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ORNL/TM-7477

**The Whole Body Counting Facility
at
Oak Ridge National Laboratory
Systems and Procedure Review**

C. D. Berger
R. E. Goans
R. T. Greene

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Industrial Safety and Applied Health Physics Division

THE WHOLE BODY COUNTING FACILITY
AT
OAK RIDGE NATIONAL LABORATORY

SYSTEMS AND PROCEDURE REVIEW

C. D. Berger
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THE ORNL WHOLE BODY COUNTER

Introduction

Since their conception, whole body counters have been called by various names--in vivo gamma spectrometers, total body counters, whole body counters, etc. In 1962 the International Atomic Energy Agency (IAEA) made a survey of all laboratories operating such equipment and published a directory in 1964 entitled "Directory of Whole Body Radioactivity Monitors." The ORNL facility, which has been in operation since May 1961, is called the ORNL Whole Body Counter.

Whole body counting is generally accepted as a method of determining body burdens of radionuclides which emit x rays and/or gamma rays. Under certain conditions pure beta emitters can also be detected by measuring the bremsstrahlung produced and body burdens can be determined.

Shielded Room Description

The primary shield is a so-called iron room in which the crystal detectors are located and has walls, floor and ceiling constructed of pre-WWII naval armor plate steel. Walls, etc., are laminated to a total thickness of 35.6 cm. Inside dimensions of the room are 3 x 3 x 3 meters. Figure 1 is of a model of the iron room with the change room facilities shown in the background.

Degraded cosmic radiation from outside the shield and iron-room background gammas produce photoelectric events at the inner surface of the iron shield which result in characteristic iron X rays. Sheets of 0.32-cm-thick, special low-radioactivity lead are used to line the inside of the iron room to absorb the iron X rays. Since the lead itself also produces low-energy X rays and the detector crystals are pointed downward toward the floor, the floor has an additional graded shielding of 0.1-cm-thick sheets of tin and cadmium and a 0.03-cm-thick sheet of copper, topped by virgin vinyl floor tile.

Because much of the natural radiation background stems from the gases radon and thoron and their decay products, normally present in the atmosphere,

ORNL PHOTO 48409

Figure 1
Model of ORNL Whole Body Counter Vault

an attempt is made to reduce the admission of these radionuclides into the iron room by providing a positive supply of compressed, bottled air under positive pressure, which has been stored 30 days or more to permit the natural radioactivity to decay. A solenoid-controlled valve, actuated by opening the outer door to the iron room, permits a rapid influx of the low-background air while persons are entering or leaving the iron room. The air in the building annex which houses the iron room is continuously recirculated through absolute filters to reduce the concentration of atmospheric dust on which daughters of gaseous radioactivities are adsorbed.

Crystal Description

It is possible, at the ORNL Whole Body Counter, to detect a variety of internally deposited radioisotopes which emit photons in the energy range 1.6×10^3 aJ - 4.8×10^5 aJ.* In order to accomplish this, the facility is equipped with several detectors that can be calibrated and arranged to operate in various combinations. The general procedure is to run a whole body count with a standard crystal configuration and energy calibration, using one phoswich detector, a large hyperpure germanium array, and a 23 x 23 cm NaI(Tl) detector. If a radioisotope is detected in an energy region that is not optimum for quantification with this standard setup, another count can be performed with a different set of crystal and energy parameters. A list of the detectors available presently at the facility is as follows:

1. A 2.5 mm x 1.6 mm NaI(Tl) crystal mounted on a free-standing rack. This crystal is generally calibrated to cover the range from zero to 3.2×10^4 aJ. It is quite useful as a wound probe, where suspected contamination is localized in a small area, although the advances made in the solid state detector make it a much more efficient wound probe than this NaI crystal.
2. A 7.6 x 7.6 cm NaI(Tl) crystal, also mounted on its own moveable pedestal. This crystal is collimated in such a way that it can be positioned over specific body organs (such as the thyroid, kidneys, liver, etc.) for detection of radionuclides which could possibly concentrate in these organs.

---

*1 electron volt = 0.16 aJ.

3. A 20.3 x 10.2 cm NaI(Tl) crystal, with three 7.6-cm phototubes mounted on the detector suspension system, above the subject to be counted. This detector can be used in either a stationary count mode or in a scan count mode, where the subject moves under the crystal at a rate of 1.52 m in 20 minutes. This crystal is generally calibrated at 8×10^2 aJ per channel, to cover the overlap range between the two standard counting configurations.
4. A 23 x 23 cm NaI(Tl) crystal mounted under the bed upon which the subject lies. It has a high gamma detection efficiency due to its large volume, and, therefore, is used for all routine counts for high energy gamma detection. Calibration is set up routinely at 1.9×10^3 aJ per channel for 256 channels.
5. For detection of low-energy gammas and X rays, in general (and transuranics, in particular), counting is done with either one or two 12.7-cm-diameter phoswich detectors mounted on the primary structure and positioned over the subject's chest. These detectors are composed of 0.15 cm of NaI(Tl) optically coupled to a 2.54 cm or 5.08 cm CsI mantle and a photomultiplier tube, respectively. These dual crystal detectors have been very efficient in detecting internal contamination, which emits low energy photons, since pulse-shape discrimination techniques can be utilized to reduce the background interference. This technique takes advantage of the fact that the fluorescent decay times in the NaI and CsI differ. Therefore, the electrical signals at the photomultiplier tube have different rise times. The CsI crystal acts as a Compton suppression mantle which allows one to remove from the spectrum high-energy (or cosmic ray) events and/or gamma rays that are scattered from the thin NaI crystal into the thicker CsI crystal. Sophisticated timing used in conjunction with these detector affords a very effective means of reducing background and counting low-energy photons. These detectors are calibrated at 80 aJ per channel for 256 channels.
6. A recent addition to the detector inventory at the whole body counter facility is an array of six hyperpure germanium detectors (80 cm^2

total area) also to be used in the detection of low-energy photons. This detector has been put into operation recently. Its calibration is approximately 10.4 aJ (65 eV) per channel over 2048 channels. It is hoped that the low background typically found in solid state detectors, coupled with their much improved resolution over NaI(Tl) will greatly advance the state-of-the-art of in-vivo measurement of low-energy photon emitters. Its uses are for routine chest counting, wound counting, thyroid counting and skull counting (to be investigated).

Calibration Procedure

The theory behind gamma-ray spectrometry is based on the fact that the signal pulses received and recorded by the multichannel analyzer are in some way proportional to the energy of the photons emitted from the source being investigated. This becomes particularly important when identifying and/or quantifying the radiations emitted from the human body. In order to do this, it is most important that one know the relationship of spectrum channel number to gamma-ray energy. Therefore, as part of the whole body counting procedure, the system must be thoroughly calibrated for the following modes: resolution, energy, timing and quantification.

Resolution Calibration

To achieve the maximum resolution attainable on the phoswich detectors, it is necessary that the high voltage on the photomultiplier tubes be adjusted so that both detectors respond equally to a given energy. To accomplish this, a source (such as ^{137}Cs) is placed under the two detectors, the signal from each individual photomultiplier tube is input into the multichannel analyzer and a spectrum is obtained for each. The voltage applied to each tube is then adjusted so that the peak observed in both spectra falls within the same channel number. When this is accomplished, the output from both phototubes is well matched.

Energy Calibration

For accurate identification and quantification of internally deposited radionuclides, it is necessary to obtain a linear energy response. In other words, a plot of energy vs. channel number should yield a straight line passing through zero. This can be accomplished by using standard sources that emit gamma rays of different energies. These sources should be placed under the detectors, and the amplifier gain adjusted so that the photopeak falls within the appropriate channel [i.e., depending on whether the calibration is 1.6×10^3 aJ/channel, 8.0×10^2 aJ/channel, etc.]. Fig. 2 is a photograph of the energy calibration spectrum for the 23 x 23 cm NaI and the phoswich using a ^{137}Cs as a source. The peaks should fall in channel 55 for the 23 x 23 cm crystal, and channel 320 for the phoswich detectors. Using ^{40}K as a source for the 23 x 23 should also display the 2.3×10^5 aJ gamma line in channel 121. These calibrations correspond to a slope of 2.0×10^3 aJ/ch for the 23 x 23 and approximately 88.0 aJ/ch for the phoswich. Offsets are generally -1.17×10^3 aJ for the 23 x 23 and -16 aJ for the phoswich.

Timing Calibration

As said before, the phoswich detector system is based on the decay time differences in the phototube signals between CsI and NaI. The timing circuitry isolates and transmits only those pulses coming from the NaI not in coincidence with the CsI pulses. Therefore, the timing window requires very critical adjustment. If the timing window is not set appropriately, more noise pulses (i.e., background interference) will be added to the phoswich spectrum, thereby raising the detection limits. Fig. 3 is a photograph of a typical time spectrum. Note the NaI time peak. The window must be set (by the single channel analyzer associated with each time-to-pulse height-converter) to incorporate only the pulses falling within this peak. A picture of an appropriately set window, using ^{239}Pu pulses is seen at the bottom of Figure 2.

ORNL-DWG 78-21409

ENERGY CALIBRATION SPECTRUM — ^{137}Cs
PEAKS SHOULD FALL IN
CHANNELS 55 AND 320
RESPECTIVELY

TIME SPECTRUM — ^{239}Pu
NOTE Cs! TIME PULSES UNDER
MARKER

TIME WINDOW — ^{239}Pu

Figure 2. Phoswich Spectra

Figure 3. Phoswich Timing Spectrum

Quantification Calibration

Since one of the primary purposes of the whole body counting system is to quantify as well as identify internally deposited radioactive isotopes, the final check in the system calibration should be to determine reproducibility of total counts from a given source. These should only vary within the range of normal counting statistics. It is important to note that in order to accomplish this task, one must duplicate the counting geometry as exactly as possible each time. The same source must be used (preferably one with a long half-life) and must be positioned the same way each time the quantification calibration is done. ^{239}Pu and ^{40}K sources are used for the phoswich and 23 x 23 cm crystals, respectively. Standard counts are taken for 120 seconds and the total energy peaks are integrated within a defined energy range. A daily log is kept of both energy and quantification calibration results.

Detailed Description of the Phoswich Electronics

Pulses from the dual phoswich assembly are summed at the phototube and input into an Ortec-113 scintillation preamp. Negative output pulses from the preamp go into a three-branched circuit as shown in Figure 4. The center branch is the timing network, the upper one is an overload rejection circuit and the bottom branch treats the energy analyzed pulses from the phoswich. The timing branch is the most critical part and will be considered first. Bipolar pulses from the delay line timing amplifier (Ortec 460) go into two constant fraction timing single-channel analyzers (Ortec 455) with fractions set at 0.2 and zero crossover, respectively. The outputs from the single-channel analyzers are the start and stop pulses for a time-to-amplitude converter, TAC, (Ortec 467). The output of the TAC is an analog signal whose magnitude is proportional to the fall time of the bipolar pulse from the Ortec 460 delay line amplifier. Since NaI and CsI have different scintillation decay times (0.25 and 1.0 μs , respectively), pulses from the NaI and CsI portions of the phoswich system will, therefore, cause different timing distributions from the TAC as shown in Figure 3.

Figure 4. Block Diagram of Phoswich Electronics

Following the TAC is a standard Ortec 406A single-channel analyzer with window set over only the NaI distribution. Simultaneously with the above timing considerations, pulses from the preamp are routed over the energy circuit (bottom branch), and delayed for approximately 3 μ s to arrive in coincidence at an Ortec 426 linear gate with the NaI gating pulse from the timing branch. Therefore, only pulses with the time signature of NaI are routed to the computer system for analysis.

Because of the large number of overload pulses, it is necessary to devise some means of turning off the TAC when a very large pulse enters the system so that ringing and other oscillations will not be interpreted as real NaI signals. One simple way to accomplish this is to use a linear amplifier-discriminator combination to trigger a gate generator whenever an overload occurs. The gate generator has an adjustable pulse width, and should be adjusted somewhere in the range 100 μ s to 3 ms, depending on dead time considerations. The upper level logic output of one of the timing single-channel analyzers is equally effective to drive the gate generator. A complete timing diagram for the phoswich system is given in Figure 5.

For routine chest counting, phoswich pulses from the linear gate are routed to the analysis system through a Nuclear Data ND568 gated analog router along with pulses from the 23 x 23 NaI detector. The router gates the detector pulses along with routing information to an ND570, 80 MHz analog-to-digital converter connected to a ND6620 minicomputer system for storage of data. (A detailed description of the computer system is given in Appendix 1.)

The phoswich has very good sensitivity for low-energy photons but has poor resolution ($\frac{\Delta E}{E} \sim 35\%$). Typical spectra for ^{239}Pu , ^{241}Am and human background are given in Figure 6.

Detailed Description of the Hyperpure Germanium System

A large hyperpure Ge system (80 cm^2) for actinide counting has been implemented recently at the whole body counter (1 Oct. 78). This unit consists of six detectors with an average resolution (FWHM) of

Figure 5. Output from Various Timing Components for a Phoswich Detector as seen from an Oscilloscope

Figure 6. Phoswich Energy Spectra

76 aJ at 1.0×10^3 aJ and 98 aJ at 1.95×10^4 aJ. The detectors are multiplexed together to function as a single entity. The multiplexed system has resolution performance of approximately 77 aJ at the ^{241}Am L line 3.0×10^3 aJ and approximately 83 aJ at the ^{241}Am 9.5×10^3 aJ line. The detectors are in a close-packed, rectangular array and are designed to cover a single lung for in-vivo counting of actinide nuclides as shown in Figure 7. The unit in its typical counting configuration is shown in Figure 8.

Figure 9 presents typical line shapes for L_{α_1} , L_{β_1, β_2} , L_{γ_1} , and the 4.2×10^3 aJ line from ^{241}Am (top spectrum) and for L_{α_1} , L_{β_1, β_2} , and L_{γ_1} for ^{238}Pu (bottom spectrum). In Figure 10 (left) is shown a comparison of the phoswich detector (top spectrum) and the Ge system (bottom spectrum) for an individual contaminated with approximately 148 Bq (4 nCi) of ^{241}Am . In Figure 10 (right) is shown a case of very slight contamination with ^{241}Am (~ 4 Bq or 1.0 nCi) which was evident only on the Ge system.

In general, the Ge array performs considerably better than a single phoswich, even though the array has been plagued with mechanical difficulties in the past. Compared to a single 125 cm^2 phoswich detector, sensitivity to ^{239}Pu appears to have been improved by greater than 50 percent and sensitivity to ^{241}Am by approximately a factor of 14 when referenced to human backgrounds, using the Ge array. Efforts are continuing to improve upon these values.

Procedure Summary

The following is what one might call a "cook book" method for obtaining a whole body count in its entirety. One should be able to complete the procedure--from subject positioning to data removal and storage--by following these steps. Energy, time, and quantification calibration should be performed before the subject arrives (see Calibration Procedure). Phototube voltages on the phoswich detectors should be aligned, if necessary. (See Appendix 8 for entrance requirements for the WBC vault.)

1. When the subject arrives, give the subject a pair of socks, paper scuffs, and white coveralls. Direct the subject to the change room, instructing removal of all clothing and jewelry, to lock personal

Figure 7. Hyperpure Germanium Array - Bottom View

Figure 8. Hyperpure Germanium Array Positioned
Over a "REMAB" Phantom

Figure 9. Ge Spectra - (top) ^{241}Am Source
- (bottom) ^{239}Pu Source

Figure 10. Comparison of Ge (Bottom) and Phoswich (Top) Human Spectra. Left, ~ 148 Bq (4.0 nCi) ^{241}Am . Right, ~ 4.0 Bq (0.1 nCi) ^{241}Am .

articles in the locker provided, shower, don the appropriate clothing, and meet the attendant by the scales (see Appendix 8).

2. Vital statistics are to be taken (only sex and smoking history) and recorded on the back of the whole body count request card (to be used later for count identification, i.e., "header," information).
3. The subject is then escorted into the counting vault and assisted onto the bed, lying face up. The bed is positioned such that the 23 x 23 cm crystal is located directly under the Ge detector. (A line is drawn on the floor to assist in this procedure.) The phoswich detector is lowered to less than one centimeter above the subject's left lung field. The solid state detector is lowered similarly over the right lung field. Move the subject around, if necessary, so that each detector is centered over the upper portion of a lung and the 23 x 23 NaI(Tl) is directly under the back.
4. Instruct the subject: to lie still and relax, that the count will take one hour, the intercom system is on, and the doors do open from the inside. Close both doors to the vault as you leave.
5. Set up the screen at the computer terminal so that you are viewing analog-to-digital converter 2, group 1 (ADC 2/1). Start the count by typing the following exactly as it is written, followed by a carriage return:

JOB AO.BDYON

One should then be able to see counts being accumulated on the screen.

6. While the count is in progress, one should input the phoswich "header" information. To do this, first set up the header in a temporary file by typing the following, followed by a carriage return:

JOB AO.HEADER,,,TTY

After completion of the above, input the remainder of the header information by typing the following:

R PAMS

Fill in each parameter in order, except the "Detector Specs" (DS) which was done in the above job stream. Be sure to include which

background spectrum to be used for the analysis in the paragraph (PA).
This procedure is repeated for the solid state header by typing in:

JOB AO.GEHEAD,,,TTY

followed by:

R PAMS
etc.

7. Check the test word. It should correspond to the number of the previous count--not the one in progress. To do this, type:

R TWORD (see appendix)
SET

The computer will display what the last test word was. If it is correct, merely input the same number again. If not, make the appropriate change. Example: The file identifier for the count in progress will be "B80.S325". The test word should be set at "324" before the analysis is run.

8. After the count has terminated (60 minutes elapsed live time) one is ready to run the analysis. Set up the "main" and "overlap" ADC's on the viewing screen to 2/2 and 2/4, respectively. Type in the following:

JOB AO.ANAL4,,,TTY

Then wait for the analysis to run. The screen will display the net results and a hard copy will be produced on the line printer. Data will be stored on disk and magnetic tape, each with the appropriate file identifier. The solid state spectra are displayed in ADC's 4/1 (multiplexed spectrum) and 1/1 (single detector spectra).
(See Appendix 2 for a sample copy of the whole body counting analysis, including appropriate header format.)

9. Assist the subject in exiting from the counting room, and advise to return to "street" clothes.

APPENDIX 1

INTRODUCTION TO THE ND6620 MINICOMPUTER SYSTEM

Brief Specifications

The system CPU is a Digital Equipment Corporation LSI-11 micro-processor with an instruction set essentially equivalent to the DEC Systems PDP 11/35. The bus (Combus) is a non-dedicated, high speed, decentralized, synchronous bus which permits direct, bidirectional communication between system components. The combus protocol is such that "read" or "write" transfers occur in discrete 160 ns time slots. The display and acquisition system (DAS) has a display rate of 200 kHz, both linear and log display capability, a display group size of from 1 to 8192 channels per group with 1 to 2^{29} counts/channel. The display resolution is one part in 4096 for both x and y axes. The DAS is controlled by a DEC LSI-11 microprocessor identical to that in the CPU.

The whole body counting ND6620 computer has a dual hard disk system: one cartridge is fixed (DK0) and one is removable (KD1). Typically, the operating system, FORTRAN libraries and programs, and the FORTRAN compiler and BASIC interpreter reside on DK0. DK1 typically serves as a data disk for whole body counts. The storage capacity of a single disk is 2.5 megabytes. The bit density is 2200 bits per inch with a track density of 100 tracks per inch. The random access transfer rate is 312.5 kilobytes per second. The spindle speed is approximately 2400 rpm. The system is also equipped with a magnetic tape drive (9 track, 800 bpi, 25 ips). The data transfer rate is 20 kHz at 800 bpi for 25 inches per second. The total system memory configuration is currently 64 kilowords or 128 kilobytes.

The Whole Body Counter ND6620 system is also equipped with four ND570 analog-to-digital converters for accumulation of gamma spectra. These are 80 MHz units with a conversion gain range of 256-8K. Two ND568 gated analog routers are used in conjunction with the ND570 ADC's for multiplexing spectra.

Definitions

Bit - A binary variable having a value of either 1 or 0.

Byte - 8 bits.

Word - 2 bytes or 16 bits.

Sector - disk space equivalent to 128 16-bit words.

Disk Space Required for Spectral Data

Regardless of the bits/channel assigned to an ADC (see the AADC command), each channel is written to disk as a 32-bit word. Consequently, the number of 16-bit words required for N channels is $2N$. Since a sector is 128 16-bit words, the number of sectors required to hold N channels of spectral data is $2 \times N/128 = N/64$. Also, the first two sectors of each disk file used for storage of spectral data are reserved for header (identification) information. Consequently, the total number of sectors that must be reserved for N channels is

$$N/64 + 2$$

For example, the disk storage required to store a 512-channel spectrum is 10 sectors. If we wish to create a file named DATA.CH512 on disk DK0 to hold 512 channels of spectral data, the appropriate command would be

RESERVE DATA.CH512,DK0,10

where the file data already exists.

File Naming Conventions

The naming convention for files on the 6620 is as follows:

FILE.ELEMENT

It is useful to use the analogy of an office file drawer. Here the file is analogous with the file drawer and the element corresponds to a file folder. Each file element may contain spectral data, programs, or essentially anything. The appropriate command to create a file called EXAMPL is as follows:

FILE EXAMPL,DK0,5000,200,D,W

where EXAMPL starts on sector 5000 of DK0, is 200 sectors long, is

directoried, and is write-protected. For further examples and other options, see the system manual.

Other Useful Commands

1. DIR - lists file directory of DK1 and DK0.
2. DIR FILE - lists element directory of the given file.
3. DIS - after a brief time, this command displays the managed memory configuration, the number of words of consecutive memory and certain other data useful for programming considerations.

APPENDIX 2

REFERENCE SOURCES

Nuclear Data ND6620 System Instruction Manual

Part 1 - System Specifications

Part 2 - Terminal and Keyboard Manipulations

Part 3 - Nuclide Identification Programs

Part 4 - Description and Examples of System Commands

Part 5 - Examples of the Use of the Text Editor and Job Streams

Part 6 - FORTRAN and BASIC Programming Considerations

Description and examples of the FORTRAN extension library subroutines. These are extremely useful for accessing ADC data with FORTRAN or BASIC programs.

Part 7 - Extended System Summary

ND6600 Disk File Format Description

Summary of system file layout. Mandatory reading if one wants to be able to access information stored in data or header files.

ND6600 7/9 Track Magnetic Tape System

Operational Instruction Documentation - Description of current magnetic tape commands.

Midas⁺ Supplement

ND6600 Operational Instruction Documentation

Update on current operating system.

ND6600 Basic Physics Application

Package Program Algorithms - Documentation on numerical techniques used in various system routines. (Does not apply to current whole body counting operations.)

ND6600 Nuclide Identification Package

Program Algorithms - Documentation on techniques used in peak search routines and other programs pertinent to high resolution detectors. (Does not apply to current whole body counting operations.)

APPENDIX 3

USER COMMANDS

System Setup

1. DATE   Sets system date: DATE 29 OCT 78 sets system date to Oct. 29, 1978.
2. TIME   Sets system time: TIME 8:30:00 sets system time to 8:30 a.m.
3. LUP   Displays logical unit table for a given user.
4. DEF   Define command defines a given logical unit.
DEF 6 TTY defines LU 6 as terminal,
DEF 6 LP defines LU 6 as line printer,
DEF 1 DATA.CH512 defines LU 1 as file DATA.CH512,
DEF 3 SCR1 defines LU 3 as scratch file SCR1.
5. AADC   Assign ADC command assigns memory and live time for data acquisition. For example, AADC 2,5,512,16,3600 assigns five groups of 512 channels each at 16 bits per channel to ADC 2. The live time is 3600 seconds.
AADC 1,2,1000,24,10 assigns two groups of 1000 channels having 24 bits per channel to ADC 1. The live time is 10 seconds. Note that the number of channels need not be a multiple of two.
6. RADC   Release ADC command releases a given ADC and its associated memory. For example, RADC 2 releases ADC 2 from the user along with its memory requirements. RADC 1,2 releases ADC's 1 and 2, etc.
7. RMEM   Release memory command releases the memory assigned to an ADC but allows it to still belong to the current user. For example, RMEM 1,2 releases memory assigned to ADC's 1,2 but allows them to remain owned by the current user.
8. ADON   ADC-on command allows the user to turn on a given ADC. ADON 1/1,1/2 turns on ADC 1, Group 1 and ADC 1, Group 2. Also, ADON turns on all assigned ADC's.

9. AOFF   ADC-off command turns off an ADC with the same format as above. For example, AOFF 1,2 turns off ADC's 1 and 2.
10. ERASE   The erase command erases a group in a given ADC.
For example, ERASE 2/1 erases Group 1 of ADC 2.
11. HEL   The hello command allows a user to sign on the system.
For example, the following sequence signs user 50 on the system.

```
HEL 50
PASSWORD: BODY
```

(Where BODY is the password for user 50****.)

12. AUT   Autofile command - This command allows the user to designate a job stream to be run automatically when he/she signs on. For example, AUT lists the current autofile while AUT A0.A5A5 designates file A0.A5A5 to be run on startup. This procedure is mainly used to set up a standard ADC configuration. The hello format for this case is:

```
HEL 50,A
PASSWORD: BODY
```

The above command causes A0.A5A5 to be run immediately after the password is given.

13. BYE   This command signs the user off. For example,
BYE 50 signs off user 50.

File Manipulation

1. COPY   The copy command copies an existing file into a new file with all the proper space attributes. For example, COPY DATA.CH512,DATA.NEW copies the existing file DATA.CH512 into the new file DATA.NEW.
2. REPLACE   The replace command copies one existing file into a destination file which already exists. For example, REPLACE DATA.CH512,DATA.OLD copies the file DATA.CH512 into the existing file DATA.OLD. This command is useful in editing source programs, etc.

3.   MERGE   This command is used mainly to output files to the line printer. For example, MERGE LP,SOURCE.PROG lists the contents of file SOURCE.PROG on the line printer. For additional applications, see the systems manual.
4.   FILE   The file command is useful in creating a new file with given attributes. For an example see the systems manual. This command is rarely used since almost all new files of interest in whole body counting can be created using the COPY command.

Read-Write Considerations

Definitions:

READ   takes data from an existing disk file and puts it in a designated ADC memory group.

WRITE   takes data from an existing ADC memory group and writes it on a designated disk file.

1.   Define LU 8 and 12 as the file to read from or to be written to.
2.   Format of READ is as follows:

```
R READ
ADC/GRP: 2/1
```

Above statements read from file defined in LU 8 and 12 and place data in ADC 2, Group 1.

3.   Format of WRITE is as follows:

```
R WRITE
ADC/GRP:2/1
```

Above statements write data from ADC 2, Group 1 to the file specified in LU 8 and 12.

Disk Duplication

The system disk and data disk should be duplicated periodically so that programs and data will not be lost if the system "crashes" or if someone mistakenly erases a file. The procedure for copying the system disk is as follows:

```

DUPLICATE
INPUT ARGUMENTS:DK0,DK1,V
HIT CR WHEN READY:

```

These statements cause duplication of the system disk (DK0) onto a removable platter (DK1) with verification.

Fortran Considerations

Definitions:

SOURCE.PROG	file containing the FORTRAN source statements. These have typically been put in SOURCE.PROG using the text editor.
SOURCE.LINK	file containing list of files to be linked during the link phase.
OBJX.PROG	file containing the compiled object program.
SCR1	scratch file of length 100 sectors.
SCR3	scratch file of length 300 sectors.

Logical Unit Definitions:

```

DEF 2 SOURCE.PROG
DEF 3 SCR1
DEF 6 LP or TTY (depending whether output is going to LP or TTY)
DEF 8 SOURCE.LINK
DEF 11 SCR3.

```

FORTTRAN Compilation:

R FORTRAN - LU 3 (SCR1 above) contains compiled main program.

Program Link:

R NDLINK LU 8 contains link list. This is a list of object files to be linked together. Output of linker appears in the file in LU 11 (SCR3 above). SOURCE.LINK (containing link list) is simply a listing of the different object modules to be linked together. An example of SOURCE.LINK follows:

```

F!           tells linker that following files are
              FORTRAN program steps.
SCR1         file containing FORTRAN program just
              compiled.

```

OBJX.SUB1   object file containing compiled subroutine.

OBJX.SUBN   N-th subroutine.

&AUTO.FORLIB   main FORTRAN library.

&AUTO.EXTLIB   FORTRAN extension library.

\$ delimiter.

Run Step:

After the link, SCR3 contains the main program linked together with all subroutines and the required portions of the FORTRAN system library. The program can be tested merely by the following: RUN SCR3 after all debugging. The final object file can be saved by the following: COPY SCR3,OBJX.PROG.

Program Execution Considerations

Suppose, for example, that a compiled FORTRAN program is in OBJX.PROG. In order to run this program, we merely type in

RUN OBJX.PROG

and the program begins execution. If the program is in the APS file, then either of the commands below will effect execution:

RUN APS.PROG
R PROG

The latter command is generally preferable.

In general, the APS file is considered to be the R file and is set to this default as follows:

RFILE APS

However, other files can be designated as the R file since each user has his/her own R file.

Certain system programs are used often enough to warrant a brief description at this stage. They are:

1. R DMAN   Runs program to totalize counts under a peak or perform smoothing by 3, 5 or 7 points.

2. R ENERGY   Runs program to give the user either a linear or quadratic fit to energy vs. channel number data. This gives the user an energy calibration function with a reduced chi square figure for goodness of fit.
3. R MANIP   Runs program to perform arithmetic (+,-,*,/) manipulations on spectral files.

Many other system routines exist for specialized purposes. The reader is referred to the system manual for details of these programs.

Advanced FORTRAN Considerations

There are several programs on the Whole Body Counter ND6620 system which are useful. A few of these are:

1. SUBROUTINE ADD(N1,N2,RESULT,ARRAY) - Subroutine to integrate from channels N1 to N2 in ARRAY and return the sum in RESULTS.
2. SUBROUTINE ERROR(X,RESULT) - Computes ERF(X) and returns the answer in result.
3. SUBROUTINE DIRACC(LUN,ARRAY,NCHS) - Reads spectrum from logical unit LUN into ARRAY. NCHS is the number of channels in the spectrum.
4. SUBROUTINE DIFF(ARRAY,DIFF,SC,EC) - Differentiation subroutine to return the derivative in array DIFF of the spectrum specified by the argument ARRAY. SC and EC are the start and end channels of interest.
5. SOURCE.LSQ - Source program for linear regression. (Compiled file has been removed from the system for space considerations.)
6. SOURCE.ANAL - Actinide analysis program for Whole Body Counter. Requires the following definitions:
LU 6 - TTY or LP
LU 9 - Phantom background file, typically BKG.BDY
LU 10 - file containing gross subject count, typically either DATA.CH512 or DATA.TM2A.
7. SOURCE.TWORD - program to update the system test word. Object file is APS:TWORD and program is executed by R TWORD. This is an excellent example of ND6620 disk reads and writes.
8. SOURCE.GSTRIP - program to fit WBC net spectrum with ^{40}K and ^{137}Cs fit. This is a good example of the use of several FORTRAN extension library subroutines.
9. SOURCE.PARMS - source program for header construction. This is another good example of disk reads and writes.

APPENDIX 4
MAGNETIC TAPE INSTRUCTIONS

Reference: ND6620 Mag Tape Documentation Manual

1. R MTOPN Opens Transport 1
2. R MTCLS Closes Transport
3. R MTINI Command to initialize a virgin tape. Used to input volume number and owner ID.
4. R MTRDD Used to read a data file from an existing tape and transfer it to an ADC.
5. R MTWRT Used to write data from a given ADC to a file on tape. The user is asked for a file identifier label.
6. R MTPST Used to move to a specified position on the tape designated by the file identifier the system requests.
7. R MTSPF Command to allow the user to skip N files.
8. R MTLST Command to list the tape volume information and all files on the tape.
9. R MTEOT Command to move to the logical end of tape (EOT).
10. R MTRWD Command to rewind tape back to the load point.
11. R MTFID Prints current file ID to terminal.
12. R MTOFF Rewinds tape, closes the transport, and takes it off-line.
13. R XXPST Command to position to a given tagword on tapes written with the old ND format.
14. R XXRDD Command to read spectral files written in the old tape format.

APPENDIX 5

JOB STREAMS

A job stream allows the user to set up a sequence of commands to be automatically executed when needed. This can be a useful process if a lengthy series of commands are used frequently. A job stream will eliminate the need for inputting and executing each command separately, thereby reducing the possibility of typing errors, and/or system command errors that could be fatal (such as executing a "read" statement instead of a "write"). It must be stressed that a functional understanding of each job stream is necessary. It is just as easy to lose data by inappropriate use of a job stream as it is to input erroneous system commands.

A job stream is simple to create. It is set up using the text editor. It is assumed that the user is familiar with the text editor operation. (A short discussion of text editor operation can be found in the system manual.)

Essentially, all one must do is call the text editor program, enter job stream commands in order of execution, exit from the text editor, and write the buffer contents (which now consist of the job stream) to the editor output file. Finally, either run the output file as it is, or copy it to a permanent storage file. An example of this is as follows:

1. Call the text editor program (see system manual).
2. Enter job stream commands

```
BIAADC 1, PL=12Ø
AADC 2, PL=12Ø
ADON 1/1
ADON 2/1
ENDJOB
```
3. Exit from the text editor program (see system manual).
4. Run logical unit #2 file, or copy what is in logical unit #2 to a permanent file. (The above job stream can be found in file "AO", element "SEC120", designated as "AO.SEC120".)

Execution of a job stream is as follows: check to be sure that the logical units to be used in the job stream are appropriately defined. Then merely type the following:

JOB AO.SEC120,,,TTY

This command will execute the above job stream commands in the order you have designated.

The Nuclear Data system used at the ORNL Whole Body Counter is currently equipped with a large list of job streams. A condensation of the most frequently used job streams are in the following list:

1. AO.BDYON Starts ADC's 1, 2 and 4 counting for 3600 seconds. This command is used for initiation of a whole body count.
2. AO.BKGRND Starts ADC's 1, 2, and 4 counting for 50,000 seconds. This time period is useful for overnight background counts.
3. AO.HEADER Sets up header in file "DATA.TM2A" and fills in detector specifications for the phoswich system. "R PAMS" is generally used following this job stream to complete header information.
4. AO.GEHEAD Sets up header in file "DATA.CH2048" and fills in detector specifications for the solid state system. "R PAMS" is generally used following this job stream to complete header information.
5. AO.ANAL3 Standard job stream for whole body counting analysis. (Header must be in "DATA.TM2A" and "DATA.CH2048" as stated above, and appropriate background spectra must be in "BKG.BDY" and "BKG.GE".) Job stream runs through the analysis, giving a hard copy of all information, displays a net and predicted (via stripping technique) spectrum on the CRT screen, prints solid state analysis for ^{239}Pu and ^{241}Am , stores gross and net spectra on disk, and files gross spectra on magnetic tape. File identifier is assigned in this job stream; therefore, the test word must be updated before execution.

6. AO.BALONEY Adds together each of the six single, solid-state spectra in ADC 1/1 and puts the sum in the first 512 channels of 1/1. The energy calibration for 1/1 is approximately 80 aJ/channel; therefore, the 3.0×10^4 aJ line from ^{235}U can be easily seen when this job stream is run.

A quick up-to-date job stream reference list and list of current system changes can be obtained by typing in the following:

JOB AO.NUSTUF,,,TTY

APPENDIX 6

WBC ANALYSIS PROCEDURE

Figure 11 shows the first page of the output from a whole body count. These data are primarily for subject identification. Figure 12 presents the phoswich analysis given by program SOURCE.ANAL1 (object module: OBJX.ANAL1). The salient features are presented below and identified by number with the items in Figure 12:

1. Net spectrum obtained by subtracting a suitably normalized 50,000 s phantom background from the subject's gross count.
2. Net count rates for the Pu region 2.7×10^3 aJ, Am region 9.6×10^3 aJ, upper end 1.6×10^4 aJ, and 23×23 ^{40}K integral.
3. Various ratios computed from the count. Pu/ $_{23\text{x}23}$, Am/ $_{23\text{x}23}$, UEND/ $_{23\text{x}23}$, Pu/UEND, and Am/UEND ratios are constant for a given normal population as shown in Table 6-1.

Table 6-1

	<u>Single Phoswich (#89)</u>	<u>Double Phoswich (1+89)</u>
Pu/ $_{23\text{x}23}$	0.0098 ± 0.002	0.22 ± 0.0034
Am/ $_{23\text{x}23}$	0.084 ± 0.02	0.155 ± 0.027
UEND/ $_{23\text{x}23}$	0.071 ± 0.014	0.118 ± 0.019
Pu/UEND	0.14 ± 0.03	0.179 ± 0.027
Am/UEND	1.17 ± 0.16	1.312 ± 0.099

The uncertainties shown in Table 6-1 correspond to a one sigma confidence level. For example, consider the use of the ratio Pu/ $_{23\text{x}23}$ in estimating the normal human background in the Pu region of the phoswich. The net 23×23 count is known as well as the Pu/ $_{23\text{x}23}$ ratio. Therefore, the predicted count rate in the Pu region is (Pu/ $_{23\text{x}23}$)(23×23 rate). Any excess above the predicted rate may be attributed either to an actinide or to Compton scatter from a high-energy gamma, such as from ^{137}Cs or ^{60}Co . Judgement and further analysis of the 23×23 spectrum for high-energy emitters will aid in making this decision.

```

*****
***** 4 SEP 1980  2:56:01 PM *****
*****

```

DETECTOR SETUP :
 SPECT(E, [9X9]@12); SPECT(E, [89]@0.5); ADC2@2X256 - SINGLE TIME

NAME: DOE, J. M.
 SOCIAL SECURITY: 55555
 DIVISION, BUILDING, SS 3038
 BODY STATISTICS: MALE
 FILE IDENTIFIER: B80.P556

```

*****

```

AQUISITION DATE: 4 SEP 1980 2:55:36 PM
 ELAPSED LIVE TIME: 0 SEC
 KEY/CHNL: 12.2877884
 OFFSET: -17.9187889

```

*****

```

B526

```

*****
*****

```

Figure 11
 Header Information

4 SEP 1980 2:49:42 PM
SPECTRUM/BG = 3.39032E-01 TIME RATIO = 0.39649E-01
THE NET SPECTRUM IS

1984.	0.	-10.	152.	197.	332.	538.	735.	747.	733.	630.	837.	709.	641.	594.	576.
554.	579.	531.	559.	540.	494.	419.	449.	374.	429.	409.	314.	355.	280.	329.	345.
192.	247.	218.	228.	207.	229.	183.	162.	197.	191.	168.	219.	145.	194.	155.	168.
217.	145.	178.	158.	188.	217.	207.	199.	236.	181.	192.	180.	137.	123.	99.	136.
77.	101.	118.	90.	144.	100.	103.	60.	102.	94.	115.	129.	85.	81.	111.	120.
115.	113.	133.	134.	114.	126.	87.	109.	143.	130.	148.	138.	119.	135.	114.	140.
112.	103.	100.	116.	136.	120.	114.	109.	92.	110.	71.	162.	103.	128.	124.	165.
192.	227.	258.	328.	470.	451.	505.	576.	608.	504.	441.	446.	342.	243.	178.	153.
43.	59.	47.	13.	34.	8.	-6.	8.	22.	2.	3.	-5.	-0.	6.	19.	-1.
-2.	3.	17.	-11.	-3.	-11.	16.	4.	1.	-8.	-13.	13.	-13.	-12.	-6.	8.
-1.	15.	-5.	14.	6.	-6.	7.	11.	1.	-1.	9.	11.	14.	-7.	-2.	-8.
-8.	-2.	-1.	0.	-2.	-5.	1.	-17.	3.	8.	-10.	-18.	-4.	7.	4.	8.
-11.	-6.	6.	-2.	3.	16.	1.	-8.	-11.	1.	-0.	-3.	9.	-2.	2.	8.
-4.	-5.	-9.	7.	-4.	0.	15.	-5.	2.	-5.	-2.	-13.	6.	9.	5.	2.
2.	4.	-14.	3.	-6.	11.	-7.	5.	-7.	-3.	-8.	-2.	3.	-4.	-8.	4.
1.	-2.	-6.	-5.	1.	2.	0.	4.	-1.	-0.	-0.	-0.	0.	0.	0.	0.
1972.	0.	0.	1.	-1.	1.	-0.	-2.	-2.	3.	0.	1.	0.	1.	1.	1.
-0.	-0.	1.	-1.	1.	6.	6.	-3.	-2.	0.	5.	-1.	-0.	2.	5.	3.
1.	1.	2.	3.	0.	8.	3.	3.	7.	5.	3.	5.	6.	11.	8.	-1.
9.	2.	11.	2.	4.	6.	10.	9.	8.	4.	9.	11.	7.	8.	9.	15.
10.	6.	8.	12.	12.	13.	9.	7.	7.	6.	12.	14.	19.	14.	4.	7.
5.	10.	16.	15.	9.	8.	5.	6.	13.	10.	18.	16.	9.	10.	10.	10.
8.	10.	8.	21.	5.	9.	16.	5.	16.	24.	21.	8.	17.	14.	16.	11.
18.	14.	24.	19.	14.	6.	14.	17.	12.	13.	9.	11.	15.	11.	16.	8.
13.	10.	5.	10.	14.	12.	15.	17.	20.	8.	7.	14.	19.	17.	9.	6.
15.	13.	5.	7.	14.	8.	15.	12.	6.	12.	9.	15.	12.	15.	14.	8.
8.	10.	10.	9.	8.	5.	10.	11.	8.	7.	6.	17.	12.	13.	16.	5.
13.	13.	5.	6.	12.	10.	6.	8.	5.	10.	12.	9.	11.	4.	9.	7.
5.	8.	4.	6.	3.	4.	7.	15.	10.	11.	8.	8.	2.	6.	5.	1.
3.	9.	5.	8.	7.	13.	4.	8.	5.	12.	5.	7.	8.	7.	7.	6.
8.	4.	7.	3.	5.	7.	3.	2.	1.	10.	6.	9.	5.	1.	5.	5.
6.	11.	2.	1.	7.	4.	1.	4.	3.	4.	1.	5.	7.	2.	4.	3.

THE FOLLOWING INFORMATION REFERS TO NET VALUES
PU, AM, AND UPPER END RATES ARE 1.8E 15.39 14.61 CPM
THE 9X9 RATE IS 171.64 CPM
THE PHOS/9X9 RATIOS ARE 0.0010 0.1130 0.0051
PU/UE, AM/UE ARE 0.1290 1.3271
Z VALUES (ROBS-RAVG)/SIGMA ARE:
NET PU/9X9: 0.58E PERCENTILE = 0.722
NET AM/9X9: 1.44E PERCENTILE = 0.926
NET UE/9X9: 1.00E PERCENTILE = 0.843
NET PU/UE: -0.36E PERCENTILE = 0.356
NET AM/UE: 0.98E PERCENTILE = 0.837
FRACTION OF HUMAN2 STD. = 0.71997E 00
ESTIMATED BURDEN OF CS-137 = 0.27629E 01 NCI

TOBACCO ANALYSIS

*****

COUNTS IN PB-210 REGION= 227.00

COUNT RATE IN PB-210 REGION= 6.30 CPM

BKG. COUNT RATE = 5.0E CPM

LEAD RATIO= 1.24

Figure 12
Computer Analysis Output

4. Z values and percentile rank are calculated here. The Z value for each ratio is defined as the number of standard deviations the given ratio is either above or below the mean for a normal population. The ratio is then assigned a percentile rank based on a normal (Gaussian) distribution.
5. Estimated percent of standard human ^{40}K spectrum.
6. Estimated body burden of ^{137}Cs in nCi.

After the analysis of the phoswich and 23 x 23 NaI(Tl) spectra are complete, the ND6600 computer then analyzes the solid state spectrum. In essence, this analysis program "looks" at specific regions of the spectrum (those corresponding to the gamma and X-ray emissions from the decay of ^{239}Pu and ^{241}Am) and determines if there are statistically significant counts in excess of normal. Output will show the counts per minute within each of these regions. If the count rate is not found to be more than two standard deviations above what is considered to be normal, the output will state that the body burden of ^{239}Pu cannot be calculated. If the count rate is statistically significant, the body burden of ^{239}Pu is calculated, along with the range of error, and is printed out on the hard copy along with the minimum detectable activity (MDA) for the subject. The count rate and body burden (if any) in the 9.6×10 aJ region of ^{241}Am is then printed out in the same way (see Figure 13).

*****

SOLID STATE ANALYSIS

*****

CPM UNDER L-XRAY REGION= 1.867

CPM UNDER BACKGROUND REGION= 2.516

RATIO = 0.74

NEGATIVE SPECTRUM FOR PU-239

*****

CPM UNDER 60 KEV REGION= 0.700

CPM UNDER BACKGROUND REGION= 0.600

RATIO = 1.17

NEGATIVE SPECTRUM FOR AM-241

*****

Figure 13
SSD Analysis

APPENDIX 7

DETAILED ANOTATION OF FREQUENTLY USED JOB STREAMS

1. AO.BDYON (Turns on counting system)
  - AADC 1, PL=3610
  - AADC 4, PL=3600   Assigns preset live times for count
  - AADC 2, PL=3600
  - ERASE 2/1,2/2
  - ERASE 1,4   - Erase ADC's
  - ADON 2/1,1,4   - Turn on ADC 1,2,4
  - ENDJOB
2. AO.HEADER (Initializes file for 23 x 23 and phoswich)
  - DEFINE 8,DATA.TM2A   - Sets logical units 8,12 to file
  - DATA.TM2A
  - DEFINE 12,DATA.TM2A
  - ERASE 2/5
  - R WRITE   - Zeros file
  - 2/5
  - R PAMS
  - DS   - Puts detector specs in header
  - SPECT(E,[9X9]@12);SPECT(E,[89]@0.5);ADC2@2X2
  - EX
  - DEF 6, TTY
  - ENDJOB
3. AO.GEHEAD (Initializes file for Ge system)
  - DEFINE 8, DATA.CH2048 - sets logical units 8, 12
  - to file DATA.CH2048
  - DEFINE 12,DATA.CH2048
  - R PAMS
  - DS
  - SOLID STATE ARRAY - APPROX. 65EV/CH - puts detector specs in
  - header
  - EX
  - DEF 6, TTY
  - ENDJOB
4. AO.ANAL3 (WBC analysis job stream)
  - RADC 3 - releases ADC 3
  - ERASE 2/2,2/3,2/4 - erases groups 2, 3, 4 of ADC 2

```

PACK DATA
DEF 8, DATA.TM2A
DEF 6, LP
DEF 12, DATA.TM2A
R WRITE
2/1      - writes gross 23 x 23 and phoswich spectrum to
          disk (DATA.TM2A)
CHK)R MTOPN
1
GOTO CHK-GE,,1000000    - opens mag tape
R MTEOT              - positions tape to EOT
R TWORD
ADD                - increments testword
R MTWRT              writes gross 23 x 23 and phoswich spectrum to
2/1      - tape with file ID given by current value
          of testword
B80.S***
R HEADER            - writes header to LP
REPLACE DATA.TM2A, DATA.CH512
PACK DATA
DEF 8 DATA.CH512;12 DATA.CH512
DEF 9,BKG.BDY
DEF 10,DATA.CH512
RUN OBJX.ANAL1 - runs analysis program
R WRITE
2/2      - writes net 23 x 23 and phoswich to disk
RUN OBJX.AV35    - runs spectrum averaging program
R STRIP          - runs spectrum stripping program
R SEQ
COPY DATA.TM2A,B79.S*** - copies gross 23x23 and phoswich to
                        B79.S***
COPY DATA.CH512,BDYNT.S*** - copies net 23x23 and phoswich
DEF 8 DATA.CH2048;12 DATA.CH2048to BDYNT.S*
DEF 10, DATA.CH2048
R MTWRT          - writes multiplexed Ge spectrum to tape
4/1
GE79.S***

```

R WRITE

4/1 - writes Ge spectrum temporarily to disk

R SKIP

RUN OBJ.ANAL3 - runs current Ge analysis program

R MTCLS

DEF 8 DATA.CH4096;12 DATA.CH4096

DEF 10 DATA.CH4096

R WRITE

1/1

RUN AUTO.GROSS -- sums gross integrals on individual Ge detectors

DEF 6, LP

DEF 10 DATA.CH2048

R TOBACO - runs tobacco analysis program

DEF 6 TTY

AADC 3,1,2048,16,50000

ERASE 3/1

DEF 8, DATA.CH2048 - sets up sample ^{241}Am spectrum
to show subject

DEF 12, DATA.CH2048

PACK DATA

REPLACE STD.AM241, DATA.CH2048

R READ

3/1

R DMAN

SM7 - smooths Ge spectrum for better signal to noise

4/1

R DMAN

TOT

4/1,295,309

PAUSE 4

R DMAN

TOT

4/1,448,459

PAUSE 4

R DMAN

TOT

4/1,510,519

temporary integrals for ratio analysis

PAUSE 4

R DMAN

TOT

4/1,601,610

PAUSE 4

R DMAN

TOT

4/1,640,680

ENDJOB - end of job stream

APPENDIX 8

ENTRANCE REQUIREMENTS FOR WBC VAULT

The ORNL Whole Body Counter (WBC) is primarily used to identify and quantify internally deposited, low-energy X-ray and gamma-emitting nuclides. Background reduction and stability are major requirements for in vivo counting. A shielded room and an aged air system are two primary aspects of background suppression. (See Shielded Room Description in procedure manual for description of shielded room and air system.) To further suppress the background interference in the shielded room, certain "housekeeping" and entrance requirements must be set. These are discussed in the following.

Decontamination of Subjects

When any subject arrives to be counted they are instructed to shower and shampoo. This is required to eliminate any radioactive contamination which may be collected by their skin or hair and ultimately contribute to erroneous results. Both men's and women's change rooms are equipped with showers, soap, and shampoo. Towels are provided.

Clothing Requirements

Included in the entrance requirements are the use of issued clothing. This clothing is worn inside of the WBC building only. They are contracted to be laundered outside of the Laboratory so as to maintain their contamination-free state. Subjects to be counted are issued coveralls, socks, disposable paper scuffs and, when necessary, gloves and head covers. All others entering the vault must wear lab coats and shoe covers over their street clothes.

Annex Entrance Requirements

The WBC annex, which contains the shielded room, is considered to be a clean zone. Requirements for entrance are as follows:

1. No contamination allowed.
2. No smoking.

3. Escort required.
4. Subjects to be counted must be dressed in issued clothing.
5. All others must be dressed in lab coats and shoe covers.

Vault Entrance

The shielded room (vault) is equipped with a double-door air lock and a supply of aged air (see Shielded Room Description) to prevent rapid variations in airborne radon and its daughters (a situation which would reduce the accuracy of results). The size of the air lock limits the number of people entering or leaving the vault, and is, therefore, confined to a maximum of three at one time. Prior to entrance into the air lock, subject to be counted will remove his/her paper scuffs and place them in the container which is provided. Air lock entrance procedure is as follows:

1. Open outer door and enter the air lock.
2. Close outer door, open the inner door and enter the vault.
3. Close the inner door.
4. Reverse procedure when exiting.

Sources

All sources which are taken into the shielded room must be suitably contained so as to prevent contamination of the vault. Since they may not be free of external contamination, sources (other than calibration sources) must be enclosed in plastic bags.

Occasionally the need arises for analysis of environmental samples and animals at the WBC facility. To prevent possible contamination of the vault and/or detectors, these samples must be double-enclosed in sealed plastic bags.

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