INTERNATIONAL TRAINING COURSE ON IMPLEMENTATION
OF STATE SYSTEMS OF ACCOUNTING FOR
AND CONTROL OF NUCLEAR MATERIALS

October 17-November 4, 1983

SESSION 16: TOUR OF LOS ALAMOS SAFEGUARDS R & D LABORATORIES: DEMONSTRATION AND USE OF NDA INSTRUMENTS AND MATERIAL CONTROL AND ACCOUNTING SIMULATION

Los Alamos Safeguards Staff

I. INTRODUCTION

This session will be devoted to a "hands on" tour of non-destructive assay techniques and instrumentation which can be used to measure the fissile content of unirradiated nuclear fuel assemblies and fuel components. In addition, time will be allocated for all students to experience a computer simulation of a materials accounting exercise during attempted diversions of material in a nuclear process. There are stations set up on the tour to allow the exploration of five different exercises:

Station	Title
1	Measurement of Uranium Enrichment: The portable, intelligent multichannel analyzer and stabilized assay meters.
2	Measurement of LWR Fuel Assemblies in the Field: The neutron coincidence collar.
3	Active Neutron Coincidence Assay of Uranium-Bearing Fuel: The active-well coincidence counter (AWCC).
4	Passive, Transmission-Corrected Gamma-Ray Assay of Uranium Waste Containers: The segmented gamma scanner.
5	Real Time Materials Accounting Systems Simulator (RTMASS).

At each station, there will be approximately one hour available during which members of the Los Alamos National Laboratory Safeguards Assay Group and Safeguards Systems Group will explain the exercises and encourage the course participants to take part in the activities themselves. There should be ample time for all participants to sample the measurements and simulator and to discuss their uses and significance with the staff.

The tour participants will be divided into five groups, and the groups will circulate among the five demonstration stations according to the following schedule:

	Station 1	Station 2	Station 3	Station 4	Station 5
9:00 AM	Introductory Lecture and Coffee Break				
10:00 AM	Group 1	Group 2	Group 3	Group 4	Group 5
11:00 AM	Group 2	Group 3	Group 4	Group 5	Group 1
12:00 N	----- Lunch at LANL Cafeteria -----				
1:30 PM	Group 3	Group 4	Group 5	Group 1	Group 2
2:30 PM	Group 4	Group 5	Group 1	Group 2	Group 3
3:30 PM	----------- Coffee Break -----------				
4:00 PM	Group 5	Group 1	Group 2	Group 3	Group 4
5:00 PM					

Stations 1-3 are located in the Safeguards Assay Group Instructional center (building 110); station 4 is in the gamma-ray laboratory in building 2; and station 5 is in the conference room of building 27. Participants will be guided to the stations outside building 110.

II. STATION 1: MEASUREMENT OF URANIUM ENRICHMENT: THE PORTABLE, INTELLIGENT MULTICHANNEL ANALYZER

A. Description

The goal of this exercise is to measure the ^{235}U enrichment of uranium oxide. The measurement is based on the fact that the emission rate of the 185.7-keV gamma ray from an infinitely thick sample (4.0 g/cm^2 or 4mm of sintered oxide) is directly proportional to the atom fraction of ^{235}U in the sample. The equipment used for this measurement is a 1.9-cm x 1.9-cm NaI detector and a battery-powered, 1024-channel analyzer. The detector has an ^{241}Am alpha source which provides a reference peak in the output spectrum that is used to stabilize the instrument. A two-window peak area determination is made using one window set over the 185.7-keV peak and another set just above this to sample the Compton background produced in the detector by higher energy gamma rays from ^{238}U and its daughter products. The ^{235}U enrichment is determined from the equation:

$$\%^{235}U = A * C_1 + B * C_2$$

where C_1 and C_2 are the measured activities in the two windows and A and B are calibration constants. The calibration constants are determined by measuring two samples of known enrichment. The MCA has a software function ENRH which guides the user through the calibration and subsequent measurement of unknown samples.

B. Procedure

1. Turn PWR switch on (up).

2. Press SHFT STAT and set MCA parameters as follows:
   CT = 100
   DETECTOR = 1 (NAI)
   INPUT POL = 0 (-)
   GAIN = 16
   LLD = 15
   ULD = 255
   MEMORY GROUP = 4 of 4

3. Place the 10% uranium oxide can on the detector and collect a 100-s spectrum, press STOP/START/1/ENTR. The MCA will collect the spectrum and stop after 100 s. Observe the spectrum and identify the 185.7-keV peak from ^{235}U.

4. Press SHFT ENRH and follow instructions:
   set CT = 300 s
   use PRESET WINDOWS

5. Place 17.5% can on detector, enter 17.5 as enrichment for standard 1 and press start.* At end of the 300-s measurement of first standard record C_1 and C_2 at the top of the attached data sheet.

6. Place 1.96% can on detector, enter 1.96 as enrichment for standard 2 and press start. Record C_1 and C_2 and the calibration constants A and B on the data sheet.

7. The system is now calibrated and ready to measure unknown samples. Measure other cans as time allows and record the results on the lower part of the data sheet. During the assay the system displays a running estimate of the enrichment based on the accumulated counts.

8. The SAM-2 uses a similar NaI detector and two single-channel analyzers (SCA) to make the same enrichment measurement. This instrument is much more limited in application than the portable MCA but can be used for enrichment measurements. Several SAM-2 instruments have been calibrated and should give the same value for the unknown sample enrichments as the MCA. Take a sample can and place it on the SAM detector. Press RESET/START. At the end of two minutes, the enrichment will be displayed on the front panel; this is a cumulative measurement so the intermediate readings have no meaning.

C. References

1. L. A. Kull and R. O. Ginaven, "Guidelines for Gamma-Ray Spectroscopy Measurements of ^{235}U Enrichment," Brookhaven National Laboratory report BNL-50414 (1974).

2. T. D. Reilly, "Gamma-Ray Measurements for Uranium Enrichments Standards," in Measurement Technology for Safeguards and Materials Control, (NBS Special Publication 582, Nat. Bur. Std., 1980) T. R. Canada and B. S. Carpenter, Eds., Proc. ANS Topical Meeting, Kiawah Island, SC, November 26-30, 1979, pp. 103-110.

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*The enrichment, 17.5%, is entered as "1", "7", "ENTER", "5", "ENTER".

DATA SHEET FOR ENRICHMENT MEASUREMENT WITH NAI AND PORTABLE MCA

CALIBRATION:

$\%^{235}U$	C_1	C_2	TIME
17.5			300 s
1.96			300 s

A = ______________________

B = ______________________

MEASUREMENT OF UNKNOWN CANS:

CAN NO.	$\%^{235}U$	±	ERROR	KNOWN $\%^{235}U$

The Los Alamos Portable Multichannel Analyzer, along with the NaI detector in the configuration appropriate for enrichment measurements. The analyzer is battery powered and contains sufficient measurement and analysis software to direct and carry out a complete enrichment measurement.

V. STATION 4: PASSIVE, TRANSMISSION-CORRECTED GAMMA-RAY ASSAY OF URANIUM WASTE CONTAINERS: THE SEGMENTED GAMMA SCANNER (SGS)

A. Description

The goal of this exercise is to measure the ^{235}U content of 30-gallon barrels of low-density, uranium-bearing waste materials. To overcome the variability typical of waste samples, a powerful method for making such measurements is the segmented gamma scan. In this procedure, individual horizontal segments of the sample are assayed for ^{235}U content. In the assay of each segment, a transmission correction is measured and applied, using a ^{169}Yb gamma-ray source external to the sample and mounted on the instrument. As was discussed in the session on NDA fundamentals, such a correction allows the assay to take into account the absorption of gamma rays by the sample material.

The measurement instrument is fully automated, with the motion of the sample table, data acquisition, and data analysis being performed under computer control. As a result, required operator interactions are minimized. The measurement result is a geometric profile of the SNM in the container and the total ^{235}U content. These results are printed out by the computer as the measurement concludes.

The SGS in this exercise is designed to handle large barrels of material, and the assay procedure used is a so-called "one-pass" assay. In this procedure, both the sample and the transmission source gamma ray intensities are measured simultaneously. The portion of the gamma-ray spectrum of interest is shown in Figure 1. The sample transmissions at the ^{169}Yb gamma-ray energies (177 and 198 keV) are interpolated to give the transmission at the assay energy

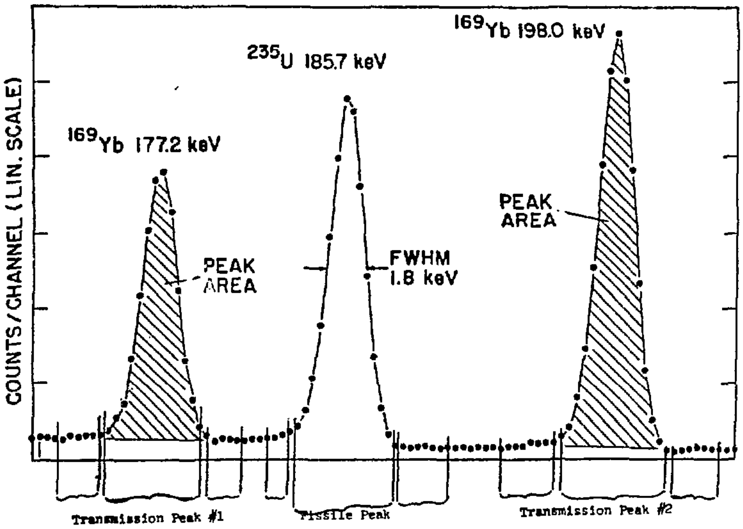


Figure 1. High-resolution gamma-ray spectrum for SGS assay in the energy region 165-205 keV.

(185 keV). The measured assay peak intensity is corrected accordingly, and the assay proceeds. If the ^{235}U loading of the sample is very low, then the 185-keV peak will be very weak and may be seriously distorted by the strong ^{169}Yb peaks on either side of it. In such a case, a so-called "two-pass" assay is performed, where the 185-keV gamma-ray intensity is first measured with the ^{169}Yb source shielded; then the Yb transmission gamma rays are counted in a second measurement.

Other designs of the SGS exist which facilitate the measurement of smaller samples, such as small process cans or even smaller laboratory samples in bottles or vials. Examples of these other SGS designs will be shown during the exercise.

B. Procedure

The SGS is calibrated by measurement of samples of known composition and loading. To save time, we have performed this calibration measurement in advance of the laboratory exercise. The SNM profile of the calibration sample will be displayed near the instrument. Sample measurements will be performed by removing arbitrary amounts of material from the calibration sample and remeasuring the barrel.

The segmentation configuration for the measurements is chosen at the beginning of the assay procedure, and this choice has also been made in advance. The segmentation chosen for this exercise is shown in Figure 2. The sample barrel contains several sealed plastic bags of cleaning tissues which have been dusted with uranium oxide powder. As a result, material can be removed from, added to, and repositioned in the sample barrel with little effort.

Waste Sample Segmenting Scheme

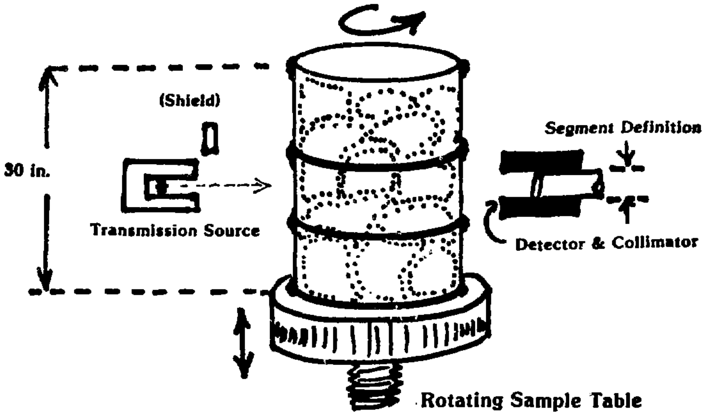


Figure 2. The sample barrel is 30 inches high and is divided into ten 3-inch segments, as defined by the detector collimator. As each segment is assayed, the barrel is rotated to smooth out any inhomogeneities in material placement.

The measurement has been set up in advance to involve the one-pass assay with the segmentation shown in Figure 2. The assay is begun by choosing the total count time for the 10 segments, which determines the assay precision for that measurement. As the measurement proceeds, the instructor will discuss the gamma scanning technique in more detail and also show the other SGS instruments in the laboratory. Measurement results for each exercise will be duplicated so that each student can have a personal copy.

The students should be aware of the precision obtained in each measurement as a function of total counting time. Record the measurement results in the table below for later reference.

C. Reference

1. "Gamma-Ray Measurements with the Segmented Gamma Scan," E. Martin, D. Jones, and J. Parker, Los Alamos Report LA-7059-M (1977).

DATA TABLE FOR SGS MEASUREMENT RESULTS:

Calibration data: __________ Corrected counts/gram Uranium
[Supplied by instructor from previous measurements]

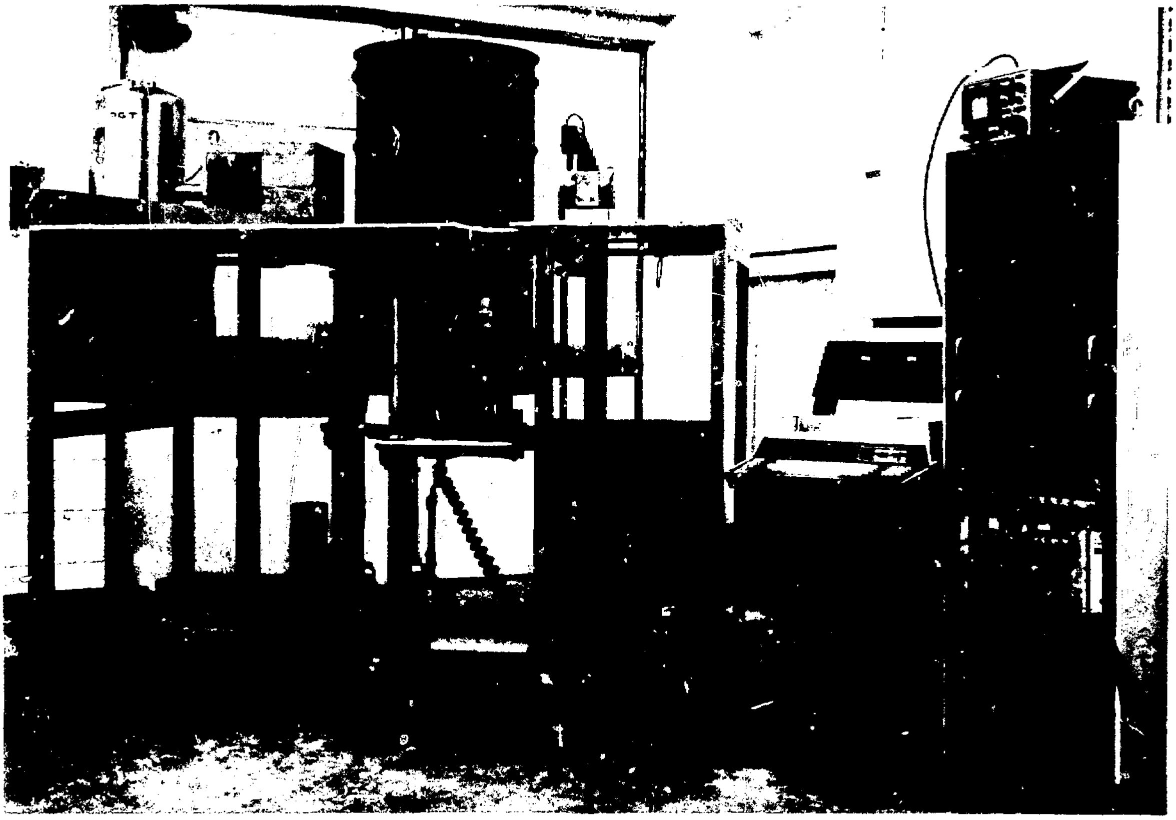
Segmentation: 10 3-inch segments, one-pass assay

Measurement #	Count time/segment [T]	Total U(g) [M_U]	$\sigma(M_U)$	$\sigma^r(M_U)$

Note: The quantity $\sigma(M_U)$ is the statistical uncertainty of the assay result, in grams. The quantity $\sigma^r(M_U)$ is the <u>relative</u> or <u>fractional</u> uncertainty in M_U, defined by:

$$\sigma^r(M_U) = \sigma(M_U)/M_U$$

It is the quantity $\sigma^r(M_U)$ that will improve (decrease) as the counting time is increased.



The Segmented Gamma Scanner (SGS) for transmission-corrected passive gamma-ray assay of large containers of low-density uranium-bearing materials. The measurement of the container is divided into discrete segments; each segment is individually assayed for U-235, with transmission correction. From these data, the total U-235 content and an SNM profile are obtained for that container. The sample is automatically rotated during the assay in order to smooth out any inhomogeneities. The entire apparatus and the measurement procedure are computer controlled for added ease of operation.

Similar gamma-scanners exist on smaller scales, to measure typical uranium oxide cans and even smaller samples in bottles and vials.

VI. STATION 5: REAL TIME MATERIALS ACCOUNTING SYSTEMS SIMULATOR

A. Introduction

The Real Time Materials Accounting Systems Simulator (RTMASS) has been developed primarily as an educational tool to simulate in real time the operation of a nuclear materials accounting system. In essence the RTMASS is a computer game with two principal players, the Diverter and the Nuclear Material Control Officer (NMCO). The Diverter attempts to steal a goal quantity of nuclear material while the NMCO tries to detect the missing material. Each of the players has his or her own computer terminal for interfacing with the RTMASS.

The RTMASS encompasses the three major codes, MODEL, MEASIM, and DECANAL, that have been developed primarily for Safeguards Systems Studies at Los Alamos. The MODEL code is used for the simulation modeling of the process. This code consists of the SLAM II[1] Simulation Language along with some auxiliary input and output subroutines. The MEASIM[2] code simulates the process measurements and computes the measurement error variances. DECANAL[3], the DECision ANALysis code, consists of a series of detection algorithms that can be used to determine the presence of a diversion.

A block diagram showing the flow of information in the simulator is shown in Fig. 1. The Process Model block simulates the process. Output from this block consists of the arrays of process variables that serve as the input to the Measurement Model. The measured values of the process variables are computed by the Measurement Model. These measured values are then input to the Decision Analysis block where calculations are made to determine if a diversion has taken place. As can be seen in Fig. 1, the Diverter interfaces with the process model in the theft of material, while the NMCO monitors the outputs from the decision analysis algorithms. After this analysis the NMCO makes a decision of either "diversion" or "no diversion." If the decision is "diversion," the simulation is terminated, whereas if the decision is "no diversion," the simulation continues. In addition to modeling the process, SLAM II is also used to control the flow of information for the complete RTMASS system as represented in Fig. 1.

B. Model Description

The RTMASS has been designed to allow for flexibility with regard to the particular process being simulated. For purposes of education on the simulator, however, a simple process serves just as well as a more complicated process and also improves the response time because of the reduced computational requirements. A simple tank with a single input and single output as shown in Fig. 2 is used for the process in this exercise. The tank has an inventory of 100 kg with daily batch input and output transfers of 10 kg each. Materials balances are drawn around the process at a frequency of once per day. The process measured values are assumed to behave according to the following equations.

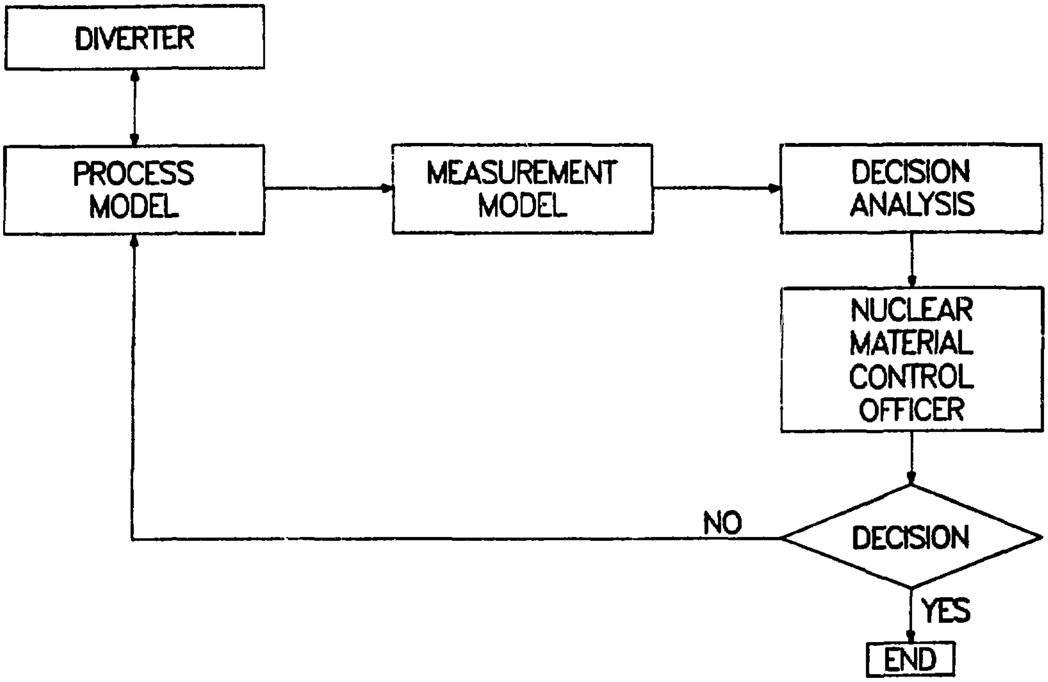


Fig. 1. Information flow diagram for the RTMASS.

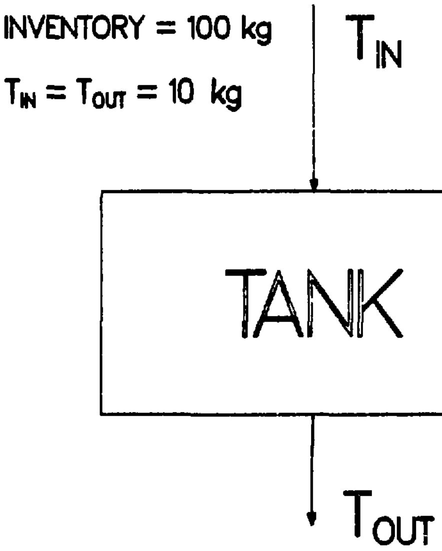


Fig. 2. Process model for the RTMASS.

$$I_m = I(1 + \varepsilon_I) \quad (1)$$

$$T_m = T(1 + \varepsilon_T + \eta_T) \quad (2)$$

where

I_m = measured value of the inventory,
I = actual true value of the inventory,
ε_I = inventory random error,
T_m = measured value of the transfer,
T = actual true value of the transfer,
ε_T = transfer random error, and
η_T = transfer systematic (correlated) error.

Both the input and output transfer measurements are assumed to behave according to the same equation. All the measurement errors are assumed to have a standard deviation of 0.006868 kg, that is,

$$\sigma_{\varepsilon_I} = \sigma_{\varepsilon_T} = \sigma_{\eta_T} = 0.006868 \quad . \quad (3)$$

C. Detection Algorithms

As indicated above, the game is played by the Diverter trying to steal material and the NMCO attempting to detect this loss of material. If there were no measurement errors, the NMCO would be able to detect the loss of material without fail. With measurement errors present, however, the NMCO cannot be sure if the signals he observes from the decision analysis tests are due to a real diversion or to measurement errors. The NMCO has at his disposal a number of tests that he can use to detect a diversion. These include the Shewart, CUSUM, Uniform Divergence (UDT), CUMUF, and Residual MUF tests. Alarm charts are employed in the first three of these tests, Shewart, CUSUM and UDT, to assist in making the decision regarding diversion or no diversion. The alarms on the chart consist of color-shaded squares ranging from a dark blue for a very weak alarm to dark red for a very strong alarm. The CUMUF and Residual MUF tests employ threshold boundary crossings to indicate the presence of a diversion.

D. Diversion Sensitivity

The simulation is designed to run for a maximum of 50 days with a materials balance taken once per day. The goal quantity of material to be taken by the diverter over this time period is calculated for this exercise from the "diversion sensitivity."

"Diversion sensitivity" is an important consideration for this system from a safequards standpoint. For the purposes of this discussion "diversion sensitivity" is that quantity of material diverted over a given period of time that can be detected as missing by the NMCO with some reasonable probability of success and with a relatively small false-alarm probability. One way of calculating "diversion sensitivity" is via the standard deviation for the CUSUM over the time interval being considered. If N is equal to the number of balances and σ is the CUSUM standard deviation for N balances, then a uniform diversion of $2\sigma/N$ over these N balances can be detected via the sequential CUMUF test $\sim$60% of the time with a false-alarm probability of 5%. Hence, the 2σ value is one way of measuring "diversion sensitivity." In this simulator exercise the 2σ value will be used to define the goal quantity of material to be diverted.

For the simple process of Fig. 2 and the measurement error models of Eq. (1) and (2), it can easily be shown that the CUSUM variance for N balances is given by

$$\sigma^2 = 2I^2\sigma^2_{\varepsilon_I} + 2NT^2(\sigma^2_{\varepsilon_T} + N\sigma^2_{\eta_T}) \quad , \qquad (4)$$

where

σ^2 = CUSUM variance for N balances,

N = number of balances,

σ^2_ε = variance of the inventory random error,

σ^2_ε = variance of the transfer random error, and

σ^2_η = variance of the transfer systematic error.

From Eq. 3 and with N = 50 it follows that

$$\sigma = 5.0 \quad .$$

Hence, the "diversion sensitivity," or 2σ as it has been defined for the purposes of this exercise, is equal to 10 kg. This is the amount of material that the Diverter will attempt to steal over N balances without being detected by the NMCO.

E. Operational Procedures

As indicated above, the RTMASS is designed to simulate 50 days of the process with materials balances drawn once per day. Control of the system alternates between the Diverter and the NMCO. For the first 10 days of the simulation, the Diverter can divert material but the NMCO cannot observe any of the data. At the end of 10 days the NMCO enters the game to observe the outputs from the decision analysis tests. He now has the opportunity to observe the results from the following decision analysis tests:

1. Shewart,
2. CUSUM,
3. Uniform Diversion Test (Kalman Filter),
4. CUMUF and Residual MUF test.

The CUMUF and Residual MUF tests are separate tests, but the results are presented simultaneously on the same screen. The NMCO enters a carriage return to bring up another test on the screen. After viewing the resultant graphical output from the decision analysis tests, the NMCO makes the decision "diversion" or "no diversion." If he concludes that a diversion has taken place, he terminates the simulation by entering a "0" at the terminal. If he is uncertain at this point about "diversion," he continues the simulation by entering a "1" and then enters the number of days to which he would like the simulation to continue before he analyzes more data. The Diverter is then given another chance to divert material, and the cycle repeats itself. If the simulation continues for 50 days without the NMCO detecting a diversion, then by default the decision is "no diversion."

F. References

1. A. A. B. Pritsker and C. D. Pegden, Introduction to Simulation and SLAM (Halstead Press, New York, 1979)
2. E. A. Kern, "User's Manual for a Measurement Simulation Code," Los Alamos National Laboratory report LA-9246-M (July 1982).
3. J. T. Markin, A. L. Baker, and J. P. Shipley, "DECANAL User's Manual," Los Alamos National Laboratory report LA-9043-M (April 1982).

DIVERSION TABLE
REAL TIME MATERIALS ACCOUNTING SYSTEMS SIMULATOR

DIVERTER ______________________________

DATE ________________________________

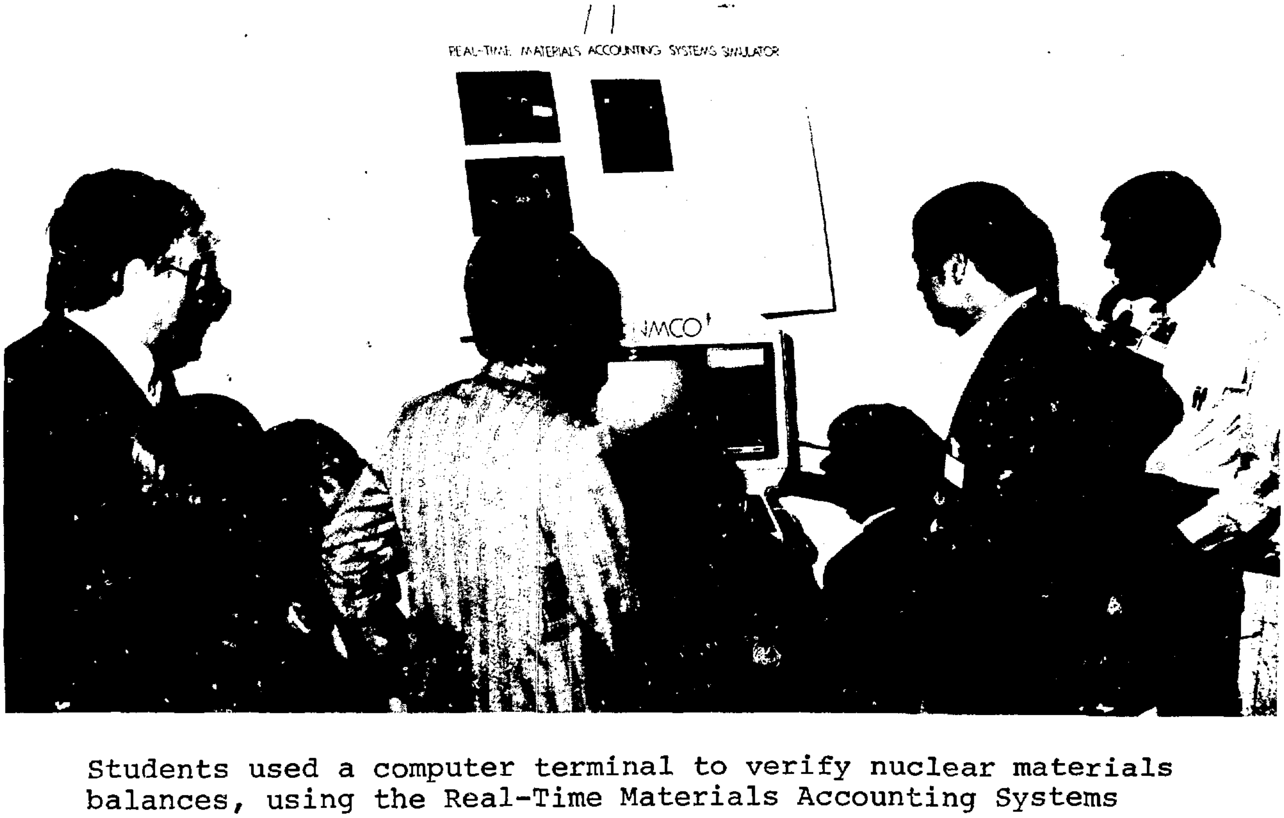
DAY	DIVERSION	DAY	DIVERSION	DAY	DIVERSION
1		21		41	
2		22		42	
3		23		43	
4		24		44	
5		25		45	
6		26		46	
7		27		47	
8		28		48	
9		29		49	
10		30		50	
11		31			
12		32			
13		33			
14		34			
15		35			
16		36			
17		37			
18		38			
19		39			
20		40			

TOTAL DIVERTED ______________

WIN ____________

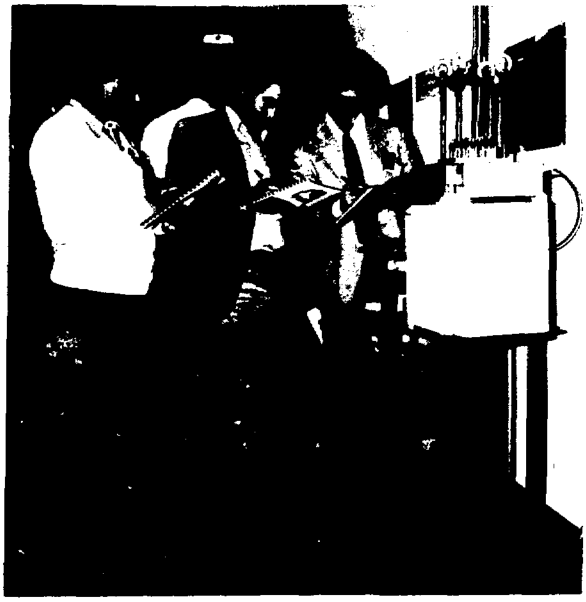
LOSE ___________

The instructor, Jim Halbig, explains the operation of the portable multichannel analyzer for uranium enrichment measurements.



Students used a computer terminal to verify nuclear materials balances, using the Real-Time Materials Accounting Systems Simulator (RTMASS).

A uranium oxide sample is inserted into the Active Well Coincidence Counter by the assayist and his "assistants."



Data acquisition with the Neutron Coincidence Collar on a model LWR fuel assembly.

The instructor, Dick Siebelist, describes the operation of the Segmented Gamma Scanner.

VII. PARALLEL SESSIONS:

NDA WORKSHOP
MC&A WORKSHOP

In the morning wrap-up session on the second day, the participants will divide into 5 subgroups to discuss NDA or MC&A problems of their choice. The five subgroup topics will be as follows:

NDA

1. Measurement of UF_6 Cylinders (full cylinders, heels)
2. Measurement of Bulk Uranium Oxide (U_3O_8 powder, UO_2 pellets)
3. Measurement of Finished Fuel Materials (loaded rods, fuel assemblies)
4. Measurement of Scrap and Waste (recoverable scrap, low-level waste)

MC&A

5. General Materials Accounting Analysis

The MC&A Workshop will begin with a discussion of some practical considerations in establishing a materials accounting system: setting boundaries for material balance areas, locating key measurement points, measurement errors, and frequency of materials balance closure. The participants will then discuss the calculation of MUF and σ(MUF) and study (through worked examples) the relationship of these quantities to plant throughput, measurement errors, and detection goal quantities.

In the NDA exercises, the participants will address one of the measurement tasks listed above and establish which NDA technique(s) are the most suitable for the goals of the measurement. Further consideration will be given to other NDA techniques, pointing out their shortcomings for the measurement task or possible complementary information other NDA techniques might provide.

At the end of approximately one hour, each of the subgroups will select a rapporteur who will report to all of the participants on the conclusions of his group.

NDA Workshop

DISCUSSION OUTLINE

In considering your measurement task, recall the instruments with which you worked yesterday:

- o The Active-Well Neutron Coincidence Counter
- o The Neutron Coincidence Collar
- o The Segmented Gamma Scanner
- o The Mini-multichannel Analyzer and NaI Detector

[Consider also such options as Rod Scanning and weighing]

FOR THE REPORT FROM YOUR GROUP, ADDRESS THE FOLLOWING QUESTIONS:

1. What measurements are possible on this material?
    a. Uranium enrichment?
    b. Total U-235 mass?
    c. Total Uranium Mass
    d. Verification of some other measurement?
    e. Weight of the sample
2. Is this measurement a candidate for materials accounting or for process control and verification? Would an inspector wish to measure this type of sample?
3. What radiations are emitted by this material? Can they be used for NDA?
4. What radiations can be induced in this material for assay purposes?
5. Which of the NDA instruments would best achieve your measurement goals?
6. For the instrument you have chosen, what are the limitations on the measurement as to:
    a. sample size
    b. density of material; matrix material
    c. container type
    d. count times
    e. attainable precisions
7. Discuss the disadvantages or shortcomings of the other NDA instruments you rejected for this particular measurement task.
8. Given the instrument you have chosen, discuss the measurement itself:
    a. What sample preparation is required, if any?
    b. Can you measure all or only part of the sample?
    c. What information will you obtain about the material in the sample?
9. Can some other measurement and/or measurement instrument be combined with your optimum choice to give more precise or more complete assay results on this sample?

Participants should prepare a set of answers and comments pertaining to these questions and organize them into a short oral report, lasting approximately 10 minutes. Each subgroup should select a rapporteur, who will report to all the participants on the conclusions of the subgroup's discussions.

Prepared viewgraphs, blank transparency sheets, and marking pens will be provided for each group, so that the rapporteur can use visual aids, if desired.

Time for subgroup discussion: Approximately one hour.

Time for subgroup reports: Approximately ten minutes per group.

MEASUREMENT TASKS:

1. MEASUREMENT OF UF_6 CYLINDERS:

Full Cylinders arrive at the plant receiving dock with shipper declaration of total UF_6 weight and U-235 enrichment. Plant personnel require some verification of these data for economic and materials control reasons. Plant inspectors are usually interested in verification of enrichment and traceable data on total U-235 arriving at the plant.

Cylinder heels are residual contents in cylinders that have been emptied. They constitute a small amount of SNM which should be accounted for.

2. MEASUREMENT OF BULK URANIUM OXIDE:

U_3O_8 powder is the immediate result of fluoride-to-oxide conversion. The powder contains some moisture and may be in the form of bulk powder or green pellets. The powder is relatively high-density material.

UO_2 pellets are produced when the green U_3O_8 pellets are sintered. They are found in open containers before loading into fuel rods.

3. MEASUREMENT OF FINISHED FUEL MATERIALS:

Loaded rods are sealed zircalloy tubes containing UO_2 pellets. The amount of SNM in the rods can be determined by tracing accounting records (ledger entries). The rods must be checked for pellet-to-pellet uniformity, nominal enrichment, and active length.

Fuel assemblies need to be checked for fissile content and verified as to enrichment. Total SNM content is also available from ledger records.

4. MEASUREMENT OF WASTE MATERIALS:

Recoverable scrap may be in the form of bulk oxide powder or broken pellets, resulting from the sintering, pelletizing, grinding, and loading steps in the process. This material should be accounted for and returned to the process.

Low-level waste contains very small amounts of SNM in the form of trace contamination on gloves, rags, and other low-density items. The material is usually stored in barrels for disposal, after SNM content is verified to be below allowed values.

M C & A Workshop

DISCUSSION OUTLINE

DISCUSSION: SOME PRACTICAL CONSIDERATIONS IN ESTABLISHING A MATERIALS ACCOUNTING SYSTEM

1. System designer must know
   - Process flowsheet.
   - Operating scheme - days and hours of operation, timing of process steps, batch operation versus continuous processing.
   - Physical layout.
   - Process control measurements.

2. Setting boundaries of materials balance areas
   - Do on basis of flowsheet and layout.
   - Consider ability to make good transfer measurements.
   - Quantity of in-process inventory.

3. Locating measurement points
   - What materials should be measured?
   - What measurement techniques are available?
   - Process control measurements that can be used to provide materials accounting information.
   - Additional measurements that may be required.

4. Random and systematic errors and their propagation.

5. Frequency of materials balance closure
   - Process logic.
   - Schedule closure to avoid difficult measurement or estimation problems.
   - Timeliness of detection of anomalies.

6. How can materials accounting aid process operator?
   - Provide additional information useful for process control.
   - Timely warning of process anomalies.

MUF = MATERIAL UNACCOUNTED FOR

- MUF = Beginning Inventory + Receipts - Removals - Ending Inventory

- Book Inventory = (Beginning Inventory + Receipts - Removals)
  = "What Should Be"

- Physical Inventory = Ending Inventory = "What Is"

- MUF = Book - Physical = ("What Should Be") - ("What Is")

- If there were no losses and measurements were perfect: MUF = 0

- However, MUF ≠ 0. Measurement Uncertainties, Process Losses (Buildup), Diversion.