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FIELD EXPERIENCE WITH THE AEC MEASUREMENT VAN

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ABSTRACT

Nuclear Materials Safeguards inspections by the District I Safeguards Office include independent tests of the licensee's physical inventory. The Division of Nuclear Materials Safeguards District I Office personnel have performed on site measurements of items of inventories using a mobile computerized multi-channel gamma spectrometer at different types of facilities during the early months of 1971. The equipment, field tests performed, and capabilities are discussed in this paper.

INTRODUCTION

At the 11th annual meeting of the Institute of Nuclear Materials Management at Gatlinburg we indicated (The Division of Nuclear Materials Safeguards. . . "The Second Year") that "We are now planning to supplement our single channel gamma spectrometer capability with a measurement van containing new passive assaying equipment. The basic equipment in the van will be a multi-channel analyzer system with both a standard and well type sodium iodide crystal. The van will also be equipped with a neutron coincidence counter to provide plutonium measurement capability."

The Technical Support Organization at the Brookhaven National Laboratory has assisted us in the completion of our plans in that they are credited with help in the choice of the analyzer system, installation of the system, and most of the modifications to the vehicle. The technical support group gave our original plans a sophisticated touch in that they recommended inclusion of a mini-computer in the analyzer system.

WHY A MEASUREMENT VAN?

The District I Safeguards Office performs routine nuclear material safeguards inspection of licensees in their district which include independent tests of the special nuclear material inventories. Non-routine verifications and tests are also performed when unreasonable losses have occurred at licensee sites. Use of the measurement van for routine and non-routine inspections offer the following advantages over previous analyzer systems in that:

- (1) Prompt test results can be available within a few hours. A measuring capability can be delivered to any of the District I licensees and measurements can be performed within minutes of arrival.
- (2) The measurement van can be self supporting in that we have our own power supply. During the operations to date we have used the licensees power supply.
- (3) Use of the measurement van minimizes dependence upon the licensees for office space and services.
- (4) It provides a minimum interference with licensee's operations in that our tests are performed outside of the facility. In some instances, this can be a disadvantage in that the measurement van could be a long distance from the inventory and present a transportation problem. During the inspections performed we were able to practically drive the van inside the licensee's vault.
- (5) The van increases our measurement capability in that we can now perform qualitative and quantitative tests of a greater variety of items in a shorter period of time.

This afternoon I would like to touch on the highlights associated with the measurement van, its capabilities, and experiences to date. The van is being exhibited and members of District I Safeguards are available to discuss any of the finer details. The motor vehicle (See Fig. 1) is a five passenger Ford Club Wagon on a 123 inch wheelbase and is equipped with factory installed, 302 cubic inch V-8 engine, heavy duty suspension, oversize tires, cruise-o-matic transmission, dual western mirror, air conditioning, AM radio and 70 ampere battery. Additional equipment installations by contractors are a Turtle Top manual liftable roof with side awnings and a swivel base for the front passenger seat. The Turtle Top roof provides an extra 18 inches of headroom when extended and the passenger seat can be swivelled to face to the rear for desk work. A spare battery was wired into the vehicle's electrical system and has been used on a number of occasions to start the vehicle when the main battery has run down. A 120 volt 60 hertz 2,850 watt portable electric generator is available for use when line voltage is not accessible. A 6,000 BTU DUO Therm "Brisk Air" air conditioner is mounted in the rear of the vehicle and is used to keep the equipment at room temperature during the summer months. We have found however that the 6,000 BTU is not sufficient during extremely hot days. The rear seat was removed, the spare tire was stowed on the outside rear of the vehicle on a swing down mount so that there is access to the back of the analyzer system. Shock mounted racks were installed to house the analyzer system. (See Fig. 2)

Two 120 volt 30 amp electrical circuits with outside inlets were installed with two 50 foot cables provided for hook-up to line voltage. One circuit is used for the air conditioner, fluorescent lights, electric heater, calculator, and adding machine. Forty electrical outlets on a plug in strips were installed to provide convenient access to current at any part of the van. Formica top cabinets were custom made and installed. The cabinets are used to store general office equipment, computer software, instruction manuals, sample bottles, tools and spare parts. The cabinet tops serve as work space

Figure 1

Figure 2

for two or three inspectors. Hold down rings were mounted on the floor so that shock cords could be used, when in transit, to tie down chairs, electric generator, the sample support, or any other equipment not permanently installed. Cafe curtains were installed to provide some privacy and protection from direct sunlight. Lighting is provided by four fluorescent lamp fixtures and two high intensity lamps.

ANALYZER SYSTEM

Figure 3 presents a block diagram of the Analyzer System.

- (1) Two types of sodium iodide detectors are used. Both are 2" by 2" diameter. One is solid and the other has a well $1\frac{1}{2}$ " by $\frac{3}{4}$ " diameter for use with sample vials. The crystal detector is held in a lead shield which serves as a sample support. Collimators can be inserted at the surface of the crystal.
- (2) The detector is powered by a continuously variable 500-2000 volt power supply. The normal operating voltage range is 740-780 volts.
- (3) A NIM bin supplies 24 volts to the preamplifier.
- (4) The preamplifier has voltage gain steps of 1, 2, 4 or 8. The normal operating setting is 8.
- (5) The analog to digital converter (ADC) is operated in the pulse height analysis mode which takes a pulse train from the preamplifier and converts it into binary words. Dead time can be up to 40 microseconds per event and is dependent on the number of channels being used for spectrum accumulation and the activity of the sample, we attempt to keep dead time below 10%, this is usually done by use of collimators, or the lowering of the crystal in the shielding.
- (6) The power supply and interface provide power to the ADC, transfer the binary word from the ADC to the computer and provides timing. We have been using clock timing however live time can be used.
- (7) A Hewlett Packard 2114B digital computer with an 8192 word memory is the heart of the system. The computer has eight pages of memory containing 1024 words each and each word having 16 bits of information. The computer can be programmed by Assembly, Algol, Fortran, or Basic Computer language. Information can be transferred to and from the computer by the ADC power supply and interface, teletype, high speed punch, and photoreader. When using the computer as an analyzer the binary word from the power supply interface unit is the address of a word in memory. When a word address is received by the computer, the memory of that address is increased by one. Each memory location is the same as a channel and each channel can be 16, 20, 24, or 32 bits in length which correspond to 65,535; 1,048,575; 16,777,215 or 4,294,697,291 counts per channel. We have been using a 1,048,575 counts per channel. This count is necessary as the integrated values can easily exceed 65,000.
- (8) The teletype is used for input commands to the computer and the output of hard copy data. The teletype is also used in the preparation of a system tape.
- (9) The photoreader is used to transmit punched data and programs into the computer.
- (10) The high speed punch can be used to accumulate and store data, duplicate existing tapes, or in preparing new systems tapes.

Figure 3

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- (11) The display unit converts information in the computer's memory from binary bits to analog pulses which can be displayed on the oscilloscope.
- (12) The oscilloscope displays accumulated counts on the Y-axis and in their respective channel on the X-axis. A spectrum formation can be observed while counting samples.

GENERAL PURPOSE PROGRAM FOR U-235 DETERMINATION

Figure 4 presents a keyboard program for U-235 determination. This program is one of many which can be entered into the computers memory by the teletype keyboard after an initial system tape is loaded through the high speed photoreader.

The system tape determines the commands available and the keyboard programming capability. This tape is generated by reading a series of tapes into the computer memory which allocates storage locations and the required subroutines. The system tape we are now using nearly requires the full memory, has 26 available commands and three regions for the accumulation and/or storage of data. The keyboard program utilizes the three regions for the accumulation and manipulation of spectral data. These regions are referred to as R0, R1 and R2. Each region has 512 channels with a maximum count per channel of 1,048,575. The background (which is treated as a constant in the program) is accumulated and stored in region R2. A DO loop starts the program by erasing regions R0 and R1 displaying R0 on the oscilloscope and accumulating the spectrum of the unknown or standard sample in region R0. The spectrum in R0 is now transferred to region R1 for data manipulation while the same spectrum in R0 undergoes a smoothing operation for visual display on the oscilloscope. The portion of the spectrum in region R1 of interest is intergrated and the value is printed on the teletype. The program halts with the smooth spectrum on the oscilloscope. The following explains the terms used in keyboard programming:

- (1) The command "term" terminates any list of commands previously started and not ended so that this program is not placed into another program already in the computer.
- (2) The command "Clear" clears the memory block allocated for keyboard programming.
- (3) The "list" command checks to see if any instructions are left in this data block. If any commands are present, they are printed out on the teletype indicating that the clear command wasn't initiated.
- (4) DSE, R2 displays region two of the memory allocated for spectrum storage. The background is stored in this region.
- (5) ERA, R2 erases region two and places zero's in all channels.
- (6) ACS1, 512, 1, R2, 30, 1 accumulates data via a software subprogram from the system tape using 512 channels in region two for thirty seconds. The first No. 1, is the y dimension expressed as the number of channels and the last No. 1 is the number of analog to digital converters being used.

Figure 4

- 7 -

- (7) Item (7) is a reply by the computer indicating that the command listed above has been executed. The background can be observed on the oscilloscope and will remain in memory as a constant for the execution of the following steps of the program.
- (8) The "store" command will place the commands following in memory for execution.
- (9) DO, 1 is a do loop which will be executed once.
- (10) ERA, R0 erases the data in region zero.
- (11) ERA, R1 erases the data in the region one.
- (12) DSP, R0 displays the data in region zero on the oscilloscope.
- (13) ACS1, 512, 1, R0, 30, 1 is the same as item six except that region zero is used to accumulate the spectrum of a known or unknown. The spectrum can be observed as it is being accumulated.
- (14) WAIT, ACS1 requires the computer to halt execution of the program until the spectrum accumulate command in item 13 is finished and then continue with the DO loop.
- (15) BSUB, R0, R2 -1 subtracts the background stored in region two from the spectrum in region zero. The -1 is the algebraic decimal ratio which is multiplied by the data in region two.
- (16) XFR, R1, R0 transfers the spectrum in region zero to region one while retaining the spectrum in region zero also.
- (17) SMO, R0 calls a subroutine from memory which smooths the spectrum in region zero.
- (18) SMO, R0 is the same as item 17. The smoothed spectrum in region zero is smoothed a second time.
- (19) INT, 62C167R1 integrates the spectrum in region one from channel 167 to channel 228 by an accumulation summation of the channel and placing the final result in the last channel. This is the total number of counts around the 185 KEV peak due primarily to the U-235 isotope.
- (20) WDK, 1C228R1 prints out the integrated value of the peak on the teleprinter.
- (21) END is the end of the DO loop.
- (22) STOP halts the above program when it is executed.
- (23) TERM ends the store operation.
- (24) STORE STATUS 14 gives the number of commands in the program. This statement is printed by the computer after the command term is given. In this program, items 9 through 22 are the executable commands.

PROGRAM EXECUTION

After the program has been entered by the teletype keyboard and the computer has typed store status 14, the program is ready for execution. A sample or item is placed on the detector and the sample identification is typed on the teletype between two slash marks. The slash marks tell the computer that the sample identification is for information only. Slash marks can also be used to record any notes such as time of day, licensee, etc. To initiate the program the command JUMP, 0 is typed on the keyboard. The computer transfers control to the first command in the program which is the DO loop which then executes the program and furnishes the printout of data shown in Fig. 5.

Figure 5

EXAMPLE OF PRINTOUT

The WAIT STATUS 6 indicates that the spectrum is being accumulated by the ACS1 instruction. The next two lines indicate that spectrum accumulation has been completed. WDK is the command which tells the computer to print out on the teletype, the information from region R1. The first number is the channel where the integrated value of the peak counts after background subtraction. STOP STATUS 14 indicates that the program has halted and is ready for another sample.

EXPERIENCE TO DATE

The measurement van has been used in conjunction with safeguards inspections since March 1971 at five different licensee facilities. Since March there were six inspections for which the measurement van could have been used. The sixth inspection had been performed concurrently with another inspection at which the van had been used. Four of the five inspections were routine and the fifth was a special inspection. The total number of enriched uranium inventory items measured during the routine inspections were 648; these contained 434.4 kg. of U-235. These samples were mainly highly enriched uranium. The types of items were: fuel plates, compacts, uranium compounds, calcined ash and fuel rods. Whole item samples as well as sub-samples were analyzed. Figures 6, 7, 8, 9 illustrate countings of compacts, fuel plates, as received U_3O_8 , and in process material. During the non-routine inspection, 250 depleted uranium items in the form of metal ranging from 2 grams to 50 kilograms were analyzed to determine whether the items were depleted uranium.

The limits of error for a single determination have been no greater than $\pm 15\%$ at the 95% confidence limit. Counting times have ranged from 10 seconds to 30 seconds depending upon the activity of the item or sample. During this counting interval we obtain approximately 10,000 integrated counts which yield a 1% counting error. We can measure 100-300 items or samples per day depending upon the licensee's restrictions on the movement of containers. The upper limit of 300 can be achieved for fuel plates and fuel rods while the lower limit of 100 would be achieved for containers of virgin 93% enriched uranium or containers of virgin plutonium oxide and metal.

We have also performed qualitative measurement of 40 plutonium fuel rods and 30 containers of plutonium oxides and mixed oxides. This was done with the sodium iodide crystal. The van is equipped with a neutron coincidence counter to perform plutonium measurement. However, to date no measurements have been performed with this instrument. We plan to increase our plutonium capability and are currently thinking about purchasing a Germanium detector and we will ask the Technical Support Group to assist us in this selection. We plan to program the computer to convert counting rates to quantities of U-235 or plutonium per item; this operation would relieve us of time consuming calculations.

Figure 6

Figure 7

- 12 -

Figure 8

Figure 9

- 14 -

ACKNOWLEDGEMENT

We offer our thanks to the Technical Support Group of the Brookhaven National Laboratory for their advice, design, and installation effort.

Thanks are also given to the New Brunswick Laboratory who have provided counting standards and sample verification during shakedown of the equipment.

1. TERM
2. CLEAR
3. LIST
4. DSP, R2
5. ERA, R2
6. ACS1, 512, 1, R2, 30, 1
7. #/ ADC 30.0 S
- #0 ADC 30.0 S
8. STORE
9. DO, 1
10. ERA, R0
11. ERA, R1
12. DSP, R0
13. ACS1, 512, 1, R0, 30, 1
14. WAIT, ACS1
15. BSUB, R0, R2, -1
16. XFR, R1, R0
17. SMO, R0
18. SMO, R0
19. INT, 62C167R1
20. WDK, 1C228R1
21. END
22. STOP
23. TERM
24. STORE STATUS 14

Keyboard Program for U-235 Determination

/SAMPLE NO. 50, U308/

JUMP, 0

WAIT STATUS 6

#/ ADC 30.0 S

#0 ADC 30.0S

WDK

R1

228 20,786

STOP STATUS 14