the area to be smeared.)

Measurement and Survey Techniques

- Surveys are conducted for two types of surface contamination:
  - Total/fixed contamination which consists of either a scan or direct measurements
  - Removable contamination which consists of either a large area wipe or a smear survey.

Survey for Removable Contamination

- A large area wipe survey is used to qualitatively detect gross removable contamination.
- This technique tends to concentrate low level contamination that may be present.
- Surfaces to be wiped should be free of debris or grease which would attenuate alpha radiation.
- An alpha survey meter is held near contact with the surface of the wipe; if contamination is detected then swipe surveys should be used.
- A nonabsorbent material should be used (i.e. masslinn).

Survey for Removable Contamination

- A smear survey is used to locate and quantify removable contamination that is known or suspected to exist.
- A smear or swipe survey is performed by wiping a cloth or filter over a 100 cm^2 area of the surface.
- The swipe should be taken with a dry medium using moderate pressure.
- Common practice is to use two fingers to press the swipe against the surface to be swiped then move along in a S shaped path with a nominal length of 8 to 10 inches (20 to 25 cm).

Survey for Removable Contamination

- **When the potential contamination emits alpha radiation, paper or fiberglass filters should be used so as to not bury the alpha activity in the filter.**
- **If a scan survey detects contamination, a smear survey should be taken to determine if the contamination is removable or not.**

Survey for Fixed Contamination

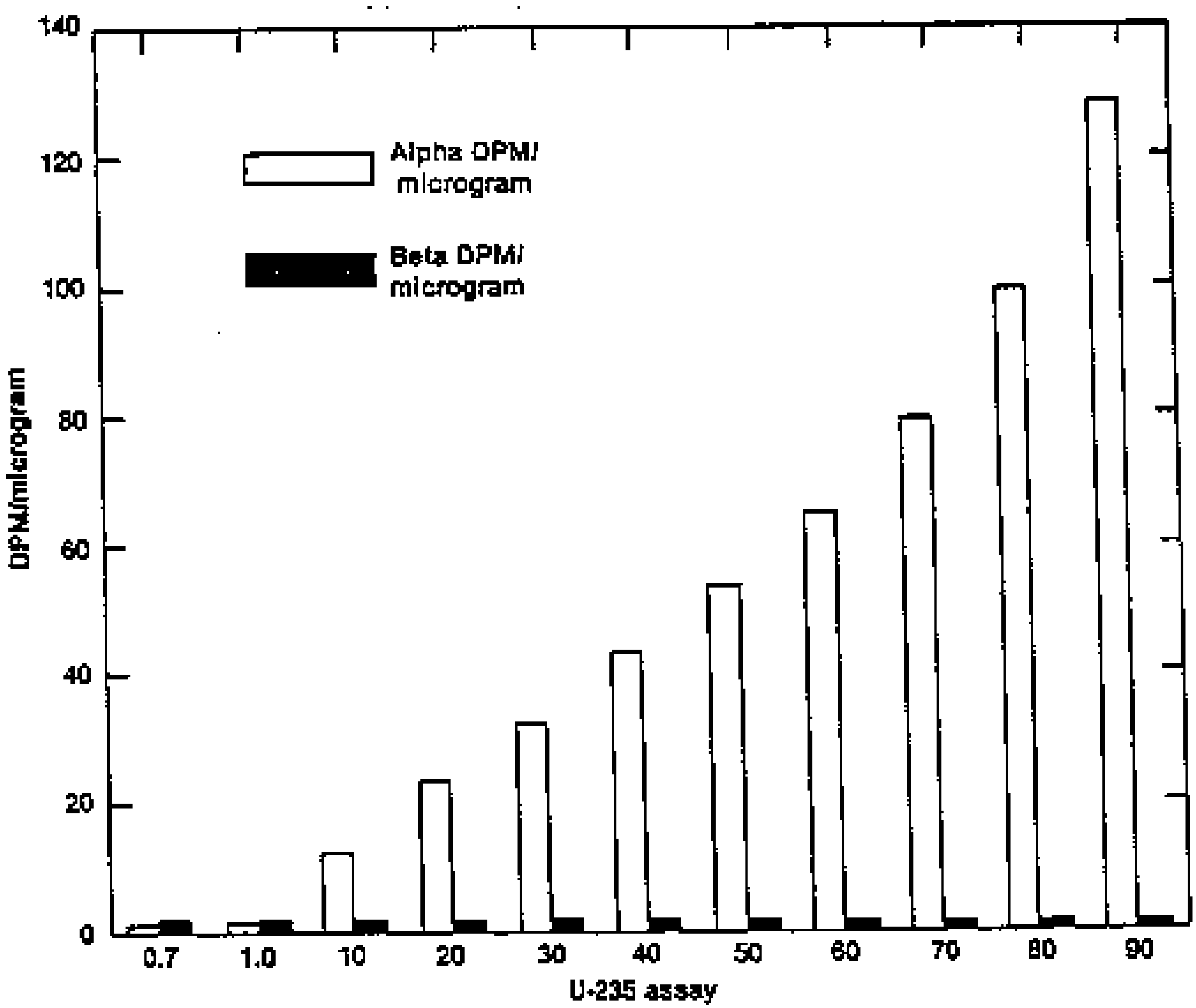
- A scan survey for fixed contamination requires passing a detector attached to a portable instrument over the surface of the area being surveyed at a fixed, known scan speed and at a specified distance from the surface.
- Typically, the scan speed is 2 in per second (approximately one detector width) and the maximum distance is 0.25 inches for alpha contamination.
- During the performance of a scan survey, the audible response is faster than the needle deflection.
- Audible response should be used to find the contamination, then take a reading with the meter in place.

Survey for Fixed Contamination

- When conducting alpha surveys, the surveyor should pause for 3 to 5 seconds each time an audible response is heard.
- This will allow a longer count to be done so the surveyor can determine if there is actual contamination or a background fluctuation.
- When conducting release surveys after scan surveys, one minute direct counts should be conducted at locations that indicated contamination and at random locations.

Uranium Contamination Detection

- Typically, detection of uranium contamination has been performed using alpha activity.
- For some situations detection of the beta/gamma radiation from uranium decay products may be more sensitive and more appropriate.
- For natural uranium, depleted uranium, and low-enriched uranium that are in equilibrium with their decay products, the detection sensitivity is higher for the beta/gamma radiation than for alpha.
- If the uranium is recently processed, as is the case in uranium recovery facilities, then detection of the alpha radiation is more appropriate.


140
120
100
80
60
40
20
0
DPM/microgram
Alpha DPM/ microgram
Beta DPM/ microgram
0.7
1.0
10
20
30
40
50
60
70
80
90
U-235 assay

Radon and Surface Contamination

- Radon can cause an interference with contamination surveying due to plate out of the decay products.
- This can happen especially when there is rain.
- The rain will wash out the decay products and the moisture in the atmosphere will cause the radon gas to hug the ground, which increases the radon gas and decay product concentrations.
- Decay products tend to plate out on areas with a static charge, e.g., TV or CRT monitor screens.

Personnel Contamination Control

- The primary hazard to personnel from uranium is from internal exposure; however, contamination is also of concern because of potential skin doses.
- Additionally an objective of the contamination control program is to confine uranium contamination to production/work areas.
- Guidelines for allowable contamination on personnel and personnel clothing/shoes are required for both inside the plant and prior to exiting radiological areas

Personnel Contamination Control

- A personnel monitoring program must be developed with adequate monitoring equipment and sensitivity to provide assurance that contamination is effectively controlled.
- The guidelines should be developed considering the following:
  - The need to prevent activity above limits from appearing outside the controlled area.
  - The degree of risk to the health of the employees, their families, and the public from contamination
  - The technical feasibility of measurement of the guide levels
  - Issues of public concern over uncontrolled releases

Monitoring Program

- Instrumentation should be provided and personnel should be required to conduct surveys of themselves before exiting contamination areas.
- Assurance should be provided that personnel are monitored prior to breaks, meals, or exiting from the plant site.
- Hand and foot monitors are preferred to portable survey instruments for personnel surveying.
- Random audits and confirmatory surveys should be conducted.

Protective Clothing

- It is advisable for the company to issue clothing for personnel to wear in work areas.
- In addition to company issued clothing, additional PPE may be required:
  - Shoe covers
  - Lab coats
  - Coveralls
- Decontamination should be performed if alpha contamination of skin or clothing of workers is found to exceed 1000 dpm/100 cm^2

Personnel Decontamination

- Skin decontamination should be performed by health physics technicians or other members of the health physics staff.
- Non-abrasive methods should be used for skin decontamination to protect the tissue from deeper contamination.
- Masking tape can be used for dry decontamination.
- Wet decontamination can be accomplished with soap and lukewarm water.
- If initial decontamination is unsuccessful, then further efforts should be handled on a case by case basis, often with consultation from occupational medicine staff.