LA-UR-17-28569
Approved for public release; distribution is unlimited.

Title: IdentiFINDER Laboratory Exercise

Author(s): Weinmann-Smith, Robert

Intended for: Training Course

Issued: 2017-09-21

IdentiFINDER LABORATORY EXERCISE

Objective:	To provide the participant with a thorough understanding of the operation and capability of the identiFINDER and the ability to interpret measurement results.
Equipment:	(1) identiFINDER handheld instrument (2) Computer with identiFINDER software
Nuclear Materials:	(1) Uranium standard of various enrichment (2) Plutonium standards (3) Standard gamma-ray check sources
Required Exercises:	Using the NaI detector and MCA, perform calibration and verification measurements using hand calculations. Uranium oxide powders and NBS standards are used.
Optional Exercises	(1) Geometry and attenuation effects (2) Measurement background effects (3) Enrichment measurement using HPGe detector (4) Isotopic measurement using HPGe detector
Time Required:	1/2 day
Group Size:	2-3 participants

Introduction

The identiFINDER2 is an easily portable handheld NaI gamma detector. The IAEA uses the safeguards version of the identiFINDER2 and calls it the HM-5. The HM-5 has built in software to analyze the detection signal specifically for IAEA verification applications and can perform the following tasks:

HM-5 Capabilities
Display dose rate and accumulated dose
Alert on proximity to a radioactive source and help the user to locate sources
Identify radioactive isotopes by analyzing the detected gamma spectrum and characterizing the typical use of the identified isotopes
Acquire spectra and analyze peaks with the built in Multi-Channel Analyzer (MCA)
Verify the presence of uranium and plutonium for an Attribute verification measurement
Measure the ^{235}U enrichment utilizing the NaIGEM software analysis software
Determine the active length of fresh fuel rods or assemblies

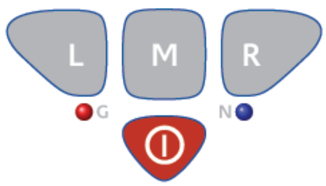
Some features of the HM-5 are listed below

HM-5 Features
Hand-held gamma-ray spectrometer configured with a sodium iodide detector NaI (Tl) crystal with a 23-mm diameter and 21-mm thickness.
A Geiger-Muller (GM) detector is also installed to measure high gamma dose rates, from 250 uSv/h up to 1 mSv/h. This detector is located inside the instrument case at a position indicated by the red dot.
Each instrument has a ^{137}Cs check source with an activity of ~620 Bq. The source is affixed to the inside of the red protective cap which is used for performing energy calibrations, as needed
The photomultiplier tube contains an LED (light emitting diode) which provides continuous gain stabilization. This minimizes the need for inspector-initiated energy calibrations.
An annular-shaped, 5-mm thick tungsten collimator surrounds the sodium iodide detector, which is necessary for uranium enrichment measurements
The battery life of the re-chargeable NiMH batteries is ~6 hours under normal use at room temperatures.
The instrument should always be charged overnight prior to planed use the following day
The included CD contains the driver necessary to connect the device to a computer

Instrument Familiarization

- Turn on the instrument by pressing the red power key.

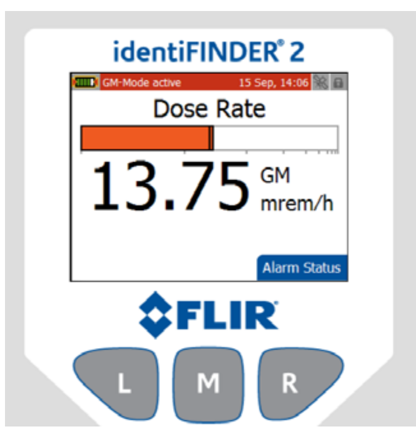
Wait for the HM-5 to initialize and to perform the startup calibration. The dose rate will be displayed. The three HM-5 keys, Left (L), Middle (M), and Right (R), correspond to the options displayed in the screen above them. Most menus use L to scroll down, M to select an option, and R to exit. When R is not available to exit, skip or the power key can be used instead. When changing, some fields the keys will correspond to skip, +, and -. The + and – keys change the field, and 'skip' and 'accept' will confirm the change.



The initial options are HM-5, Finder & ID, and Options.

- Use the keys to enter, scroll through, and exit the initial options to become familiar with them.
- Turn off the detector and place it in a high radiation field (several highly active Pu sources). Turn the detector back on. What happens? Move the detector to a low background area and note the dose rate. Restart the detector and note the dose rate. Are there any differences?

At high dose rates the detector switches from NaI to Geiger-Muller (GM). The image below shows the screen that will appear when the detector switches from NaI to GM. The information in the red bar indicates which mode the HM-5 is operating in to measure the dose rate.



- Use sources to find the point at which this happens

Source Finder

In this section you will use the source finder mode to locate a radiation source. The display, red LED, vibrator, and beeper of the HM-5 all increase activity as they are moved closer to a source.

- Enter source finder settings mode by selecting **Finder & ID > Finder > Finder Settings**. Set the values to match the table below.

HM-5 finder settings		
Setting	Use	Suggested Value
Time	Data logging rate. The detector updates faster at lower values	5s/10 (0.5 seconds)
Sensitivity	1-sigma threshold above background. The HM-5 considers doses above this threshold as being in proximity to a source	100%

- Exit finder settings.

When you select **Finder** the detector will immediately take a background measurement. Make sure to take the background in a low radiation environment. When the background measurement is finished, the display will show the dose rate. The red dashed line represents the sensitivity value. When the dose goes above this value the detector will alarm.

- Select **Finder**.

The effects of the 5mm tungsten collimator can be seen by rotating the detector slowly in a circle with a source on one side.

- Test the collimation to understand how the detector will respond to being pointed at sources.
- Now try to locate the hidden sources in the area identified by the instructor.

Calibration Check

In this section you will perform a calibration check. The detector will zoom into the position of an expected peak, and if the source is present you will see the peak form. Confirming that the peak is in the expected position will verify that the HM-5's energy calibration is correct.

- Start the calibration check by going to **HM-5 > Check Calibration**.

The current nuclide is specified in the top right, and the built in Cs-137 source is always available.

- Use the built in Cs-137 source to verify the calibration and fill the table below.

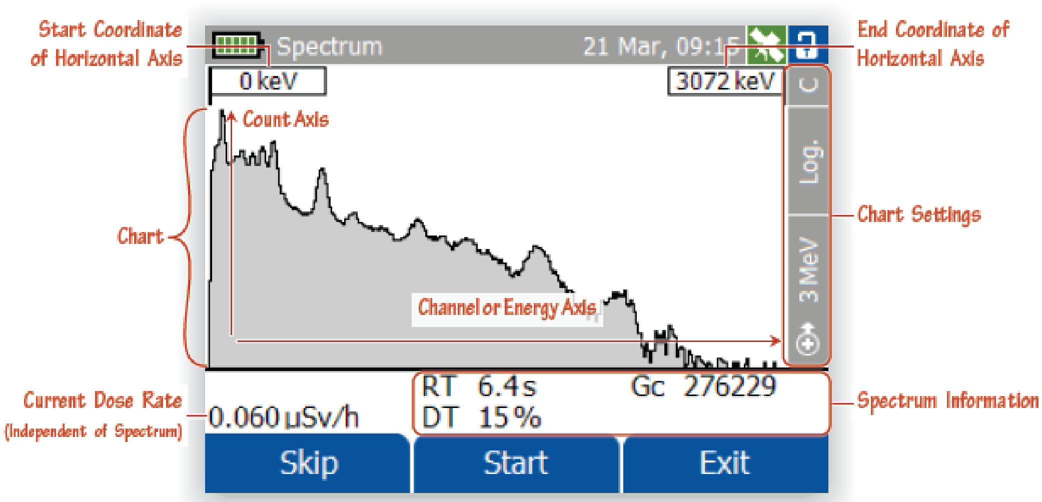
HM-5 Calibration Check			
Nuclide	Peak Position	Uncertainty	Deviation
Cs137			

The calibration check does not update the calibration. If the calibration is wrong it can be updated through **Options > Advanced Menu > Recalibrate.**

Spectrum Acquisition

In this section you will acquire gamma spectra and use the HM-5 gamma spectra features. Gamma spectra can be used to identify sources, and can be saved for later analysis. The gamma spectrum settings can be changed after selecting **HM-5 > spectrum**. Pressing 'skip' will cycle through the available gamma options.

- Select the 'preset' options. Set the live time, real time, and counts to 'no limit' to allow an indefinite counting time. To stop the spectrum acquisition cycle through the options until you can select stop.
- Press skip to cycle through the options and select 'clear' to clear the spectrum.
- Place an instructor-provided source in front of the detector and select 'start' to begin the spectrum acquisition. An example spectrum is shown below.



You will now use the gamma spectra features. Some of the features are listed in the table below.

- Select each feature in the table with notes to see its effects.

Gamma Spectrum Features			
M Key	notes	R key	notes
Zoom	1:1, ROI, 3MeV, 1.5 MeV	Clear	
Identify		Raw	Switches from corrected counts to raw counts. The current mode is indicated in the top right. Corrected subtracts the contribution from the built-in Cs-137 source, and frequently causes incorrect spectra
Y axis	Cycles through linear, square root, logarithmic, Ymax/2, Ymax/4. The current mode is indicated in the middle right	X axis	Cycles between channel and energy on the X axis
Calibration		Live time	Cycles between live time and real time. The current mode is indicated on the bottom middle

Use the cursor and mark channel keys to identify the peaks present in the spectrum. Zoom into the ROI. Fill in the table below.

HM-5 Spectrum Peak Identification	
Peak	Resolution

Do the peak and resolution values match what you would expect from your source and a NaI detector?

Radionuclide Identification

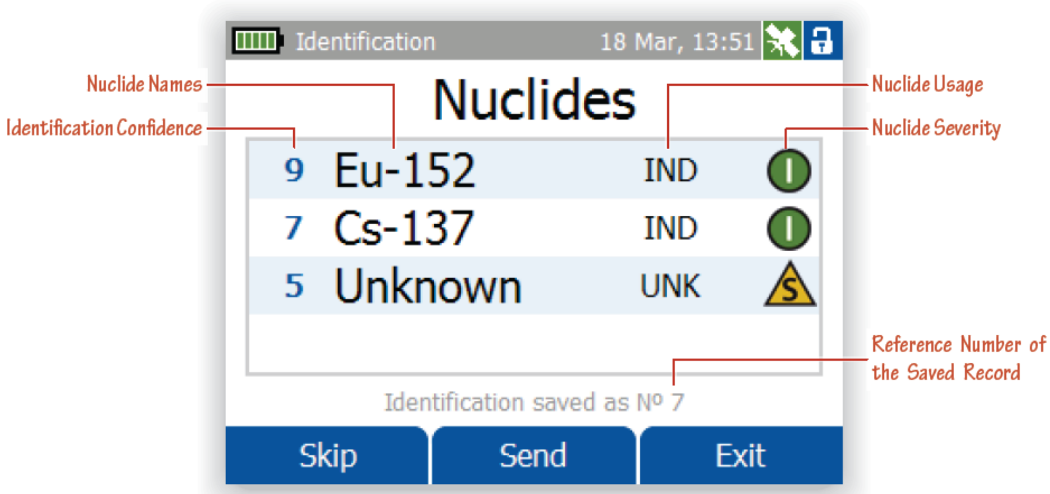
In this section you will use the identification feature of the HM-5 to identify sources. The HM-5 has libraries of many known sources and will match an acquired spectrum to library isotopes. Make sure to note the item number of all future measurements so you can identify them later.

From **Finder & ID > Identification**, there are 5 options. Identify begins the source identification, Identification Settings controls the measurement properties and reporting options, and the remaining 3 options control what nuclides are shown, what industries they are associated with, and if they are considered a threat.

- Enter **Identification Settings**. Change the settings to match the table below.

HM-5 Identification Settings		
Setting	Use	Value
Duration	Counting time. Can be switched to 8,000 total counts by setting the time to 0 (dynamic)	Dynamic
Extra Duration	Additional counting time if the user requires	30 s
Confidence	A 1-10 rating of the confidence level, mostly based on statistics. Identifying only some peaks of an isotope will reduce confidence	Show
Usage	Display which usage each isotope is associated with, Industry, Medical, Naturally Occurring Nuclear Material, Special Nuclear Material, or Nuc (old name for SNM)	Show
Severity	Display whether isotopes are innocent, suspicious, or threatening	Show
U, Pu	Identify all U isotopes together as uranium, or separately as U-235, U-238. Likewise for Pu. Not available for all models	Together
Isotope	Switch between displaying isotopes by symbol or name	Symbol

- Return to the Identification main menu. When identifying is complete the results will be similar to screen display below.



- Measure several sources and record the results in the table below.
- Continue the acquisition and see if the confidence improves. Try measuring the same source at varying distances from the detector. Measure multiple sources together. Fill in the table below and interpret your results.

HM-5 source identification		
Source	Configuration	Identification, Confidence, Time
Cs-137		
Cs-137	Light shielding	
Na-22, Th-232, Cs-137	All as close as possible	
Na-22, Th-232, Cs-137	Weakest sources closest to the detector	

How do shielding and multiple sources affect the source identification?

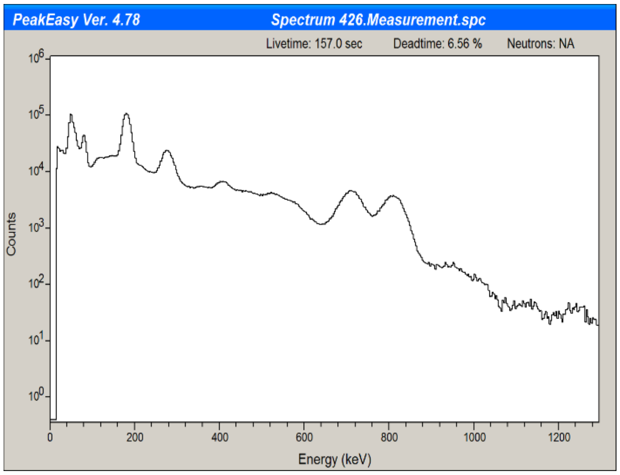
Misidentification of Benign Nuclear Materials

When handheld detectors identify nuclear material, they are not always correct. Many radionuclides produce gamma ray peaks that are similar in energy, and this may cause misidentifications. Higher-resolution measurements can resolve the problem.

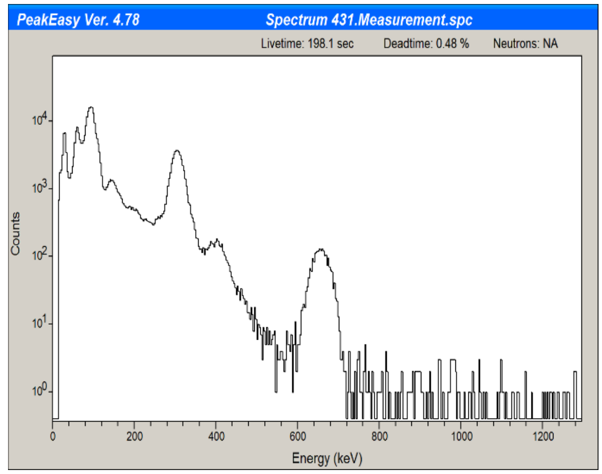
- Show that an HM-5 may misidentify Ho-166m as U-235, Lu-177m as Pu-239, WGPu, RGPu, Lu-176 as Np-237. Record the identification in the table below using an old IdentiFinder and a new IdentiFinder.
- Compare the spectra of actual U, Pu, and Np to the misidentified materials. Observe similarities of peaks at 186, 312, and 414 keV and discuss how additional peaks are useful for discrimination. Is a high resolution detector like an HPGe necessary to distinguish the materials?

Item	Old IdentiFINDER Identification, Confidence	New IdentiFINDER Identification, Confidence
Ho-166m		
WG Pu no Cd		
WG Pu with Cd		
RG Pu no Cd		
RG Pu with Cd		
Np-237		

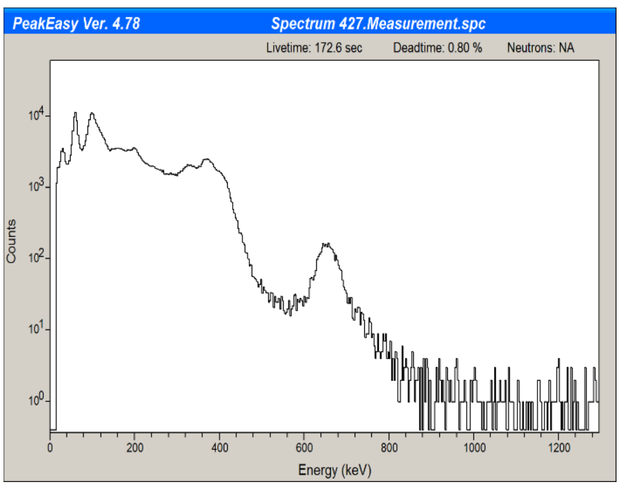
Ho-166m



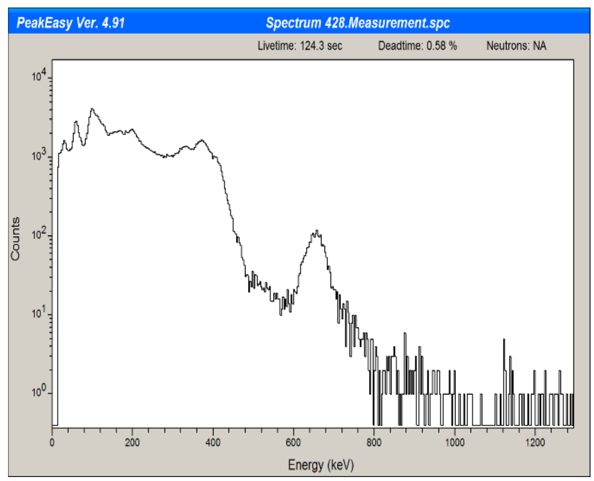
Np-237



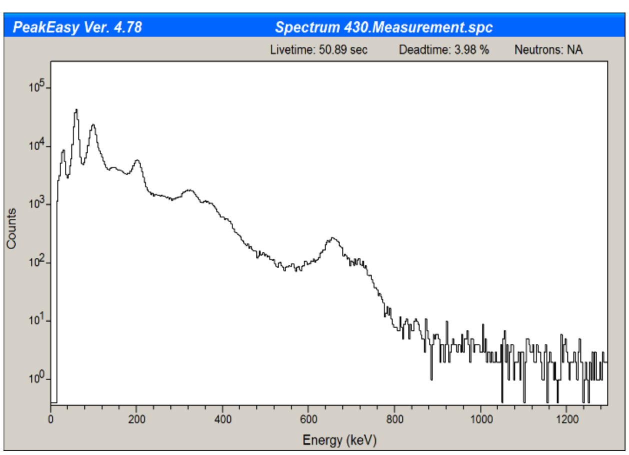
WG Pu no Cd



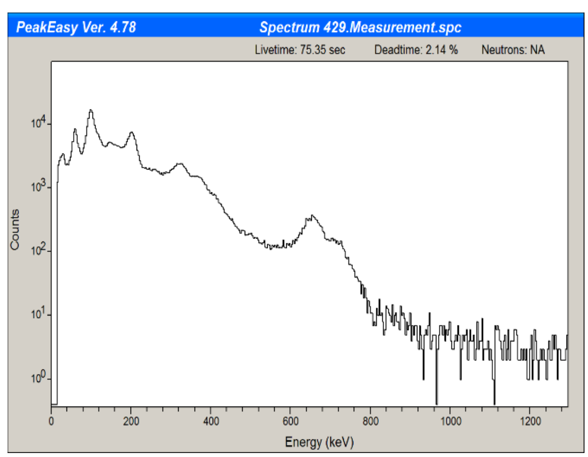
Wg Pu with Cd



RG Pu no Cd



Rg Pu with Cd

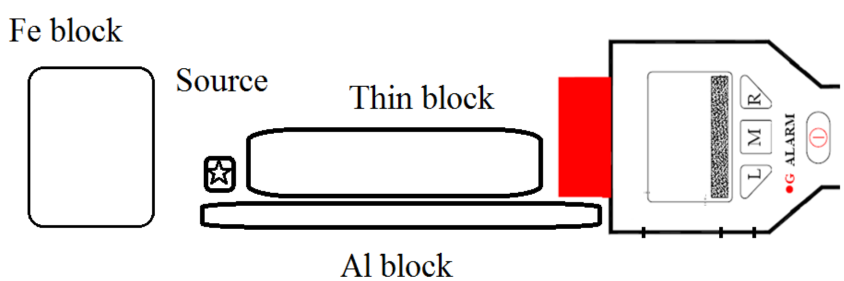


How can you verify that the identification of SNM is correct?

Compton Scattering

This exercise explores backscatter and low-angle scatter of gamma rays. These may produce features in a spectrum that are misidentified. In particular, backscatter of the Cs-137 peak may be misidentified as U-235.

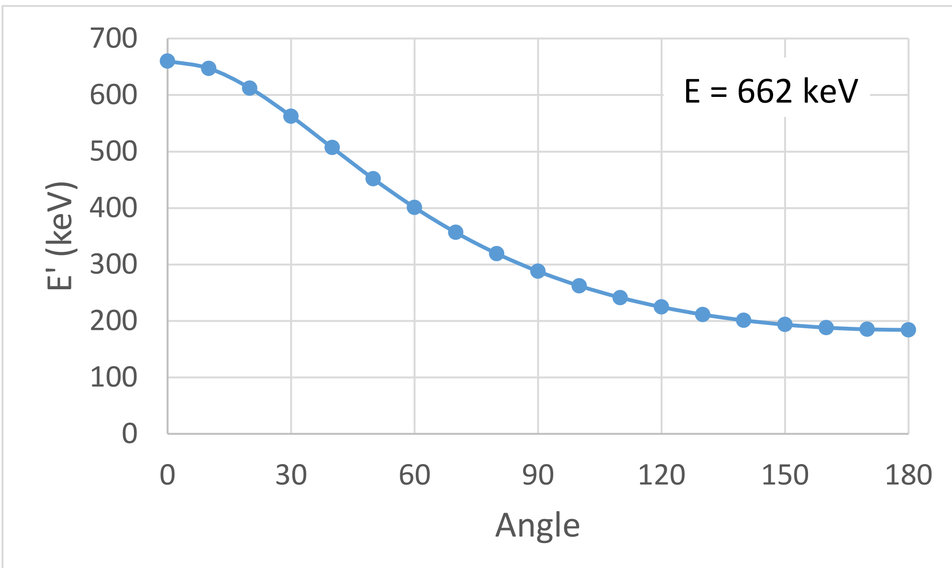
- Using a moderately strong Cs-137 source, record a spectrum with no other materials nearby. Save the spectrum number in the table.
- Place an iron (Fe) reflector behind the source so that backscatter gamma rays will reach the detector. Record a spectrum and compare with the first one. The backscatter peak should be more visible.
- Now use a 1.5 cm thin tungsten block to shield all direct gamma rays from the source, leaving only the backscatter peak. Record a spectrum and show that only the backscatter peak is visible. The setup is shown in the figure below.



Configuration	Spectrum number
Cs-137	
Cs-137 and backscatter	
Backscatter only	

- Using an HM-5 handheld instrument, show that that this peak can be misidentified as U-235.
- Now demonstrate constrained angle scatter using a strong Cs-137 source, Pb shielding, and Fe (this may take some time to get the setup correct). A peak should appear at

$$E' = \frac{E}{1 + \frac{E}{511keV}(1 - \cos\theta)}$$



Attribute Verification

In this section you will measure a source. The detector will verify the presence of a specified nuclide. The detector acquires a spectrum with background correction and analyzes a region of interest specific to the selected nuclide. The detector identifies the nuclide when the A/3S parameter is above a threshold. The A/3S parameter is related to the signal being statistically significant, and roughly translates to the signal net counts A divided by the 3 sigma uncertainty of the A value.

The attribute verification mode is found in **HM-5 > Attribute Verification**
Verify that the attribute measurement settings match the table below

HM-5 Attribute Verification Settings		
Setting	Use	Suggested Value
Attribute	Select which isotope to look for	Instructor supplied
RT Preset	Duration of data acquisition in real time	No limit
LT Preset	Duration of data acquisition in live time	No limit
A/3S Preset	Duration of data acquisition based on A/3S preset	No limit
T background	Background counting time	30s

Your instructor will supply a source. Minimize the background of the room and measure the source. Then, use additional sources to repeat the measurement with increased background. Fill in the table with your results. Record the time and A/3S Value it takes for the instrument to positively identify the source.

HM-5 Attribute Verification Measurement			
Source	A/3S Value	Measurement Time	Configuration
Uranium			Standard
Uranium			Specify A/3s preset to 5/10s
Uranium			Add shielding
Uranium			Verify in high background
Plutonium			Without tin filter
Plutonium			With tin filter

How does the background affect the attribute verification? How does changing the A/3S values affect the attribute verification?

Enrichment Measurements

In this section you will measure the U-235 enrichment of a uranium source. The detector calculates the enrichment based on measuring the 186 KeV peak after subtracting background. The calculation uses the NaIGEM algorithm which is built in. Because of the complicated variations due to matrix and shielding materials, a calibration must be used. The calibration can be performed in the field, or an established lab calibration can be used. In this section you will perform an in-field calibration measurement and then a verification measurement.

The enrichment measurement mode is found in **HM-5 > U-235 Enrichment**

Calibration Measurement

An in-field calibration is appropriate when the measurement conditions are not accurately represented in the lab calibration. The in-field calibration should match the measurement conditions.

Select Calibration Data to view details about the current saved calibrations.

Select **U-235 calibration** and input the parameters of the measurement configuration your instructor has provided.

Place the detector against the calibration sample and begin the measurement. When the calibration measurement is complete, save it as a field calibration. This will overwrite the previous field calibration. Complete the table below.

HM-5 U-235 Enrichment Calibration Measurement				
Declared Enrichment	Field calibration factor	Relative error	Lab calibration factor	Relative error

Why are the field and lab calibrations different?

Verification Measurement

You will now use the field and lab calibration factors to perform a verification measurement. Select **U-235 Enrichment** and input the measurement configuration parameters supplied by the instructor. Perform the measurement twice, once with the field calibration and once with the lab calibration. Record the results in the table below.

HM-5 U-235 Enrichment Verification Measurement				
	Field calibration factor:		Lab calibration factor:	
Declared Enrichment	Measured enrichment	Relative difference	Measured enrichment	Relative difference
	±		±	
	±		±	

Using the best calibration factor, repeat a measurement with a different, incorrect matrix material. Repeat the measurement with an increased uncertainty in shielding thickness. Record the results in the table below.

Calibration factor (Lab/Field) :		
Declared Enrichment	Measured enrichment	Relative difference
Incorrect matrix material		
	±	
Increased thickness uncertainty		
	±	

Repeat the measurement with increased shielding between the source and detector to explore the effects on uncertainty and the results. Fill in the table below.

HM-5 U-235 Enrichment Verification Measurement			
Shielding thickness	Declared enrichment	Measured enrichment	Relative difference
		±	
		±	
		±	

Did the field calibration work better for one source and lab calibration work better for the other? In what circumstances would that happen?

How did changing the matrix material affect the results? How did changing the shielding uncertainty affect the results?

What effects does increased shielding have on the measurements? How much shielding can be used before the detection method fails?

Active Length Determination [Optional]

In this section you will use the HM-5 to determine the active length of a uranium fuel rod. Select **HM-5 > Active Length**. The detector measures 186 KeV peak in the fuel zone and then the outside. Then, as you move the detector along the fuel rod it indicates whether you are measuring the fuel zone or outside. Use this information to identify and measure the active length of the fuel rod.
The settings control count rate and refresh rate.
Select start and find the active length. Complete the table below.

HM-5 Active Length Determination	
Feature	Value
Declared active length	____________ cm
Measured active length	____________ cm

What is the uncertainty of the transition zone location? Is this uncertainty controlled by count rate statistics or some detector feature?

Optional: repeat the measurements with different count and refresh rates. Which settings make a difference? Which setting values do you prefer?

IdentiFINDER LABORATORY EXERCISE

Estimated Module Duration: 3 hours

Facilitator(s): Sean Branney, Robbie Wienmann-Smith

Terminal Learning Objectives (TLOs):

- TLO-1: Explain the measurement applications of the HM-5 (IdentiFINDER)
- TLO-2: Demonstrate operation of the HM-5 IdentiFINDER

Enabling Learning Objectives (ELOs):

- ELO-1: Describe the features and application of the HM-5
- ELO-2: Describe the Finder Mode Feature
- ELO-3: Describe the isotope identification feature
- ELO-4: Describe the U/Pu verification feature
- ELO-5: Describe the active length measurement feature
- ELO-6: Describe the enrichment measurement feature
- ELO-7: Familiarization with the operation of the HM-5
- ELO-8: Locate sources using the Finder Mode
- ELO-9: Identify sources
- ELO-10: Perform verification measurements of U and/or Pu
- ELO-11: Measure the active length of a fuel rod or assembly
- ELO-12: Measure the enrichment of a uranium item.
- ELO-13: Quantify the limits of the measurement techniques by varying measurement conditions

Task Description for Participants:

To provide the participant with a thorough understanding of the operation and capability of the identiFINDER and the ability to interpret measurement results.

The exercise should be performed in small groups with an instructor, where the participants use an identiFINDER to perform the exercises. A detection lab is required with access to gamma sources and SNM. The exercises are described in a separate document with tables for the participants to complete documenting the results of the exercise. The exercises follow the Enabling Learning Objectives.

The participants should consider the applications and limitations of a handheld NaI detector, especially with regards to safeguards.

IdentiFINDER LABORATORY EXERCISE

Estimated Module Duration: 3 hours

Required Tools and Materials:

1. identiFINDER handheld instrument
2. Computer with identiFINDER software
3. Uranium standard of various enrichment
4. Plutonium standards
5. Standard gamma-ray check sources

References:

1. 09 HM-5 IdentiFINDER PowerPoint Presentation.
2. 09 HM-5 IdentiFINDER Instructor/Student Guide.
3. IdentiFINDER manual

Supporting Documents:

1. NDA exercise with IdentiFINDER lab

Job Aids:

1. The students will keep the NDA exercise with IdentiFINDER lab as a future reference

Terminal Learning Objectives (TLOs):

- TLO-1: Explain the measurement applications of the HM-5 (IdentiFINDER)
- TLO-2: Demonstrate operation of the HM-5 IdentiFINDER

Enabling Learning Objectives (ELOs):

- ELO-1: Describe the features and application of the HM-5
- ELO-2: Describe the Finder Mode Feature
- ELO-3: Describe the isotope identification feature
- ELO-4: Describe the U/Pu verification feature
- ELO-5: Describe the active length measurement feature
- ELO-6: Describe the enrichment measurement feature
- ELO-7: Familiarization with the operation of the HM-5
- ELO-8: Locate sources using the Finder Mode
- ELO-9: Identify sources

- ELO-10: Perform verification measurements of U and/or Pu
- ELO-11: Measure the active length of a fuel rod or assembly
- ELO-12: Measure the enrichment of an uranium item
- ELO-13: Quantify the limits of the measurement techniques by varying measurement conditions

Task Description for Participants:

To provide the participant with a thorough understanding of the operation and capability of the identiFINDER and the ability to interpret measurement results.

The exercise should be performed in small groups with an instructor, where the participants use an identiFINDER to perform the exercises. A detection lab is required with access to gamma sources and SNM. The exercises are described in a separate document with tables for the participants to complete documenting the results of the exercise. The exercises follow the Enabling Learning Objectives.

The participants should consider the applications and limitations of a handheld NaI detector, especially with regards to safeguards.

Exercise Content:

A. Familiarize with HM-5 and set up the instrument.
B. Use source finder to locate a hidden source
C. Acquire spectra and analyze peaks for different radioactive sources.
D. Identify unknown sources and demonstrate misidentifications.
E. Experiment with Compton scattering and misidentification.
F. Verify the presence of uranium and plutonium for verification measurements.
G. Measure ^{235}U enrichment.
H. Measure the active length of a fuel rod.

Little setup is required for the exercises as long as sources are available. The facilitator must have very strong sources for exercise A, turning the detector on in a high radiation background. They must also hide a source to find. The other exercises are self-explanatory, but it is recommended that the instructors perform a dry run of the lab to ensure it runs smoothly. Instructors should allow the students to perform the exercises. Instructors should ask guiding questions and explain concepts while ensuring understanding of key points by the students.

Evaluation of Participant Performance:
Instructors should introduce and review each exercise to explain the major point of the exercise. Guiding questions should be asked of students to monitor their understanding and additional explanation or exercises can be performed to reinforce concepts. The lab instructions include some guiding questions that can be discussed.