Hanford Whole Body Counting Manual

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May 1987

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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Pacific Northwest Laboratory
Richland, Washington 99352

FOREWORD

This document was originally published as a manual designed to train personnel, document operation procedures, outline quality assurance procedures, and provide information on the Hanford whole body counting facilities to the U.S. Department of Energy (DOE) Richland Operations Office and the contractor companies at Hanford. The authors are not aware of the existence of a published comprehensive document describing the operations of a whole body counting facility within the community of the DOE operations, and have received requests for copies of the manual from organizations outside the Hanford Site. In response to those requests, the Pacific Northwest Laboratory has published the Whole Body Counting Manual as a report entitled Hanford Whole Body Counting Manual, but has retained the original manual format.

The reader is reminded that equipment and procedures among the whole body counting facilities in the United States are not standardized. Therefore, following the methodology and calibration procedures will be of limited use to the reader. Nevertheless, the authors hope that this report will provide some useful information to the organizers of future whole body counting facilities and to the compilers of manuals describing existing whole body counting operations.

Requests for a copy of this document or requests to be included on a distribution list for updates to this document may be directed to:

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SUMMARY

This document is the reprint of the Whole Body Counting Manual, prepared for the U.S. Department of Energy Richland Operations Office by the Pacific Northwest Laboratory. The Whole Body Counting Manual was compiled to train personnel, document operation procedures, and outline quality assurance procedures. The following paragraphs describe the organization of the document.

The location, availability, and scope of services of Hanford's whole body counting facilities are discussed in the introductory section. An acronym list deciphers the regional terminology.

Section 1 covers the administrative aspect of the whole body counting operation: who is eligible for an in vivo count; what authorization is required; how counts are scheduled; what type of recordkeeping is required; and how results of in vivo counts are reported.

Hanford's whole body counting facilities are described in Section 2. The various shielded rooms and mobile equipment, as well as the type of detectors, are described. The data acquisition and processing equipment are also discussed. Figures depicting the calibration phantoms accompany explanations of the calibration methods.

Section 3 outlines the step-by-step procedure involved in the different types of in vivo measurements. This section is designed to help the technician learn to perform a variety of in vivo counts, use the different detectors, and calculate the activity recorded by the detectors. A number of figures indicate the proper position of counting equipment in relation to the subject being measured.

The detectors, preamplifiers and amplifiers, and spectroscopy equipment are discussed in Section 4. The quality assurance aspect of equipment calibration and recordkeeping are covered in Section 5.

Data processing, record storage, results verification, report preparation, count summaries, and unit cost accounting are addressed in Section 6. Section 7 covers the topics of minimum detectable amount and measurement accuracy and precision.

Most of the sections include a reference list. A brochure entitled "The Hanford Whole Body Counting Center" is attached to the back cover of this report. This brochure is Appendix A in the original manual. Appendix B, the quality assurance plan, is included in the bound portion of the report.

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INTRODUCTION

CHARTER AND AUTHORITY

As part of its service responsibilities, the Health Physics Department of the Pacific Northwest Laboratory (PNL)^(a) is charged with providing in vivo measurements of internally deposited radioactivity in the employees of the Hanford contractors. The authority and responsibility for providing this service are assigned through the Hanford Site Services Handbook issued by the U. S. Department of Energy's (DOE) Richland Operations Office.

The DOE Order 5480.1, Chapter XI requires that monitoring for internal radioactivity be carried out where the potential exists for an individual to receive a dose commitment in any quarter of a calendar year in excess of 10% of the quarterly standard. The radiation protection personnel of the DOE contractors make decisions on which employees in their organizations have the potential to exceed those dose standards. These decisions, as well as the frequency of in vivo bioassay (whole body counting), are based on the guidance provided by PNL-MA-575, Hanford Dosimetry Evaluation Manual, and the Internal Dosimetry Program of the Personnel Dosimetry Section in the PNL Health Physics Department.

MANUAL CONTENT

The work described in this manual is performed by the Whole Body Counter Group of the Personnel Dosimetry Section within the Health Physics Department. The manual replaces the previous internal "Whole Body Counting Procedure Manual" issued in 1980. This manual is different because the detailed procedures and instructions on the operation of the electronic equipment such as the multi-channel analyzers and the computers are not included. The extensive instructions for equipment operation will be in separate manuals, which are referenced in the appropriate places in this manual.

The purposes of this manual are to:

- provide training for whole body counter personnel
- document the methods and procedures for identifying and quantifying radioactivity in radiation workers
- fulfill quality assurance requirements

(a) PNL is operated for the U.S. Department of Energy by the Battelle Memorial Institute.

MANUAL CONTENT (contd)

- provide references to documented calibration work from which calibration factors are derived
- provide information on the facility and its capability for the DOE and the Hanford Site contractor companies.

The technical information contained within this manual was largely developed by H. E. Palmer, G. A. Rieksts, and M. C. Rhoads. The manual was compiled and edited by C. P. Brim.

PURPOSE OF THE WHOLE BODY COUNTER

The Whole Body Counter (WBC) facilities provide in vivo measurements of internally deposited radioactivity in the employees of Hanford Site contractors. This service is needed to document the absence of radioactivity in most radiation workers and to determine the amount, distribution, and retention of radioactivity in those few employees who become internally contaminated. From the results of these and other types of measurements, the internal radiation dose can be calculated.

SCOPE OF SERVICES

Whole body counting services are available to employees of all Hanford Site contractors. Whole body counting services are also extended to local private nuclear energy-based companies and to selected research studies when time and facilities are available, and upon approval by the DOE.

FACILITIES AND LOCATION

Most of the WBC equipment is located in the 747A Building; other equipment for special purposes is maintained and operated in the Emergency Decontamination Facility (EDF) located adjacent to the Kadlec Hospital in the city of Richland, and in two mobile units.

FACILITIES AVAILABILITY

Regular services are available weekdays, from 8:00 a.m. to 4:30 p.m. Emergency services are available at any time.

RELATION TO OTHER RADIATION PROTECTION FUNCTIONS

Except for routine scheduling of contractor employees for chest or lung measurements, communication with other radiation protection personnel is almost entirely with the Internal Dosimetry Group of the Personnel Dosimetry Section in PNL's Health Physics Department.

DISPOSITION OF RESULTS

All in vivo bioassay results are communicated to the Occupational Radiation Exposure (ORE) data base and the PNL Internal Dosimetry Group for evaluation and distribution to the Hanford Site contractors. A preliminary summary of results is given to each individual measured. Official measurement results are not given directly to the DOE contractors by WBC personnel. Questions from the DOE contractors about WBC results are communicated through the

**DISPOSITION OF
RESULTS**
(contd)

Internal Dosimetry Group. However, results of measurements made on employees of private companies and people involved in research studies are reported directly from the WBC.

**RECOMMENDATION FOR
TYPE OF COUNT AND
RESULTS NEEDED**

The Internal Dosimetry Group determines (based on information provided by the contractor representative) the appropriate measurements necessary to evaluate the deposition and clearance. The Internal Dosimetry Group will then advise the WBC staff of the type of measurement needed.

In the case of contamination incidents the Internal Dosimetry Group also contacts radiation monitoring for survey services. This monitoring is necessary to assure that the low background facilities do not become contaminated from external radioactivity that may be on the worker or his clothes.

**EVALUATION OF
DEPOSITION AND DOSE
COMMITMENT**

The WBC staff will provide the Internal Dosimetry Group with their best determination of the burden at the time of the measurement. Based on this information, the Internal Dosimetry Group will then evaluate the deposition and dose commitment.

FINANCIAL OPERATION

The WBC operates as a small job center, funded by each DOE contractor or company through a unit charge assessed them for each measurement made. Each year a budget request for the WBC operation (in the form of a work element plan) is prepared, reviewed with each contractor's radiation protection representative, and submitted to the DOE Richland Operations Office (DOE-RL) for approval. From the approved budget and an estimate of the number of measurements to be performed, the unit charges for each type of measurement are established for the fiscal year.

Billing for measurements performed is carried out once a month. Information on the type and number of measurements performed for each company is provided to PNL cost accounting near the end of each month. Cost accounting distributes the costs to the appropriate contractor's financial system or invoices the private company.

ACRONYM LIST

ANSI - American National Standards Institute
BCS or BCSR - Boeing Computer Services Richland
BOMAB - bottle-manikin-adsorption (phantom)
CRT - cathode ray tube
DOE - U.S. Department of Energy
DOE-RL - U.S. Department of Energy's Richland Operations Office
EDF - Emergency Decontamination Facility
FWHM - full width at half maximum
HEDL - Hanford Engineering Development Laboratory
HEHF - Hanford Environmental Health Foundation
IAEA - International Atomic Energy Agency
ICRP - International Commission on Radiological Protection
JAJ - J. A. Jones Construction Services Company
KEH - Kaiser Engineers Hanford
MCA - multichannel analyzer
MCS - multichannel scale (mode)
NBS - U.S. National Bureau of Standards
ORE - occupational radiation exposure (data base)
PAC NU - Pacific Nuclear Services
PNL - Pacific Northwest Laboratory
REMAB - radiation-equivalent-manikin-absorption (phantom)
RHO - Rockwell Hanford Operations
SCA - single channel analyzer
UNC or UNI - United Nuclear Corporation
UST - U.S. Testing Company, Inc.
WBC - whole body counting facility
WPPSS - Washington Public Power Supply System

1.0 ADMINISTRATION

This section describes the request, scheduling, authorization, preliminary procedures, and result reporting for in vivo measurements.

1.1 REQUESTS FOR WHOLE BODY COUNTS

The types of requests for the authorization of whole body counts are described in the following section. A routine measurement is classified as a Type I and maximum sensitivity measurement is classified as Type II. A maximum sensitivity measurement involves a longer period of measurement than a routine measurement. Because of the limited facilities it is not possible to perform Type II measurement for all routine measurements.

1.1.1 Routine Requests from DOE Contractors

Each contractor is responsible for determining the specific radionuclides an employee may work with. The contractor and the Internal Dosimetry Group then determine the type of count required. These measurements are typically scheduled when an employee is newly hired, terminated, beginning or ending a special project involving radioactivity, or upon the request for a periodic routine measurement.

No appointments are required for whole body counts, but an appointment must be made for a lung count. In vivo examinations normally take place on the same day of the annual physical scheduled for all radiation workers.

1.1.2 Internal Dosimetry Group Requests for Special Counts

In some cases of internal contamination, the Internal Dosimetry Group needs more information to complete dosimetry calculations. This group will then request additional WBC measurements.

These specialized measurements will be scheduled in advance to allow enough time to prepare for the requested measurements. When these requests conflict with the routine schedule, the routine measurements may be delayed or rescheduled.

1.1.3 Field Requests by DOE Contractors for Special Counts

A DOE contractor may request non-routine measurements for a number of reasons including skin contamination, elevated air samples, or concern of the worker. Such requests are termed "field requests" and the probability of the worker

1.1.3 Field Requests by DOE Contractors for Special Counts (contd)

having internal contamination is considered to be very low. All field requests are channeled through the Internal Dosimetry Group.

The Internal Dosimetry Group determines which measurements should be performed and coordinates appointments with the WBC scheduler and the contractor.

1.1.4 Incident Requests

When a worker is involved in a contamination release where a high probability of internal deposition exists, the event is called an incident. Requests for WBC measurements for the worker are phoned immediately to the Internal Dosimetry Group.

1.1.5 Urine Sample Requested by Internal Dosimetry Group

The Internal Dosimetry Group may request a spot urine sample from selected individuals involved in potential exposures. Employee information obtained and attached to the sample bottle includes (Exhibit 1.1):

- initials and last name
- payroll or social security number
- contractor
- current date
- analysis request code.

United States Testing Company

Normally the United States Testing Company (UST) will pick up any samples at the WBC on the same day they are given. Should additional sampling kits be required, a detailed map showing the location of the individual's home should be obtained and given to UST so that the kits can be delivered.

1.2 AUTHORIZATIONS FOR IN VIVO MEASUREMENTS

In vivo measurements are performed whenever a count authorization has been received. The three types of recognized and accepted authorizations are described in the following sections.

1.2.1 Computerized Authorization - Occupational Radiation Exposure Tracking System

The occupational radiation exposure (ORE) system allows any DOE contractor to input the initial request for a WBC measurement. All WBC requests for measurements for new hires, terminations, and employees beginning or ending a

1.2.1 Computerized Authorization - Occupational Radiation Exposure Tracking System
(contd)

special project involving radioactivity, and routine measurements should be scheduled by this method. Any questions regarding ORE should be directed to:

Technical Specialist/Radiation Records
376-6549
Federal Building, Room 301-F
PNL 700

Computerized scheduling eliminates the need for an employee to transmit the written authorization for a WBC measurement. This method of automated-measurement request aids the scheduling by tallying the number of counts that are requested daily. The WBC staff is also alerted to the worker's previous WBC measurement history through the automated system.

The WBC staff updates the ORE tracking system file daily, by recording whether or not employees keep their scheduled appointments for measurements. Each contractor has access to this updated file to record any appointments that were not kept.

1.2.2 Written Authorizations

Written authorizations are normally hand carried by the employee and presented to the WBC technician upon arrival. The request specifies the employee's name, payroll number, social security number, the reason for the count, and type of measurement required. Although these written requests are honored, the automated scheduling using ORE should be utilized whenever possible.

1.2.3 Special Authorizations

This type of authorization is requested by the Internal Dosimetry Group. Additional measurements may be performed on individuals for any of the following reasons:

- unusual exposures
- field request
- evaluator requests
- follow-up measurements.

1.3 SCHEDULING

The procedures for scheduling the different in vivo measurements are described in this section.

1.3.1 Routine Whole Body Counts

For DOE contractors, no specific time is assigned for the routine whole body count and a measurement will be performed on a walk-in basis as long as proper authorization has been received.

1.3.2 Lung and Head Counts

All contractors should contact the WBC scheduler at 376-4785 in advance for an appointment^(a) for a routine lung or head count. The contractor then prepares a list containing the following information for each employee tentatively scheduled for an appointment

- initials of first and middle name and complete last name
- payroll number
- social security number
- count reason (new hire, routine, beginning or end of special project involving radioactivity, visitor, or termination)
- desired appointment time and date
- Type I or Type II measurement.

This list is forwarded to:

WBC Scheduler
747A/700
PNL

The scheduler confirms the appointment and notifies the contractor if any exam requires rescheduling. Appointments are scheduled at times that will not interrupt the in vivo examinations in progress. An answering machine is used to record requests during the times that technicians are busy. The DOE-contractor appointments are scheduled during the most convenient times of the workday. Non-DOE contractors may have the remaining appointment openings.

-
- (a) The Internal Dosimetry Group may have contacted the contractor about performing special measurements in conjunction with the next routinely scheduled count. The WBC scheduler should be notified of this by the contractor when the routine lung count is scheduled.

1.3.3 Handling DOE-Contractor Employees Without Authorization Papers

Any contractor employee arriving at the WBC for a whole body count without prior authorization must fill out the preliminary record information (name, payroll number, and social security number). The WBC technician will then call the designated contractor representative from the Company Contacts List (Table 1.1).

The representative will specify the type of count(s) required. If the representative requests a lung count in addition to the whole body count, both counts will be performed that day only if the current schedule could continue without interruption. If not, the WBC technician will schedule an appointment on another day.

1.3.4 Handling Non-DOE-Contractor Employees Without Authorization Papers

A non-DOE-contractor employee requesting WBC measurement without prior authorization should be asked to wait in the reception area. Before any count is performed, the contract and count type should be verified with the WBC manager or the senior WBC technician. Any telephone contact with these company representatives should be handled by the WBC manager.

1.3.5 Visitors Entering Radiation Areas

Visitors sometimes require measurements before and after entering radiation areas. Most visitors to DOE contractors will have a special payroll number issued to them by Radiation Records (PNL) before arriving at the WBC.

Typically these visitors are employed as under special programs (e.g., NORCUS). Issued payroll numbers usually begin with AG---, OG---, OG---, IG---, RG---, and XG---.

A release form (see Exhibit 1.2) must be signed at the WBC for all visitors issued an RG--- payroll number. The signed release form allows all radiological exposure information to be forwarded. All release forms are given to:

Specialist/Radiation Records
376-6342
Federal Building 301-I
PNL 700

1.3.6 Visitors Who Come to the WBC for Special Measurements

In vivo measurements by special request shall have a special visitor payroll number FG---. This type of request usually would come for an individual who is not from the Hanford Site. The special measurement is

TABLE 1.1 List of Company Contacts

Company Name/Code	Code	Payroll Numbers	Company Representative	Count Types	Telephone Number
Boeing Computer Services (BCS)	E	4----	Mary Ann Hensyel	All	376-3538
U.S. Department of Energy (DOE)	9	G----	Gerry Yesberger	All	376-7463
Exxon	X	XVX--	Kathy Kendall Tom Probasco (alt.)	All All	375-8197 375-8193
Hanford Engineering Development Laboratory (HEDL)	V	9----	Nancy Perfect Iva Schrimsher	All All	376-5315 376-5083
Hanford Environmental Health Foundation (HEHF)	M	BG---	Mary Ann Hensyel	All	376-3538
J.A. Jones (JAJ)	T	Y or Z----	Nancy Lucke	All	376-9665
JAJ	S	YA---	Carole Weaver	(Sub-cont)	376-6616
Kaiser (KEH)	K	K----	Steve Letson	All	376-5291
Pacific Northwest Laboratory (PNL)	D	3----	Denise Martin Mary Ann Hensyel	Routines All others	376-4830 376-3538
Rockwell Hanford Operations (RHO)	B	6----	Teresa Wirth Corrine Corbin	All Routines	373-4277 373-3477
United Nuclear Corporation (UNC)	H	5----	Karen Sheeran Vicki Llewellyn (alt.)	Routines All others	373-4938 373-4546
U.S. Ecology	N	XVN--	Mike Nolan	All	377-2411
Allied Nuclear Company	Z	XVZ--	(a)		
Pacific Nuclear Systems	L	XVL--	(a)		
Teledyne Wah Chang, Albany	D	FG---	(a)		

(a) Contact WBC manager at 376-6257.

1.3.6 Visitors Who Come to the WBC for Special Measurements (contd)

requested by the WBC manager or DOE. Under this circumstance, the WBC technician will call PNL Radiation Records at 376-1513 for the payroll number assignment.

1.3.7 Foreign Visitors

Foreign nationals do not have social security numbers. Since data input requires information in this field, a special number is generated. The number for a foreign visitor would be 999-XX-XXXX. These special numbers have a 999 prefix and the individual's birthdate is entered (month/day/year) in place of the Xs to complete the number. A special payroll number is assigned to foreign visitors by Radiation Records.

1.3.8 Non-DOE-Contractor Requests

Whole Body Count

Whenever five or more employees from the same company are to be measured on one day, the WBC scheduler (376-4785) should be notified in advance. This advance notice will allow the WBC staff to schedule a specific time for the measurements that will not interfere with any DOE-contractor appointments. A written authorization should be hand carried by the employee and presented to the WBC technician upon arrival at the WBC.

Lung Count

This measurement requires an appointment by calling the WBC scheduler at 376-4785.

Emergency Counting

Notify the WBC Manager at 376-6257.

1.4 PRELIMINARY PROCEDURES FOR IN VIVO MEASUREMENTS

Subjects arriving at the WBC will fall into one of three categories:

- the routine scheduled whole body count
- the routine scheduled lung or head count
- a nonroutine count resulting from a contamination incident or a field request or a follow-up count from an incident or field request.

A description of these counting procedures is given in Section 3.

1.4.1 In Vivo Count Request Form

When the routinely scheduled subjects arrive they will be listed on the computer scheduling sheet or have an In Vivo Count Request form generated by their employer's radiation protection operation. This request will be checked for accuracy and the subject will be asked to fill out the top part of an In Vivo Count Record, form A-1200-269(3-84) shown in Exhibit 1.3.

1.4.2 Assuring Measurement of Internally Deposited Radiation

To assure that only internally deposited radioactivity is measured and to limit the amount of naturally occurring radioactivity being transferred into the shielded enclosures, several precautions are taken.

For a routine whole body count the person removes only his shoes and puts on a pair of paper slippers. If the measurement shows a detectable amount of radioactivity, the person then showers, washes his hair and changes into a pair of cotton coveralls and is counted again to determine if the radioactivity was located on the skin, clothing, or if it is truly internally deposited.

1.4.3 Lung Count

For a routine lung count, the person showers, puts on a pair of cotton coveralls and paper slippers. If the lung measurement shows a detectable amount of radioactivity, the person showers again, washes his hair, and is recounted.

1.4.4 Potential Contamination in the Last 24 Hours

In cases where the person has potential internal contamination from an incident that happened in the last 24 hours, the person must first be monitored at the WBC for external contamination by a radiation protection technologist. After this monitoring, which is done in the change room, the person showers, washes his hair, and puts on a pair of coveralls before being counted.

Storage of Street Clothes and Personal Effects

When a change of clothing is necessary, the street clothing is placed in lockers in the change room. The person brings all valuable personal items with him to be placed nearby and in view while he is being counted. Valuable personal items can also be checked with the WBC technician.

1.4.5 Information and Safety Instructions for the Subject

The person being measured should be asked if he has had a previous whole body count. If the answer is yes, he can be placed in the WBC while briefly reviewing the safety aspects of the counting procedure. If the answer is no, a

1.4.5 Information and Safety Instructions for the Subject (contd)

brief description on the purpose, method, safety precautions, and noninvasiveness of the procedure should be given to him by the technician. A brochure on the whole body counting operation should also be offered to him at the completion of the measurement (see Appendix A). If the person has further questions, he should be referred to the WBC manager.

1.5 REPORTING OF RESULTS

Results are communicated to ORE and the Internal Dosimetry Group. It is the responsibility of the Internal Dosimetry Group to assure that contractors are aware of the results. Completed in vivo measurement results are transmitted by magnetic tape into the ORE data base on a weekly basis. An audit and reconciliation of the rejected records is performed by the PNL Radiation Records staff. After the records have been accepted, each contractor may access results for their employees. Letters to each individual are generated based upon predetermined reporting levels of radioactivity.

1.5.1 Routine Counts That Show No Radioactivity: DOE Contractors

Routine measurements during which no activity was detected, are reported to the Internal Dosimetry Group on a weekly basis.

1.5.2 Field Requests, Incidents, or Positive Counts

Results of the examination are immediately conveyed to the Internal Dosimetry Group. This group interprets the internal occupational dose for the contractor representative and involved employee. Additional follow-up measurements as well as bioassay sampling may be requested to complete the evaluation.

1.5.3 Handling Concerned Subjects' Questions About Results

Many individuals are unaware that naturally occurring radiation such as potassium-40 is contained in the human body. When potassium-40 is the only radionuclide detected, the WBC technician gives the subject a brief explanation that the count was normal.

The brochure, The Hanford Whole Body Counting Center is also available in the lobby for individuals wanting more information. A copy is included in Appendix A.

1.5.3 Handling Concerned Subjects' Questions About Results (contd)

Subjects who have detectable activity are instructed to call their radiation protection officer for exam results. If the subject wants immediate information or seems worried, a staff member from the Internal Dosimetry Group will talk to the individual in person or by telephone.

Those individuals needing technical information are referred to the WBC Manager.

1.5.4 Reporting Non-DOE-Contractor Results

All results are mailed biweekly to the company representative for radiation protection. Results are telephoned to the representative immediately when any subject is measured at the specified company's reporting level. Any questions regarding results are referred to the WBC manager at 376-6257.

EXHIBIT 1.1 Urine Sample Bottle Label Form

NAME: _____

SS OR PAYROLL #: _____

CONTRACTOR: _____

DATE: _____

ANALYSIS REQUEST CODE: _____

EXHIBIT 1.2 Release Form

Battelle

Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509)
Telex 15-2874

I authorize release of my updated radiation exposure records to:

Company Name: _____

Company Address: _____

My payroll number is _____ and my Social Security Number is

(signature)

(date)

EXHIBIT 1.3 In Vivo Count Record Form

Battelle <small>Pacific Northwest Laboratories</small>		IN - VIVO COUNT RECORD			
PLEASE FILL IN THE INFORMATION IN THE BOX BELOW ONLY					
LAST NAME, INITIALS				SOCIAL SECURITY NUMBER ____ - ____ - ____	
PAYROLL NO.		EMPLOYED BY WHICH DOE CONTRACTOR?			
WORK LOCATION - BLDG / AREA	HEIGHT	WEIGHT (lbs)	AGE	SEX	TODAY'S DATE

FOR WHOLE BODY COUNTER USE ONLY					
COUNT CODES	BODY	CODE	DETECTOR USED	CODE	DETECTOR USED
Routine ☐ 1	Whole Body	01	4" x 9" NaI single crystal A		35% GeLi single crystal L
New Hire ☐ 2	Head	02	3/8" x 5" NaI 4 crystal array B		Intrinsic Germanium single array 10 cm ² M
Termination ☐ 3	Chest	03	3/8" x 5" NaI single crystal C		3/8" x 5" Phoswich single crystal N
Unusual Exposure ☐ 4	Abdomen	04	1mm x 1" NaI single crystal D		4" x 4" x 18" NaI single array O
Evaluator Request ☐ 5	Knee	05	3" x 3" NaI single crystal E		3/8" x 5" Phoswich single crystal P
Field Request ☐ 6	Throat	06	3/8" x 5" NaI 4 crystal array F		Specialized counting Q
Recount ☐ 7	Hand	07	4" x 11" NaI single crystal G		Intrinsic Germanium 3 crystal array 20 cm ² R
Followup ☐ 8	Special	08	6" x 11" NaI single crystal H		6" x 11" NaI & 2 GeLi's @ 32% & 35% S
Beginning of Work ☐ 9	Thorax	09	32% & 35% GeLi's I		Intrinsic Germanium 5 crystal array 20 cm ² T
End of Work ☐ 10			16 - single crystal array 20cm ² J		4" x 9" NaI (4) & 6" x 11" NaI U
Visitor ☐ 11			18% GeLi single crystal K		Intrinsic Germanium 6 crystal array 20 cm ² V
Contract Work ☐ 12					
Research Project ☐ 13					

Number Of Counts: _____ Measured Height: _____ Weight: _____

Body Location Code	Detector Code	Serial Number	Description
1			
2			
3			
4			
5			
6			

REQUIRED PROCEDURE(S)	COMPLETED
1. Sample	_____
2. Calc-WBC	_____
3. Calc-CHEST	_____
4. Calc-Special	_____
5. Record-SPLOG	_____
6. Accountability	_____

REQUIRED PROCEDURE(S)	COMPLETED
7. Form Return	_____
8. Plot(s)	_____
9. Phone Evaluator	_____
10. Add Comment	_____
11. Other	_____

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SECTION 1: EXHIBIT

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2.0 EQUIPMENT AND FACILITIES

The Hanford Whole Body Counting (WBC) facility maintains state-of-the-art equipment to provide the best results possible for the approximately 11,000 measurements that are made each year. Most of the measurements are made with equipment located in the 747A Building. However, other facilities do exist in the Emergency Decontamination Facility (EDF) located adjacent to Kadlec Hospital in the city of Richland, and in two mobile units that can be transported to any location when needed.

2.1 SHIELDED FACILITIES

Most of the procedures used in whole body counting require shielding to significantly reduce the natural background radioactivity associated with building materials, soil, air, and cosmic rays. These shielded facilities reduce the background by a factor of 50 to 100, depending on the energy of the radiation. The shielded facilities are briefly described in the following sections.

2.1.1 Shielded Rooms

The largest of these shielded rooms (shown in Figure 2.1) has 10-in.-thick iron walls, ceiling, and floor. The iron is material of low-background activity salvaged from a World War II battleship. A lung counter is installed in this room to measure plutonium, americium, uranium, and other low-energy photon emitters. A graded shield of lead, then cadmium, and then copper has been added to the inside of the room to further reduce the background at low energies. For further details on this room refer to the report Hanford Whole Body Counter 1959 Activities by Roesch, McCall and Palmer, available in the WBC library.

A second room has 4-in.-thick lead walls, ceiling, and floor that are covered by a thin layer of copper. This room is used for special types of measurements associated with contamination incidents. The room is also used for detailed linear scanning, for calibration studies, and the development of improved instrumentation and methods for in vivo measurement of radionuclides.

A third room (Figure 2.2) is also made of 4-in.-thick lead and is only large enough for a person to stand. This counter is called the preview counter (also known as the upright counter) because almost all people who come to the whole body counter are measured in this counter first to quickly determine if any significant gamma-ray-emitting radionuclide is present. Any significant quantity is then more thoroughly evaluated on a shadow shield counter. For

FIGURE 2.1. Iron Shielded Room

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FIGURE 2.2. Preview Counter

2.1.1 Shielded Rooms (contd)

more details on this room refer to the report Hanford Whole Body Counter 1983 Activities.^(a)

2.1.2 Shadow Shields

In shadow-shield-type counters a shield surrounds all but one side of the detector. The subject is in front of this open side. A shield behind the subject, the "shadow shield," is large enough and placed so that no photon traveling in a straight line from that side can enter the detector without passing through the shield. This shield "casts a shadow" over the opening in the detector shield.

(a) Palmer, H. E., G. A. Rieksts and H. B. Spitz. 1984. Hanford Whole Body Counter 1983 Activities. Internal report of the Pacific Northwest Laboratory, Richland, Washington.

2.1.2 Shadow Shields (contd)

The only rays that can reach the detector without attenuation by the shield are those that are emitted from the subject or the shielding material and those scattered from the subject or the shadow shield.

One shadow-shield counter is permanently installed in the 747A Building, two others are mounted in mobile truck units for use on location at the Hanford Site, emergency use, or research studies away from the Hanford Site. A fourth shadow-shield-type counter is located in the EDF and is operated by the Hanford Environmental Health Foundation (HEHF) radiosurgery facility.

Figures 2.3 through 2.5 show the shadow-shield counters mounted in the truck/van. For more information on the construction details and the operation of shadow-shield counters see the article by Palmer and Roesch (1965).

2.1.3 Mobile Facilities

Two mobile whole body counters briefly described in Section 2.1.2 are available for measuring high-energy gamma rays emitted from the body. These units contain the standard Hanford shadow-shield counter with 11.5-in.-diameter NaI(Tl) scintillation detectors.

FIGURE 2.3. An Outside View of the Two Mobile Units Containing the Shadow-Shield Counters

FIGURE 2.4. A View of the Shadow-Shield Counter Inside One of the Mobile Units

2.1.3 Mobile Facilities (contd)

One unit is mounted in a truck/van and the other is mounted in a semitrailer. These units can be powered from existing 115- or 230-V commercial power or by a portable power generator unit. The background and sensitivity of these counters is very similar to that of the shielded rooms except at locations near nuclear facilities.

More detailed information on these units is available in two reports that are available in the WBC library (Swanberg 1963; Eichner 1969).

2.1.4 Equipment in the EDF

Occasionally in vivo measurements are done at the EDF when a worker becomes so extensively contaminated that he may contaminate the low background WBC facilities in the 747 Building or when a contaminated injury has occurred. For these purposes some equipment is maintained at the EDF.

FIGURE 2.5. Shadow-Shield Whole Body Counter Mounted in the Mobile Unit (truck/van)

2.1.4 Equipment in the EDF (contd)

This equipment includes a modified shadow-shield whole body counter in which the total body and lung, liver, or bone measurements can be made; a planar germanium detector and a multichannel analyzer (MCA) for measuring plutonium-239 and americium-241 in wounds; and a medical gamma camera for imaging high levels of radioactivity in the various organs of the body. The laboratory and hood at the EDF are also utilized in the preparation of radioactive calibration solutions and sources, and phantom organs for calibrating the whole body counters.

2.2 DETECTORS

The two main types of detectors used for whole body counting are scintillation and semiconductor detectors. Refer to the book by G. F. Knoll entitled Radiation Detection

2.2 DETECTORS (contd)

and Measurement, located in the WBC library for a detailed description of the following detectors.

2.2.1 Scintillation Detectors

The scintillation detectors are mostly NaI(Tl) crystals ranging in size from 1 mm thick and 1 in. in diameter to 6 in. thick and 11.5 in. in diameter.

2.2.2 Semiconductor Detectors

Three types of semiconductor detectors are used for whole body counting: coaxial germanium detectors used for higher-energy gamma-ray measurements; planar germanium detectors used for low-energy photons between 10 and 200 keV; and lithium-drifted silicon detectors used to measure and separate the 20.16- and 20.78-keV L-gamma peaks for determining the plutonium-239-to-ameridium-241 ratio in plutonium wounds.

2.2.3 Other Detector Types

Other detectors that are used occasionally are the CdTe probe for use on plutonium wounds and the Phoswich detectors.

2.3 DATA ACQUISITION AND PROCESSING EQUIPMENT

The electronic pulses from the detectors are analyzed, stored, and displayed by several MCAs. These spectra are then transferred to a Hewlett Packard HP-9000 minicomputer. This computer has 2 megabytes of memory and has a hard disk capacity of 404 megabytes.

Spectra files are handled by a data base management system called IMAGE. The computer system has a built-in graphics capability for displaying spectra on a cathode ray tube (CRT), X-Y plotter, or graphics printer.

Once the spectra are in the computer, all calculations, storage, and reporting of data and results are handled by the main FORTRAN 77 program called EXEC. The computer is also interfaced to the ORE data base system on the UNIVAC 1100/44.

The routine counting operations are controlled by the computer which provides instantaneous calculation of results and plots of unusual spectra.

For more detailed information, consult Section 6 of this manual, and the hardware, software, and maintenance manuals that are available in the WBC library.

2.4 CALIBRATION METHODS

To determine the amount of radioactivity in the body, the detector response must be calibrated in terms of counts per photon emitted from the body. This is done by placing known amounts of radioactivity in an anthropomorphic phantom or an organ of the phantom and making a measurement of the activity in a standard reproducible position that will be used with people.

Details on calibration procedures, factors, and curves are given in Section 3 of this manual. Several types of phantoms are used and described in the following sections.

2.4.1 Bottle-Manikin-Absorption Phantom

The bottle-manikin absorption (BOMAB) phantom shown in Figure 2.6 consists of 10 polyethylene containers of sizes, which when appropriately assembled, are roughly equal to the size, weight, and shape of a Reference Man (ICRP 1975). The containers can be filled with solutions of known quantities of a radionuclide for calibration purposes. The liquid capacity of each part of the phantom is given in Table 2.1.

This phantom is used for the whole-body calibration of radionuclides uniformly distributed throughout the body. The phantom does not provide quite the amount of absorption as an actual human body and the correction factor which ranges from 10% to 25% must be applied, depending on the gamma-ray energy. Details of this correction will be given in Section 3 on calibrations.

2.4.2 Radiation-Equivalent-Manikin-Absorption Phantom

The radiation-equivalent-manikin absorption (REMAB) phantom shown in Figure 2.7 is constructed of radiolucent plastic shells and contains a human skeleton. The entire body and organs can be filled with known quantities of radioactive solutions. The skeletons come from India and are typically smaller than the average U.S. male; therefore, this phantom is rarely used at Hanford for whole body calibration purposes.

2.4.3 Tissue-Equivalent Torso Phantom

The tissue-equivalent torso phantom is shown in Figure 2.8. This phantom was specifically constructed for calibration of counting systems used to measure transuranic nuclides in the lung, liver, and pulmonary lymph nodes. However, it is also useful for high-energy gamma-emitting radionuclides in the lung and liver.

FIGURE 2.6. BOMAB Phantom

TABLE 2.1. Weight and Liquid Capacity of the BOMAB Phantom

Phantom Part	Volume, mL	Total Weight, g
Head	4,080	7,378
Neck	930	1,452
Torso	16,600	19,340
Arms	7,840	10,351
Pelvis	12,900	15,027
Upper legs	12,100	14,733
Lower legs	7,700	9,761
Total	62,150	78,042

FIGURE 2.7. REMAB Phantom

2.4.3 Tissue-Equivalent Torso Phantom (contd)

The phantom contains a rib cage of artificial bone-equivalent material, removable organs, and includes tissue-equivalent chest plates that can be placed over the torso to simulate the chests of people with a wide range of chest wall thicknesses. The radioactivity is homogeneously distributed in the lung, liver, and lymph nodes by mixing the activity into the liquid polyurethane before it cures in the mold to form a semi-hard plastic organ.

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FIGURE 2.8. Tissue-Equivalent Torso Phantom (a) Removal of the chest plate.
(b) Phantom without chest plate, organs visible.

2.4.3 Tissue-Equivalent Torso Phantom (contd)

The basic phantom is made from muscle-equivalent material. There are two sets of chest plates: one set is made of 50% fat-to-50% muscle-equivalent tissue, and the other set is made of 87% fat-to-13% muscle-equivalent tissue. For more details on this phantom see Griffith, et al. (1978).

Calibration curves corresponding to the chest wall thickness and the fat content are developed using these chest plates. The chest wall thickness of contaminated radiation workers is determined using medical ultrasound tissue thickness measurement equipment (see Section 3.10 for the details of the ultrasound procedure).

Separate lung sets containing plutonium-238 and -239, americium-241, natural uranium, enriched uranium, natural thorium, cobalt-60, cerium-144, europium-154, and cesium-137 have been purchased or constructed for use in the phantom. Radioactively tagged standard liver organs include plutonium-238 and -239, americium-241, and natural thorium.

The validity of this phantom as a good representation of absorption qualities of the human body for the L x-rays from plutonium has been proven by studies on 18 humans who inhaled known quantities of niobium-92m. This study (Gunston and Jeffries 1986; Newton et al. 1985) originated in England and was funded by the International Atomic Energy Agency (IAEA).

2.4.4 Head Phantoms

Various head phantoms are used to calibrate detectors for the amount of radioactivity in the skeleton. The only one owned by PNL was constructed from the skull of a total-body donation to the HEHF and U.S. Transuranium Registry.

This body contained 118 nCi of americium-241 in the skeleton. The level of activity was determined by measuring the content in exactly half of the skeleton and reserving the other half so that skeletal parts containing known quantities of americium-241 naturally distributed in each bone are available.

The head phantom contains half of the skull from the donated body. The half skull has been matched with an opposite half of a noncontaminated skull. The cavities of the composite skull were filled with tissue-equivalent material that simulates the brain, the inner soft tissue, and the skin. This phantom is shown in Figure 2.9.

For calibration, the detectors must be placed symmetrically on both sides of the head phantom.

FIGURE 2.9. Head Phantom for the Calibration of Radioactivity in the Skull

2.4.5 Thyroid Phantom

A thyroid phantom is shown in Figure 2.10. The phantom is made of tissue-equivalent plastic and the thyroid lobes can be filled with radioactive solutions for calibration.

FIGURE 2.10. Thyroid Phantom

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THESE ARE THE RESULTS OF THE ANALYSIS OF THE SAMPLES TAKEN AT THE SITE OF THE ACCIDENT. THE ANALYSIS WAS CONDUCTED BY THE LABORATORY OF THE MINISTRY OF THE INTERIOR, DEPARTMENT OF FORENSIC MEDICINE, IN THE CITY OF LISBON, PORTUGAL. THE RESULTS OF THE ANALYSIS ARE AS FOLLOWS:

1. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE VICTIMS SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS.

2. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE SUSPECTS SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE SUSPECTS.

3. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE WITNESSES SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE WITNESSES.

4. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

5. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

6. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

7. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

8. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

9. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

10. THE ANALYSIS OF THE BLOOD SAMPLES TAKEN FROM THE EVIDENCE SHOWED THAT THE BLOOD WAS OF THE ABO BLOOD GROUP. THE BLOOD WAS FOUND TO BE OF THE A BLOOD GROUP, WHICH IS COMPATIBLE WITH THE BLOOD OF THE VICTIMS AND SUSPECTS.

3.0 IN VIVO MEASUREMENTS

This section describes the procedures for performing the various in vivo measurements at the WBC and related facilities.

3.1 WHOLE BODY IN VIVO MEASUREMENTS

Whole body in vivo measurements are done in the preview whole body counter. This counter consists of a column of five sodium iodide (NaI) detectors, mounted in a lead-shielded booth (Figures 3.1 and 3.2). These detectors are used to determine whether detectable quantities of high-energy gamma-emitting radionuclides (such as cesium-137, cobalt-60, and manganese-54) are present anywhere in the body.

Data from the five detectors are recorded as a sum of the counts of from all five detectors, as well as an individual count from each of the upper three detectors and a combined count from the two lower detectors. The relative counts from each detector output provide a measure of the distribution of activity in the body.

Virtually all people who come to the WBC will be measured in the preview counter first. If any significant activity is detected, the subject may be measured on another type of counter for further evaluation.

3.1.1 Procedure for Daily Whole Body Counter Energy Calibration, Background Determination, and Efficiency Check

Energy Calibration

Background Determination

- Obtain the combination cesium-137 and potassium-40 sources used for large NaI(Tl) energy calibrations.
- Calibrate all 5 detectors of the preview counter using a multichannel analyzer (MCA) so that each channel represents 20 keV (refer to Section 4, Operation of Counting Equipment and see Figure 3.2).
- Vertically stack each of the 4 containers filled with plastic beads against the detectors to simulate the presence of a nonradioactive subject.
- Rotate the adjusting wheel on the outside of the counter until the detectors are at the lowest position.
- Take a 1000-second background count.
- Enter this background spectra into the computer.
- Remove the containers from the preview counter.

WHOLE BODY EXAM

FIGURE 3.1. The Preview Whole Body Counter

Data Sheet for NaI Preview Whole Body Counter

keV per channel	<u>20</u>
# of detectors	<u>5</u>
Detector code	<u>U2</u>
Body location code	<u>01</u>
# of channels	<u>1024</u>
Routine count length, sec	<u>200</u>
Background length, sec	<u>1000</u>
Source used for calibration	<u>137 Cs + K⁴⁰</u>
Source count used length	<u>40K - 200 sec</u>

FIGURE 3.2. The Preview Whole Body Counter Schematic and Data Sheet

3.1.1 Procedure for Daily Whole Body Counter Energy Calibration, Background Determination, and Efficiency Check (contd)

Efficiency Check

- Place the 9-container standard potassium-40 source in its standard position and count for 200 seconds.
- Save the spectra on the computer.

3.1.2 Procedure for Subject Measurement

- Instruct the subject to carefully step into the counting booth: standing, backside leaning against plexiglass covering the detectors.
- Adjust the height of the detectors so the largest diameter detector is centered over the lungs.
- Instruct the subject to remain in position for approximately 3 minutes until the "Finished" light goes on.
- Remind the subject to watch his step while exiting the counting booth when the count is finished.
- Count the subject for 200 seconds.
- Save the spectra.
- Analyze the results.

3.1.3 Background Correction

The procedure to obtain the daily count of the room background radiation is described in Section 3.1.1. This background activity is subtracted from the subject's whole body count spectra before quantifying any radionuclides.

3.1.4 Calculations for Total Body Activity

Computer analysis is provided automatically for the radionuclides listed in Table 3.1. The computer calculation is the same as that for the manual calculation.

For manual calculation of the total body count, the following equation is used:

$$nCi \text{ in the body} = \frac{\text{net counts per minute in the photopeak of interest}}{\text{counts/min/nCi}} \quad (3.1)$$

The count per minute per nCi (counts/min-nCi) factor is listed in the fourth column of Table 3.1.

For radionuclides not listed in Table 3.1, use the counts per gammas for the appropriate energy listed in Table 3.2 using the following equation:

TABLE 3.1 Counting Efficiency for Common Radionuclides in the Preview Counter

Radionuclide	Gamma Ray Energy, MeV	Energy Channels Used	Counts/min-nCi in the Total Body (a)	Counts/min-nCi in the Lung (b)
^{40}K	1.460	68 to 78	6.9	9.1
^{60}Co	1.173	52 to 62	65.0	84.4
^{137}Cs	0.662	30 to 36	56.7	76.2
^{54}Mn	0.840	38 to 44	66.3	87.5
^{154}Eu	1.274	57 to 68	23.2	38.0
^{22}Na	1.274	57 to 68	65.4	86.3
^{59}Fe	1.099	48 to 59	27.2	35.9
^{95}Zr	0.724 0.756	34 to 42	65.9	87.0
^{65}Zn	1.115	52 to 60	33.3	43.0
^{106}Ru	0.512	22 to 28	13.8	18.2
^{131}I	0.364	15 to 19	54.6	72.1
^{140}La	1.596	76 to 84	61.9	81.7
^{232}Th	2.612	125 to 135	23.6	31.1
^{226}Ra	1.764	83 to 97	12.2	16.1
^{144}Ce	2.18	100 to 120	0.5	0.7
^{51}Cr	0.320	13 to 17	6.0	7.9
^{110}Ag	0.658	29 to 35	63.1	83.3
^{24}Na	2.75	131 to 147	62.7	82.7

- (a) These calibration factors were developed from measurements on the BOMAB phantom containing various radionuclides uniformly distributed throughout the phantom. A known "phantom-to-people" correction has also been applied.
- (b) These calibration factors were developed from measurements on the tissue-equivalent torso phantom with the 11 1/2-in.-diameter detector located over the lungs with various radionuclides uniformly distributed in the lungs.

TABLE 3.2. Counting Efficiency at Various Energies
in the Preview Counter (count per gamma
emitted from the body)

Preview Counter Efficiency
Factors (using all counts in
the photopeaks)

<u>Energy for</u> <u>Total Body, keV</u>	<u>WBC Factor,</u> <u>counts per gamma ray</u>	<u>Lung Factor,</u> <u>counts per gamma ray</u>
100	3.06 x 10E-2	4.08 x 10E-2
200	3.05 x 10E-2	4.03 x 10E-2
300	3.04 x 10E-2	3.97 x 10E-2
400	3.03 x 10E-2	3.92 x 10E-2
500	3.02 x 10E-2	3.86 x 10E-2
600	3.01 x 10E-2	3.81 x 10E-2
700	3.00 x 10E-2	3.76 x 10E-2
800	2.99 x 10E-2	3.71 x 10E-2
900	2.98 x 10E-2	3.65 x 10E-2
1000	2.97 x 10E-2	3.60 x 10E-2
1100	2.96 x 10E-2	3.55 x 10E-2
1200	2.96 x 10E-2	3.50 x 10E-2
1300	2.95 x 10E-2	3.46 x 10E-2
1400	2.94 x 10E-2	3.41 x 10E-2
1500	2.93 x 10E-2	3.36 x 10E-2
1600	2.92 x 10E-2	3.32 x 10E-2
1700	2.91 x 10E-2	3.27 x 10E-2
1800	2.90 x 10E-2	3.22 x 10E-2
1900	2.89 x 10E-2	3.18 x 10E-2
2000	2.88 x 10E-2	3.14 x 10E-2
2100	2.87 x 10E-2	3.09 x 10E-2
2200	2.87 x 10E-2	3.05 x 10E-2
2300	2.86 x 10E-2	3.01 x 10E-2
2400	2.85 x 10E-2	2.97 x 10E-2
2500	2.84 x 10E-2	2.93 x 10E-2
2600	2.83 x 10E-2	2.89 x 10E-2
2700	2.82 x 10E-2	2.85 x 10E-2
2800	2.81 x 10E-2	2.81 x 10E-2
2900	2.80 x 10E-2	2.77 x 10E-2
3000	2.80 x 10E-2	2.73 x 10E-2

3.1.4 Calculation for Total Body Activity (contd)

$$\text{nCi in the body} = \frac{A}{B \times C \times D} \quad (3.2)$$

where A = net counts per minute in photopeak of interest
B = 2.22×10^3 dpm/nCi
C = photon yield per disintegration^(a)
D = count per gamma from second column of Table 3.2.

3.1.5 Calculations for Lung Activity

Computer analysis is provided automatically for radionuclides listed in Table 3.1. For manual calculation of the lung content the following equation is used:

$$\text{nCi in the body} = \frac{\text{net counts per minute in the photopeak of interest}}{\text{count per minute per nCi}} \quad (3.3)$$

The count per minute per nCi (counts/min-nCi) factor is listed in the fifth column of Table 3.1. For radionuclides not listed in Table 3.1, use the counts per gamma for the appropriate energy listed in the third column of Table 3.2 using the following equation:

$$\text{nCi in the lung} = \frac{A}{B \times C \times D} \quad (3.4)$$

where A = net counts per minute in photopeak of interest
B = 2.22×10^3 dpm/nCi
C = photon yield per disintegration^(a)
D = count per gamma from third column of Table 3.2.

3.1.6 Procedure for Handling Positive Cobalt-60 Whole Body Counts

The level of cobalt-60 in the body indicates the need for further studies to look for other associated, but difficult-to-detect radionuclides that may provide significant radiation exposure. A good example of such a radionuclide is cerium-144.

When cobalt-60 activity is detected follow the whole body counting procedure outlined in the flow diagram of Figure 3.3.

- (a) The photon yield per disintegrations for radionuclides can be found in Radioactive Decay Data Tables by D. C. Kocher located in the WBC library.

FIGURE 3.3. Flow Diagram for Whole Body Counting Procedure When Cobalt-60 Is Detected

3.2 IN VIVO LUNG MEASUREMENTS OF LOW-ENERGY PHOTONS (<200 keV)

In vivo lung measurements focus on activity deposited in the respiratory system. The low-energy photons of radiation emitted from the lung are measured by an array of 6 germanium planar detectors. These detectors are placed over the subject in a supine or semireclining position; a semireclining position affords the highest counting efficiency for women and overweight men.

The activity detected in the lung is affected by the chest wall thickness of the subject and any activity that might be emitted from the ribs. To obtain an accurate measurement of activity that has been initially detected by the lung counter, a chest wall thickness measurement is made (see Section 3.10).

To determine the activity, if any, emitted from the ribs (bone), a head count is taken to measure skeletal activity. From this value measured lung activity can be corrected.

3.2.1 Procedure for Energy Calibration and Efficiency Check of Germanium Planar Detectors for Lung Counts

Energy Calibration

- Review system data sheet in Figure 3.4.
- Obtain the americium-241 and uranium-235 sources.
- Calibrate and balance each planar germanium detector using an MCA so that each channel represents 0.500 keV. (Refer to Section 4, Operation of Counting Equipment)
- Remove calibration sources.
- Close iron room door.
- Preset time for 1000 seconds.
- Count background.
- Save and enter background spectra in the computer.
- Open the iron room.

Efficiency Check

- Position the plexiglass jig containing the americium-241 source and adjust all detectors as close as possible to the jig (see Figure 3.5).
- Close the door.

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FIGURE 3.4. In Vivo Lung Count Equipment and Data Sheet

FIGURE 3.5. Calibration of Detectors for In Vivo Lung Count

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3.2.1 Procedure for Energy Calibration and Efficiency Check of Germanium Planar Detectors for Lung Counts
(contd)

- Preset the time for 300 seconds and acquire a source count.
- Save the spectra on the computer.

3.2.2 Procedure for Subject Measurement

Preparing the subject for the count

- Have the subject shower and change into paper slippers and cotton coveralls.
- Measure and record the subject's height and weight on the In Vivo Count Record.

Positioning the detectors

- USE EXTREME CAUTION WHEN POSITIONING THE DETECTORS OVER THE SUBJECT. The detectors are evacuated underneath the 20-mil-thick beryllium windows. The windows are brittle and could possibly implode.
- Pull chair from underneath the detectors.
- Holding the chair in place, instruct the subject to sit down.
- Instruct the subject to carefully swing his legs on the chair without bumping the detectors and then recline on the chair.
- Move the chair horizontally until the subject's lung area is beneath the detectors.
- Tilt the back of the chair until the level bubble is centered.
- Position the detectors by slowly raising the chair height and adjusting the tilt of the detectors by rotating the handle. The edge of the detector closest to the head should be just below the clavicle. Refer to Figure 3.6.
- The detectors should be placed as close as possible to the surface of the subject's lung area without restricting breathing.
- When the subject and detectors are properly positioned, lock the carriage in place.

Giving Instructions to subject prior to count

- Make sure the subject is as comfortable as possible.
- Explain the use of the emergency button and self-exit procedure.

FIGURE 3.6. Position of Detectors for a Lung Count

3.2.2 Procedure for Subject Measurement (contd)

Taking the count

- Instruct the subject not to move from underneath the detectors and to lie still for the duration of the count.
- Inform the subject of the length of the count.
- Close shielded room door.
- Start count.
- Count for preset time (usually 1000 or 2000 seconds).
- Save count on the computer.
- When the count is completed, open the shielded room door.

Giving directions after the count

- Instruct the subject not to move until asked to do so.

3.2.2 Procedure for Subject Measurement (contd)

- Slowly lower the chair.
- Release the locking mechanism.
- Slide the chair from underneath the detectors.
- Hold on to the chair and instruct the subject to carefully swing his legs to the side of the chair, stand, and watch his step while standing up and exiting the room.

3.2.3 Background Correction

The background is subtracted using the 12-channel continuum above the photopeak or the 11-point smoothing method (Spitz et al. 1984).

3.2.4 Calculation for Activity in the Lung

The computer is programmed to provide calculations using the estimated or actual chest wall thickness for the radionuclides listed in Table 3.3.

TABLE 3.3. Calibration Data for Lung Counts

<u>Radionuclide</u>	<u>Photon Energy, keV</u>	<u>Channel Group</u>
²⁴¹ Am	59.5	117 to 120
²³⁹ Pu	17	33 to 36
²³⁸ Pu	17	33 to 36
²³⁵ U	185	370 to 373
²³⁴ Th	63	125 to 128
¹⁴⁴ Ce	133	265 to 268
¹⁵⁵ Eu	86	171 to 174
¹⁵⁴ Eu	123	244 to 247
²³² Th	238	474 to 477

To manually calculate the lung activity, determine the chest wall thickness using the Equation (3.5). Using this chest wall thickness, refer to Table 3.4 and obtain the calibration factor corresponding to the determined chest wall thickness. This calibration factor used in Equation (3.6) provides the lung content.

TABLE 3.4. Calibration Factor Versus Chest Wall Thickness for Lung Counter Using the 6-Germanium-Detector Array (counts per minute per nCi)

Chest Wall Thickness, cm	Calibration Factor for Nuclides								
	²⁴¹ Am	²³⁵ U	²³⁴ Th	¹⁴⁴ Ce	²³⁹ Pu	²³⁸ Pu	¹⁵⁵ Eu	¹⁵⁴ Eu	²³² Th
1.8	13.89	12.51	1.36	3.35	0.0308	0.0888	7.12	9.37	2.09
1.9	13.46	12.18	1.32	3.26	0.0284	0.0832	6.92	9.11	2.02
2.0	13.05	11.85	1.28	3.17	0.0263	0.0779	6.72	8.85	1.96
2.1	12.65	11.54	1.25	3.08	0.0243	0.0730	6.52	8.60	1.89
2.2	12.27	11.23	1.21	3.00	0.0224	0.0684	6.34	8.36	1.83
2.3	11.89	10.93	1.17	2.92	0.0207	0.0641	6.15	8.13	1.77
2.4	11.53	10.64	1.14	2.84	0.0191	0.0600	5.97	7.90	1.71
2.5	11.18	10.36	1.10	2.77	0.0177	0.0562	5.80	7.68	1.66
2.6	10.84	10.08	1.07	2.69	0.0163	0.0527	5.63	7.47	1.61
2.7	10.50	9.81	1.04	2.62	0.0151	0.0494	5.47	7.26	1.55
2.8	10.18	9.55	1.01	2.55	0.0139	0.0462	5.31	7.06	1.50
2.9	9.87	9.30	0.98	2.48	0.0129	0.0433	5.16	6.86	1.45
3.0	9.57	9.05	0.95	2.41	0.0119	0.0406	5.01	6.67	1.41
3.1	9.28	8.81	0.92	2.35	0.0110	0.0380	4.87	6.48	1.36
3.2	9.00	8.57	0.89	2.29	0.0102	0.0356	4.73	6.30	1.32
3.3	8.72	8.34	0.87	2.23	0.0094	0.0334	4.59	6.13	1.28
3.4	8.46	8.12	0.84	2.17	0.0087	0.0313	4.46	5.96	1.23
3.5	8.20	7.91	0.82	2.11	0.0080	0.0293	4.33	5.79	1.19
3.6	7.95	7.70	0.79	2.05	0.0074	0.0274	4.20	5.63	1.16
3.7	7.70	7.49	0.77	2.00	0.0068	0.0257	4.08	5.47	1.12
3.8	7.47	7.29	0.75	1.94	0.0063	0.0241	3.96	5.32	1.08
3.9	7.24	7.10	0.72	1.89	0.0058	0.0226	3.85	5.17	1.05
4.0	7.02	6.91	0.70	1.84	0.0054	0.0211	3.74	5.03	1.01
4.1	6.81	6.72	0.68	1.79	0.0050	0.0198	3.63	4.89	0.98
4.2	6.60	6.54	0.66	1.74	0.0046	0.0186	3.53	4.75	0.95
4.3	6.40	6.37	0.64	1.70	0.0042	0.0174	3.42	4.62	0.92
4.4	6.20	6.20	0.62	1.65	0.0039	0.0163	3.33	4.49	0.89

ROI^(a)

117 to 120 370 to 373 125 to 128 265 to 268 33 to 36 33 to 36 171 to 174 244 to 247 474 to 477

CCR^(b)

122 to 133 375 to 386 130 to 141 270 to 281 44 to 55 44 to 55 176 to 187 249 to 260 484 to 495

(a) ROI = region of interest for a given nuclide by channel.

(b) CCR = region for background continuum correction by channel (not keV) spectra at 0.5 keV/channel.

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3.2.4 Calculations for Activity in the Lung

(contd)

$$\text{chest wall thickness in cm} = \left[0.68 + \left(0.974 \times \frac{\text{weight (lbs)}}{\text{height (in.)}} \right) \right] \quad (3.5)$$

$$\text{nCi activity in lung} = \frac{\text{net counts per minute in lung}}{\text{counts/min/nCi}} \quad (3.6)$$

3.2.5 Correction of the Lung Count for Activity in the Bone and Liver

When activity such as americium-241 exists in the lung, liver, and bone, the lung count must be corrected for the contribution from the other organs. The bone contribution to the lung count is 0.46 times the net counts measured in the head when using the same number and size of detectors for both measurements (see method for measuring bone content Section 3.4).

3.3 IN VIVO MEASUREMENT OF RADIOACTIVITY IN THE LIVER

Some radionuclides such as the transuranics and the rare earth elements have a preferential uptake in the liver after they are absorbed into the bloodstream of the body. Liver measurements are made using an array of three germanium planar detectors for low-energy photon emitters.

3.3.1 Procedure for Energy Calibration and Efficiency Check of the Germanium Planar Detectors

- Review data sheet in Figure 3.7.
- Energy Calibration**
 - Calibrate the MCA so that each channel is equivalent to 0.500 keV for the germanium planar detector (see Section 4 Operation of Counting Equipment).
- Efficiency Check**
 - See Section 3.2.1 for daily efficiency check of these detectors.

3.3.2 Procedure for Subject Measurement

- Have the subject lie on his back underneath the array of 3 germanium planar detectors.
- Place the detectors over the liver in contact with the body.
- Place two of the detectors on the rib cage just above the lower edge and one detector on the edge of the rib cage as shown in Figure 3.7.
- Instruct the subject not to move and to keep in light contact with the detectors.
- Describe the use of the emergency button and the self-exit procedure.
- Close the shielded room door.
- Start the count.
- Count for the preset time (usually 2000 seconds).

3.3.3 Background Correction

The background for the array of the germanium detectors is subtracted using the 12-channel continuum above the photo-peak or the the 11-point smoothing method (Spitz et al. 1984).

Position of Detectors for Liver Count

Data Sheet for Liver Count

keV per channel	<u>0.5</u>
# of detectors	<u>3</u>
Detector code	<u>R1</u>
Body location code	<u>08</u>
# of channels	<u>512</u>
Routine count length, sec	<u>2000</u>
Background length, sec	<u>NA</u>
Source used for calibration	<u>241 Am + enriched U</u>
Source count used length	<u>241 Am plexiglass jig from 6-Germanium</u>
	<u>Planar Detector Lung Count</u>

FIGURE 3.7. Data Sheet and Position of Detectors for Liver Count

3.3.4 Calculations for Liver Activity

Computer analysis is provided automatically for the radionuclides shown in Table 3.5 when the 3-germanium planar detector array is used.

TABLE 3.5 Calibration Data for Liver Counts

Radionuclide	Energy, keV	Channel Group	Counts per Minute per nCi for 3.2-cm Chest Wall Thickness
²³⁹ Pu	17.0 and 20.4	32 to 35	Calibrate for each case
²³⁸ Pu	17.0 and 20.4	32 to 35	Calibrate for each case
²⁴¹ Am	59.5	117 to 120	8.17
¹⁴⁴ Ce	134	Calibration pending	
¹⁵⁴ Eu	123	Calibration pending	
¹⁵⁵ Eu	86	Calibration pending	
²³² Th	239	Calibration pending	

The formula for manual calculation of activity in the liver is given below:

$$\text{nCi in liver} = \frac{\text{net counts/min}}{\text{counts/min/nCi}} \quad (3.7)$$

The counts per minute per nCi factors are obtained from Table 3.5. This value is for an average tissue thickness of 3.2 cm overlaying the liver. Calibration factors for different thickness overlays have not been derived. If the overlay thickness is significantly different than 3.2 cm, a calibration factor can quickly be obtained by measuring a standard liver organ with the appropriate overlay shell on the phantom. The thickness of tissue over the liver of a subject is determined by an ultrasound method as derived in Section 3.2 for lung counting.

If activity is also present in the skeleton, the liver count must be corrected for contribution from the bone that is viewed by the detectors. For americium-241, the bone contribution to the liver count rate is 0.28 times the head count rate when using the same number of germanium planar detectors for both the head and the liver.

 

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3.4 IN VIVO MEASUREMENT OF RADIOACTIVITY IN THE BONE

Radioactivity in the bone can usually be identified by noting that relatively high levels (determined by the whole body counter and compared to other parts of the body) exist in the head or in the bone joints. For radionuclides emitting high-energy gamma rays above 100 keV, a normal whole body count gives a good measurement of the content when activity does not exist in soft tissues. Most bone measurements presently made are for low-energy x-rays or gamma rays below 100 keV.

A count is made by measuring the activity content in the skull with germanium planar detectors (usually two detectors are used). The head is the preferred place for a measurement because of the high sensitivity and the low level of interference from other parts of the body. However, other parts of the body such as the knee or ankle may be used for a bone measurement if the head has extensive contamination (Palmer, Rieksts and Icyan 1983).

Efficiency Check

- Place the two detectors on the marked standard positions of the americium-241-labeled head phantom.
- Count for 2000 seconds.
- Compare the results with the original calibration results. The two sets of results should be the same.

3.4.1 Procedure for Energy Calibration and Efficiency Check of Germanium Planar Detectors

- Review the system data sheet in Figure 3.8.

Energy Calibration

- Calibrate the MCA with the americium-241 and uranium-235 sources so that each channel is equivalent to 0.500 keV (see Section 4, Operation of Counting Equipment).

3.4.2 Procedure for Subject Measurement

- Have the subject shower and wash hair to remove dust and attached radon daughter activity.
- The subject's hair should not be dried because dry hair attracts radon daughter activity from the air.
- Have the subject put on cotton coveralls for the measurement.
- Escort the subject into the shielded room and have him lie on his back on the bed that is supported by a hydraulic lifter.

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keV per channel	<u>0.5</u>
# of detectors	<u>2</u>
Detector code	<u>Q1</u>
Body location code	<u>Q2</u>
# of channels	<u>512</u>
Routine count length, sec	<u>3000</u>
Background length, sec	<u>NA</u>
Source used for calibration	<u>241 Am + enriched U</u>
Source count used / length	<u>241 Am plexiglass jig</u>

FIGURE 3.8. Head Counter Schematic and Data Sheet

3.4.2 Procedure for Subject Measurement (contd)

- Place the detectors lightly against the subject's forehead by raising the bed up until the head comes into contact with the detectors. The detectors should be positioned so their front surfaces are tangent to the head surface (Figure 3.9).
- USE EXTREME CAUTION when bringing the subject's head into contact with the detectors. The detectors are evacuated underneath the 20-mil-thick beryllium windows. The windows are brittle and could possibly implode.
- NEVER PUT THE DETECTORS OVER THE EYES.
- Place a lead shield around the neck and over the chest of the subject to absorb radiation from the other parts of the body.
- Instruct the subject not to move his head and to keep it in contact with the detectors.
- Describe the use of the emergency button and the self-exit button.
- Close the shielded room door.
- Count for the preset time (usually 3000 seconds).
- When the count is over carefully remove the lead shield first and then remove the subject from beneath the counter and remind him to watch his step when he exits.

3.4.3 Background Correction

The background is subtracted using the 12-channel continuum above the photopeak or the 11-point smoothing method (Spitz et al. 1984).

3.4.4 Calculation for Bone Activity

The computer is programmed to provide calculations for the skull and the total skeletal content of radionuclides using the calibrated factors listed in Table 3.6.

The calculation procedure determines the net count per minute in the region of interest and the net count is divided by the calibration factor given above to obtain the content in the skull. The skull content is multiplied by 6.67 to obtain the total skeleton content.

FIGURE 3.9. Position of Detectors for a Head Count

TABLE 3.6 Calibration Data for Head Counts

<u>Radionuclide</u>	<u>Photon Energy, keV</u>	<u>Channel Group</u>	<u>Counts/min/nCi in Skull from 2 Detectors</u>	<u>Counts/min/nCi in Total Skeleton from 2 Detectors</u>
^{241}Am (a)	59.5	117 to 120	7.5	1.13
^{210}Pb	46.5	92 to 94	0.70	
^{239}Pu	17.0	32 to 35	0.13	0.087
^{238}Pu	17.0	32 to 35	0.033	0.022

(a) From Palmer, Spitz and Rieksts (1985).

3.5 IN VIVO MEASUREMENT OF RADIOACTIVITY IN WOUNDS

Small injuries to the hands and arms in plutonium processing facilities often result in plutonium-239 and associated americium-241 being injected into the skin and underlying tissue. This activity can be easily detected and quantified. The determination of the 239-plutonium content in the wound usually requires a correction for the amount of americium-241 present. The exact location and depth of the activity must also be determined in some wound areas.

3.5.1 Procedure for Energy and Efficiency Calibration of the Coaxial Germanium Detectors in the Shielded Room or at the EDF

Energy Calibration

- Review the system data sheet in Figure 3.10.
- Locate the radioactive sources: americium-241, 116.5 nCi, #40; plutonium-239, 125.5 nCi, #42.
- Calibrate one coaxial germanium detector using a MCA so that each channel represents 0.500 keV. Therefore, the 59.5-keV peak from americium-241 will be stored in channel 119 and the 185.5-keV peak from uranium-235 will be stored in channel 371.

Efficiency Calibration

- Position the americium-241 source on the coaxial germanium source so that the activity side of the source is closest to the detector and count for 60 seconds.
- When the count is finished, save the americium-241 spectrum in the computer and print a hard copy.
- Remove the americium-241 source.
- Position the plutonium-239 source on the coaxial germanium detector so that the activity side of the source is closest to the detector and count for 100 seconds.
- When the count is finished, save the plutonium-239 spectrum in the computer and print a hard copy.
- Remove the plutonium-239 source.

FIGURE 3.10. Wound Counter Schematic and System Data Sheet

3.5.2 Procedure for Subject Measurement

Count an Uncontaminated Subject

- Take a count of an uncontaminated subject whenever possible.
- Position the uncontaminated subject's hand, finger, or body part corresponding to the body part of the contaminated subject in contact with the detector to simulate the same positioning when the actual subject's wound is counted.
- Set the count time for 600 seconds.

3.5.2 Procedure for Subject Measurement (contd)

Prior to Contaminated Subject's Count

- Take the count.
- Save the spectrum in the computer and print a hard copy.
- Subject is normally not required to shower.
- If the radiation protection technologist has detected external contamination in the wound area and is unable to remove the activity, cover the detector with a thin plastic bag before counting the wound.
- Position the subject comfortably with the wound centered and in contact with the detector.
- Use only light pressure against the beryllium window to avoid imploding.
- Instruct the subject to keep the wound area in contact with the detector during the count.
- Describe the use of the emergency button and the self-exit procedure.
- Close the shielded room door.

Taking the Contaminated Subject's Count

- Count for 600 seconds.
- Save the spectrum and print a hard copy.

When the Count is Finished

- Have the subject carefully leave the counter.
- Remind the subject to watch his step.

3.5.3 Background Correction

The background is subtracted using the 12-channel continuum method above the photopeak or the 11-point smoothing method (Spitz et al. 1984) when calculating the background for americium-241. The background from the uncontaminated subject is used when calculating the plutonium-239 activity.

3.5.4 Calculations for Shallow Wound Activity

The computer is programmed to provide the quantified activity using the calibration factors in Table 3.7 for measurements made using a 20-cm² detector at the 747A Building.

TABLE 3.7 Calibration Data for Wound Counts

Radionuclide	Photon Energy, keV	Channel Group	Counts/min/nCi
²⁴¹ Am	59.5	117 to 121	278.32
²³⁹ Pu	13.6 and 17	26 to 37	25.7

3.5.4 Calculations for Shallow Wound Activity (contd)

The basic method of calculation by hand is:

$$\text{activity in wound in nCi} = \frac{A - B}{C - B} \times D \quad (3.8)$$

where A = counts/min in wound
 B = background counts/min
 C = counts/min in source
 D = source strength in nCi

The detection level calculation is:

$$\text{MDA} = \frac{A}{B - C} \times D \quad (3.9)$$

where $A = 3 \sqrt{\frac{\text{background}}{\text{min}}}$

B = counts/min in source
 C = background counts/min
 D = source strength in nCi

The calculation of plutonium-239 with the correction for americium-241 is:

$$\text{nCi } ^{239}\text{Pu in wound} = \frac{A - B \left(\frac{C}{E} \right)}{D} \times F \quad (3.10)$$

where A = net counts/min in channels 26 to 37 for wound
 B = counts/min in channels 117 to 121 for wound
 C = counts/min in channels 26 to 37 for ²⁴¹Am source
 D = counts/min in channels 26 to 37 for ²³⁹Pu source
 E = counts/min in channels 117 to 121 for ²⁴¹Am source
 F = nCi in ²³⁹Pu source

The location of the activity is usually obvious from observation of the wound, but it always needs to be confirmed by placing a small (1/8-in.-diameter) lead disk over the suspected location to determine if all the activity is absorbed by the disk. If the wound is a long cut, a small lead slot collimator is useful in determining where the major portion of the activity is located.

3.6 IN VIVO MEASUREMENT OF RADIOACTIVITY IN THE THYROID

For a person with normal thyroid function, about 20% of any radioiodine incorporated into the body will be taken up by the 20- to 25-gram adult thyroid gland. Because of this relatively high concentration compared to other body tissues, the amount of iodine-131 in the thyroid is of the most interest. A single 3-in. X 3-in. NaI(Tl) detector or the large coaxial germanium detector is effective for measuring iodine-131 and two germanium planar detectors are the most effective for measuring iodine-125. Using these detectors, the minimum detectable amount in the thyroid is 20 pCi for iodine-131 in a 30-minute count and 3 pCi for iodine-125 in a 30-minute count.

3.6.1 Procedure for Energy Calibration of the Detectors for Thyroid Measurements

Calibrate the MCA so that each channel is equivalent to 10 keV for the iodine-131 measurement or 0.500 keV for the iodine-125 measurement. (See Section 4, Operation of Counting Equipment.)

Because of the short half-lives of iodine isotopes an efficiency check using iodine-125 and iodine-131 is not possible. The detectors used for this procedure have undergone efficiency checks for other radionuclides during other whole body counting procedures.

3.6.2 Procedure for Subject Measurement

Safety Precautions

- Have the subject lie on his back and place the detector(s) over the thyroid gland.
- When using the germanium planar detectors be sure that the liquid nitrogen in the detectors does not spill on the subject.
- Use care when placing the germanium planar detectors on the body, so that the thin beryllium windows are not broken. Breaking the beryllium windows could result in a minor implosion.

For an Iodine-131 Measurement

- Place the 3-in. x 3-in. NaI(Tl) detector on its side against the neck and centered between the clavicle bones (located at the base of the neck) and the thyroid cartilage, also known as the "Adams apple" (see Figure 3.11).

For an Iodine-125 Measurement

- Center the two germanium planar detectors close together on both sides of the verticle center line of the neck and in between the clavicle bones and the thyroid cartilage (see Figure 3.12).

FIGURE 3.11. Placement of Detector for an Iodine-131 Measurement of the Thyroid

FIGURE 3.12. Placement of Detectors for an Iodine-125 Measurement of the Thyroid

3.6.2 Procedure for Subject Measurement (contd)

Continuing Procedure for Both the Iodine-131 and -125 Measurements

- Angle the germanium planar detectors so that the end surface is parallel to the surface of the neck.

- Instruct the subject not to move and to keep his throat in contact with the detectors.
- Describe the use of the emergency button and the self-exit procedures.
- Close the shielded room door.

Taking the Thyroid Count

- Start the count.
- Count for preset time (usually 2000 seconds).
- Assist the subject from the counter.

When the Count is Finished

- Remind the subject to watch his step upon exiting the shielded room.

3.6.3 Background Correction

The background of an uncontaminated person is subtracted from the subject counts for the iodine-131 measurement.^(a) For the iodine-125 measurement, the background is subtracted using the 12-channel continuum method above the photopeak or the 11-point smoothing method (Spitz et al. 1984).

- (a) The net count for the iodine-131 measurement can be determined without a background count using the following equation:

$$\text{net count/min} = \frac{A - B}{C}$$

where A = counts/min in channels 33 to 39

$$B = 3.5 \left(\frac{\text{counts in channels 31} + 32}{2} + \frac{\text{counts in channels 41} + 42 + 43}{3} \right)$$

C = counting time in minutes

3.6.4 Calculations for Thyroid Activity

For Iodine-131

The computer is programmed to provide calculations for iodine-131 in the thyroid using the calibration factors listed below for a 3-in. x 3-in. NaI(Tl) detector.

Channel Group Used	Counts/min-nCi
33 to 39	130

The equation for the calculation is:

$$nCi \text{ of iodine-131} = \frac{\text{net counts/min}}{\text{counts/min-nCi}} \quad (3.11)$$

If other interfering radionuclides are present in the body a 35% Ge(Li) detector may be used in the same way as the 3-in. x 3-in. NaI(Tl) detector. The side of the detector is placed on the neck with the centerline of the throat at 2-1/4 in. from the end of the detector endcap. The calibration factor for the 35% Ge(Li) detector is 33.4 counts/min/nCi of iodine-131 in the thyroid.

For Iodine-125

The computer is programmed to provide calculations for the iodine-125 content in the thyroid using the calibration factor below.

Channel Group Used	Counts/min/nCi
54 to 56	159

The equation for the calculation is:

$$nCi \text{ of iodine-125} = \frac{\text{net counts/min}}{\text{counts/min/nCi}} \quad (3.12)$$

100-100000-100

100-100000-100

100-100000-100

100-100000-100

100-100000-100

100-100000-100

100-100000-100

100-100000-100

100-100000-100

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100-100000-100

3.7 IN VIVO MEASUREMENT OF TRANSURANIC NUCLIDES IN AXILLARY LYMPH NODES

Small insoluble particles of transuranic nuclide contamination that enter the lymphatic system through contaminated wounds can become filtered out in the axillary lymph nodes located in the area of the armpit. This activity can remain in the lymph node area for long periods of time.

A single germanium planar detector placed in the region of the armpit over the location of the axillary lymph nodes is used to measure this activity. Determining the location and depth of the nodes is difficult.

3.7.1 Procedure for Energy Calibration of the Germanium Planar Detector

Calibrate an MCA connected to a germanium planar detector so that each channel is equivalent to 0.500 keV. Refer to Section 4, Operation of Counting Equipment and the data sheet in Figure 3.13.

3.7.2 Procedure for Subject Measurement and Efficiency Calibration

- Have the subject lie on his back with the arm having the suspected contaminated lymph nodes raised up so the hand rests above his head (see Figure 3.14).
- If the wound is still contaminated, shield it with a lead sheet to absorb the radioactivity.
- Place the detector in contact with skin at the location shown in Figure 3.14.

Data Sheet for Lymph Count

keV per channel	<u>0.5</u>
# of detectors	<u>1</u>
Detector code	<u>J1</u>
Body location code	<u>08</u>
# of channels	<u>512</u>
Routine count length, sec	<u>2000</u>
Background length, sec	<u>NA</u>
Source used for calibration	<u>241 Am + enriched U</u>
Source count used /length	<u>241 Am Plexiglass jig,</u> <u>300 sec.</u>

FIGURE 3.13. Sample Data Sheet for Lymph Count

FIGURE 3.14. Proper Position of Detector for a Measurement of Radioactivity in the Axillary Lymph Node

3.7.2 Procedure for Subject Measurement and Efficiency Calibration (contd)

Efficiency Calibration

- Make several measurements at locations near the original location to determine the location giving the highest count rate.
- Determine the depth of the lymph nodes using the ratio of the various photopeaks if there is sufficient activity. If the depth cannot be determined, assume a depth of 2 centimeters.
- Obtain a standard source of the activity that is present in the lymph node (usually americium-241 or plutonium-239).
- Place the source under a thickness of tissue-equivalent CaCO_3 -loaded polyurethane that is the same as the estimated or assumed depth of the lymph node.
- With the detector in contact with the polyurethane plastic, measure the source activity for the same length of time as the lymph node count on the subject.

3.7.3 Background Correction

The background correction for the germanium planar detector is subtracted from all counts using the 12-channel continuum above the photopeak or 11-point smoothing method (Spitz et al. 1984).

3.7.4 Calculation of Axillary Lymph Node Activity

The activity in the axillary lymph nodes can be calculated manually using the following equation:

$$n\text{Ci of radionuclide} = \frac{A}{B} \times C \quad (3.13)$$

where A = net counts/min from the lymph node
B = net counts/min from the standard source
C = nCi in source

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3.8 IN VIVO MEASUREMENT OF TRANSURANIC NUCLIDES IN TRACHEOBRONCHIAL LYMPH NODES

Radioactivity in the tracheobronchial lymph nodes is difficult to detect and quantify because it is not easily distinguishable from lung-deposited activity. However, if a significant measurable fraction does exist in these lymph nodes, it can be detected and roughly quantified by making lateral scans of a cross section of both lung and tracheobronchial lymph nodes. This in vivo measurement method is still under development.

This measurement is done by using a collimated set of 2 germanium planar detectors shown in Figure 3.15. The slot collimator shown in Figure 3.16 extends 2 inches below the face of the detectors.

Figure 3.17 shows the response of such a scan with different fractions of americium-241 in the lymph nodes and lungs. Figure 3.17 also depicts the scan of a Hanford Site employee with americium-241 only in the lung.

FIGURE 3.15. Two Germanium Planar Detectors Used to Measure the Tracheobronchial Lymph Nodes

FIGURE 3.16. A Slot Collimator Which Extends Two Inches Below the Face of the Two Detectors Used to Measure the Tracheobronchial Lymph Nodes

FIGURE 3.17. Posterior Lateral Scan of Activity in the Lungs and the Tracheobronchial Lymph Nodes (LN)

3.9 IN VIVO MEASUREMENT OF RADIOACTIVITY USING A LINEAR SCAN

When the activity is not evenly distributed within the body, knowing the location of the activity can be of help to the Internal Dosimetry Group. Rough estimates of the locations of activity can be made by a rapid measurement in the preview whole body counter. For more precise location information the linear scan system must be used.

A collimated 4-in. x 4-in. x 16-in. NaI detector scanning from below the body is used to determine the location of the activity using a longitudinal scan of the body. The linear scanner is shown in Figures 3.18 and 3.19. The system uses a single-channel analyzer (SCA) to select a portion of the energy spectrum to better discriminate against background or even separate the location of one nuclide from another providing the nuclides have sufficiently separate characteristic energy peaks.

3.9.1 Procedure for Calibration of the Linear Scan Detector

- If possible set up the system using a source of the same nuclide as that observed in the subject. If such a source is not available, use the activity in the person.
- First the analyzer is set in the multichannel analyze mode; the SCA's output controls a linear gate that selects only a specific energy region output of the main amplifier. The resulting spectra on the MCA show exactly what energy region has been selected by the SCA as input to the multichannel scale mode.
- Observe the spectra on the MCA.
- Keep the calibration source on the detector and set the threshold and window settings of the SCA to select the major characteristic peak of the nuclide of interest.
- If more than one nuclide is present more sensitivity can be gained by using both peaks or all of the major peaks of interest.
- Switch the analyzer to the multichannel scale mode (MCS) to count the subject.
- Only the mode switch needs to be changed to the MCS mode since the analyzer has separate input ports for MCA and MCS functions.
- Now the same pulse that triggered the linear gate is fed to the analyzer in the MCS mode. This pulse is the output of the SCA and produces a square

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FIGURE 3.18. Subject Being Measured with the Linear Scan System
(the detector scan from below the subject's body)

FIGURE 3.19. Components of Linear Scan System

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3.9.1 Procedure for Calibration of the Linear Scan Detector

(contd)

(monoenergetic) pulse for each pulse from the detector that meets the energy range restrictions specified by the SCA.

3.9.2 Procedure for Subject Measurement

- Position the subject on the bed centered and about 6 in. from the top of the bed. This position should place the collimator slit at about the top of the head for starting position.
- Position the collimator carriage to the top of the bed position. The carriage has only one speed and is powered only in a head-to-toe direction sweep.
- To move the carriage lift the handle that holds the gear and motor assembly until the gear is disengaged from the rack (geared teeth) bolted to the floor.
- Push the following three switches at about the same time to start the analyzer counting and the detector moving at the same time: 1) the acquire button on analyzer, 2) the MCS start button, and 3) the collimator carriage drive start switch.
- Keep calibration source handy but out of the room except when the collimator slit is at the top of the head.
- When the collimator slit is at the top of the head and the count has begun, touch the calibration source to the detector end momentarily, then remove the source from the room.
- Touch the source on the detector end again when the scan is nearly complete and the bottom of the feet are even with the collimator. Other positions of interest such as liver or bone joints may be marked during the count by momentarily touching the source on the detector.
- Stop the carriage by pushing the red carriage stop switch, or let the carriage stop microswitch activate automatically when it reaches the far end.
- Print out the spectrum and label it.
- Plot the spectrum or study the analyzer display and refer to the following section for interpretation.

3.9.3 Calculations for Activity Detected with the Linear Scan

The spectrum should clearly show a peak at each end. The peak on the left of the spectrum represents the head position when the collimator slit was above the head and the source was touched to the detector. The peak at the right of the spectrum represents the foot position when the collimator slit was at the end of the feet and the source was touched to the detector.

By calculating the number of channels between the peaks and dividing the subject's height in centimeters by the number of channels between the calibration peaks and entering this number as the keV per channel value as input data to plot the spectrum, a means of referencing activity to distance from the top of the head in centimeters is obtained.

3.9.4 Alternate Modes of Use

This system can be operated in two different modes depending on the time allowed and the precision desired. The normal longitudinal count is about 15 minutes; the movement of the collimated detector is motorized and the analyzer is operated in the MCS mode.

Resolution and sensitivity can be increased by varying the slit width of the collimator, by manually moving the detector carriage to increase the dwell per position, and by leaving the carriage stationary during each counting period. In this mode each position merits having the whole spectrum saved for each location counted.

Although the manual scan method is more versatile in the types of information to be gained, it also takes more time during analysis than continuous movement of the MCS mode. The MCS mode produces a histogram of relative activity versus location and can be stored or plotted by normal spectrum-handling routines.

3.10 DETERMINING CHEST WALL THICKNESS BY ULTRASOUND

The chest wall thickness among adult males varies between 2 and 4 cm. The variation among women is even greater. Since the half thickness (half value layer) for 17-keV x-rays in muscle and fat tissue is about 7 mm, it is essential that the chest wall thickness be measured. In addition, a thicker chest wall causes the detectors to be located at a greater distance from the lungs which also results in a reduced count rate. The chest wall thickness can be measured within ± 1 mm using ultrasound equipment designed for this purpose.

3.10.1 Procedure for Determining Chest Wall Thickness

Required Supplies

- 2 bottles aquasonic transmission gel
- 3 packages Polaroid Film Type 107
- 3 bath towels
- template for 6 intrinsic germanium detector configuration (Figure 3.20)
- washable felt tip marker

Prior to Ultrasound Measurement

Preliminary adjustments for optimum clearness and machine calibration should be performed before an ultrasound measurement is taken. Refer to the routine settings listed on the machine and allow a 5-minute warmup.

FIGURE 3.20. Template Configuration

3.10.1 Procedure for Determining Chest Wall Thickness (contd)

Subject Preparation

- Place towel on recliner where subject will lie.
- Take special precautions to ensure the subject's privacy during this measurement.
- Instruct the subject to remove all clothing above the waist.
- Place one bath towel from the lower breast area down to the waist.
- Inform the subject that removable ink marks will be drawn on the chest to simulate the actual detector placement of the 6 intrinsic germanium detectors used for the in vivo lung exam.
- Position the edge of the template which has cut outs simulating the actual placement of the detectors in line with the subject's clavicle.
- Insert marker into the cut-out slots of the template and lightly draw all 12 vertical lines while holding the template in place (Figure 3.21).
- Remove the template.
- Inform the subject that the ultrasound transmission gel will be slightly cool when applied to the skin.
- Slowly squeeze gel and apply approximately 1/8-in.-thick to all drawn vertical lines. Apply the gel slowly to eliminate excessive air bubbles in the gel and for even application.

Taking the Measurement

- On the ultrasound keyboard, key in the current date, 2 spaces, subject's payroll number, 2 spaces, and the position number you wish to ultrasound first.
- Slowly apply approximately 1/8 in. of gel to the ultrasound probe.
- Lightly place the probe in contact with the gel on the subject's chest.
- Carefully adjust the controls on the ultrasound unit until a well defined interface is displayed on the screen. The probe may need to be rocked slightly back and forth to obtain a good interface (Figure 3.22).

FIGURE 3.21. Using the Template to Draw the Lines That Indicate Ultrasound Probe Placement

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FIGURE 3.22. Positioning the Ultrasound Probe to Obtain a Good Interface with the Subject's Chest

3.10.1 Procedure for Determining Chest Wall Thickness (contd)

- Make sure the probe is in the proper position before taking a polaroid picture.
- Remove the photograph and set it aside for at least one minute for development.
- Erase the old position number on the screen by using the red clear (CL) key.
- Enter the next ultrasound position on the screen.
- Apply more gel to the probe, carefully position the probe and photograph the next interface.
- Separate the photograph from the developer after 60 seconds.
- Repeat the process until all 12 positions have been recorded on photographs.
- Examine developed photos closely to determine if any positions require retakes.
- Use the third towel to remove the excess gel from the subject's chest.
- Subject may return to the main lobby of the WBC.
- Using calipers, determine and record the actual chest wall thickness for each position on the Ultrasound Measurement forms (Exhibit 3.1).
- Add all 12 positions and divide the total by 12 for an average thickness in centimeters.

After Ultrasound
Measurements Have
Been Taken

3.11 IN VIVO COUNTING FOR CRITICALITY ACCIDENTS

The exposure of workers to neutrons will result in induced radioactivity in the body from the activation of the major elements of body composition such as calcium, nitrogen, sodium, chlorine, etc.

A neutron dose of 20 mrad of fission spectra neutrons will produce approximately 10 nCi of sodium-24 in the body. Immediately after exposure calcium-49, sodium-24, chlorine-38, aluminum-28 and nitrogen-13 are easily measured, but because of the short half-lives, only sodium-24 is measurable by the time the worker is transported to the whole body counter. The assessment of sodium-24 in workers exposed to neutrons from a criticality accident provides a means of estimating the neutron dose.

After all the gamma ray emitters have decayed away in an exposed person, measurements of bremsstrahlung radiation from phosphorous-32 in the bone may give information on which portions of the body received the highest dose. Details of the bremsstrahlung measurements are not given in this procedure.

3.11.1 Procedure for Energy and Efficiency Calibration

- Use a cesium-137 and a potassium-40 source for an energy calibration of the MCA.
- Adjust MCA until each channel is equivalent to 20 keV.
- Use the standard potassium-40 source and geometry to confirm that the counting efficiency is unchanged.
- Calibration details for determining the sodium-24 content are located in the Whole Body Counter Laboratory Notebook #1, (11/11/59) HWN-2454, pages 134-135, assigned to the WBC manager.

3.11.2 Procedure for Measuring Activity Resulting from Criticality Accidents

Since the level of sodium in the body of the worker exposed to a criticality event may be relatively high, the procedure used to evaluate the amount will depend on the quantity present.

Low levels can be quickly assessed by the preview whole body counter (measurement procedure described in Section 3.1), which will automatically calculate the results. For a more precise assessment, or for levels that exceed the preview counter's capacity, follow the procedure below.

3.11.2 Procedure for Measuring Activity Resulting from Criticality Accidents (contd)

If Body Burden is
Greater than 5 μCi

Taking the Count

- Take the measurement in the lead room using the tilted chair geometry with the 4-in. x 9 3/8-in. NaI(Tl) detector in the normal position.
- See Figure 3.23 for chair and detector positioning.
- Determine the amount with the detector in the normal position at the distance shown in Figure 3.23.
- Close the lead room door
- Start the count with preset time at 5 or 10 minutes.
- Observe the MCA display to determine whether the count will overscale.
- If analyzer indications suggest that it will overscale before the count is finished, stop the count.
- Raise the detectors up to the distances shown in Figure 3.24 and begin counting again.
- Count for 1 to 10 minutes, depending on the level of activity.

3.11.3 Background Correction

The background is subtracted using a previously determined background or appropriate fraction of a long background count done with an uncontaminated person sitting in the chair. If the alternate position was used (detector raised), a background count with the detector in the same position should be used for the precise calculation of the background.

FIGURE 3.23. Detector in Normal Position

3.11.3 Background Correction (contd)

By the time the exposed person arrives at the WBC, all interfering radionuclides will usually have decayed away.

3.11.4 Calculations of Activity

Calculating the Sodium-24 body burden

The calibration factor for determining the body burden of sodium-24 using a 4-in. x 9 3/8-in. NaI(Tl) detector in the normal chair position (shown in Figure 3.23) is 6522 counts per minute per μCi . The counts per minute are determined from the 2.75-MeV peak using channels 128 to 143 inclusive. Equation (3.14) determines the total body content of sodium-24.

$$\mu\text{Ci of } ^{24}\text{Na in the body} = \frac{\text{net counts/min}}{6522} \quad (3.14)$$

The calibration factor for the detector in the raised position (Figure 3.24) is ____ (factor to be determined).

Calculating the Neutron Dose

The average total-body fast neutron dose calculated from total-body sodium-24 measurements is shown (Hanford Laboratories 1963; Harris 1961):

$$\text{dose in rads} = \frac{^{24}\text{Na activity in } \mu\text{Ci}}{\text{weight of subject in kg}} \times 226 \quad (3.15)$$

FIGURE 3.24. Detector in Raised Position

FIGURE 1. Schematic diagram of the experimental setup.

FIGURE 2. Schematic diagram of the experimental setup.

The subject was seated at a distance of 100 cm from the target. The viewing device was positioned such that the subject's line of sight was directed at the center of the target. The target was a circular object with a central dot. The subject's line of sight was indicated by a line passing through the center of the viewing device and the target. The entire setup was mounted on a base.

FIGURE 3. Schematic diagram of the experimental setup.

The subject was seated at a distance of 100 cm from the target. The viewing device was positioned such that the subject's line of sight was directed at the center of the target. The target was a circular object with a central dot. The subject's line of sight was indicated by a line passing through the center of the viewing device and the target. The entire setup was mounted on a base.

FIGURE 4. Schematic diagram of the experimental setup.

The subject was seated at a distance of 100 cm from the target. The viewing device was positioned such that the subject's line of sight was directed at the center of the target. The target was a circular object with a central dot. The subject's line of sight was indicated by a line passing through the center of the viewing device and the target. The entire setup was mounted on a base.

3.12 IDENTIFICATION OF UNKNOWN RADIONUCLIDES

Most of the radioactivity found in the Hanford employees is easily identified because it has been observed many times before. Occasionally a radionuclide is observed which is not immediately identified. This usually occurs as a result of a radiopharmaceutical that has been given to the person as part of a diagnostic nuclear medical procedure at a hospital or a new process or procedure being used at Hanford.

3.12.1 Procedure to Identify Unknown Radionuclides

- Use the germanium planar detectors at the WBC to determine the exact energy of unknown radionuclides.
- Determine the exact energy of all the unknown photopeaks in the spectrum. Remember that more than one radionuclide may be present.
- Observe the relative heights of the various photopeaks.
- Refer to Slater (1962), and note radionuclides with gamma-ray energies corresponding to those in the spectrum from the contaminated subject.
- Keep in mind that the radionuclides with a half-life of 1 day or less are not usually present unless they are a daughter of a long-lived parent.
- Select one or two possible radionuclides.
- Go to the spectra catalogues in the library and compare the spectrum from the body with that in the catalogue, taking in consideration that absorption occurs in the body at lower energies. The photopeak energy in conjunction with radionuclide gamma ray energy tables and gamma ray spectra catalogues usually provide all the information needed to identify any unusual radionuclides.
- If the presence of a radiopharmaceutical is detected, notify the Internal Dosimetry Group of this nonoccupational exposure.

The following information was obtained from the records of the Department of the Interior, Bureau of Land Management, regarding the land owned by the United States in the State of California.

The land is located in the County of San Diego, State of California, and is situated in the Township of San Diego, Range 12 North, and Section 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

UNITED STATES DEPARTMENT OF THE INTERIOR

The following information was obtained from the records of the Department of the Interior, Bureau of Land Management, regarding the land owned by the United States in the State of California.

The land is located in the County of San Diego, State of California, and is situated in the Township of San Diego, Range 12 North, and Section 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

3.13 REFERENCES

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EXHIBIT 3.1. Ultrasound Measurement Form

Name: _____ Date: _____

Payroll No: _____ Height: _____ Weight: _____

Comments: _____

ULTRASOUND POSITIONS

Position 1: _____ Position 2: _____ Position 3: _____

Position 4: _____ Position 5: _____ Position 6: _____

Position 7: _____ Position 8: _____ Position 9: _____

Position 10: _____ Position 11: _____ Position 12: _____

Total of all 12 Positions = _____

Divided by 12 = _____

Chest Wall Thickness in centimeters

NOTE: Configuration is for six intrinsic germanium detectors

3-19-84

4.0 OPERATION OF COUNTING EQUIPMENT

This section describes the operation and maintenance of the WBC counting equipment which consists of detectors, preamplifiers, amplifiers, and multichannel analyzers (MCAs).

4.1 DETECTORS

In Section 2 the detectors were briefly described. In this section, the operation, construction, maintenance, and repair of the detectors will be discussed.

4.1.1 Detector Types

The two types of detectors used in the WBC are the scintillation and semiconductors. Both types of detectors require very little maintenance but require close observation to detect any malfunction.

High Voltage Required

High voltage is required for the operation of both types of detectors. The scintillation detectors require positive high voltage, typically 800 to 1200 V; the semiconductor detectors require 2000 to 5000 V of positive or negative voltage, depending on the type of semiconductor detector.

CAUTION

High voltage can be very dangerous. The detectors must be turned off and disconnected whenever they are being moved or repaired.

4.1.2 Detector Hookup Design

The scintillation detectors are connected to the high voltage supply and signal processing instrumentation as shown in Figure 4.1.

FIGURE 4.1. Schematic of a Scintillation Detector

4.1.2 Detector Hookup Design (contd)

The semiconductor detectors are connected to the high voltage and signal processing instrumentation as shown in Figure 4.2.

FIGURE 4.2. Schematic of a Semiconductor Detector

4.1.3 Detector Maintenance and Repair

Semiconductor Detectors

The only maintenance required for the semiconductor detectors is keeping them cooled with liquid nitrogen. All repairs on these detectors must be done by the manufacturer.

Scintillation Detectors

The NaI(Tl) scintillation detectors operate at room temperature and require only minimal maintenance. This maintenance includes balancing the photomultiplier tubes every 6 months and replacing the optical coupling compound between the photomultiplier tubes and the detector windows every 2 or 3 years as needed. Deterioration of the detector resolution would result from the imbalance of photomultiplier tubes and hardened coupling compound.

The replacement of the optical coupling can be performed by the instrument technician assigned to WBC. The balancing of the photomultiplier tubes is done by the WBC technicians.

The procedure for balancing the photomultiplier tubes in the scintillation detector is:

- Center a cesium-137 source at least 12 inches from the face of the detector.
- Disconnect all high voltage leads from the photomultiplier tubes.

4.1.3 Detector Maintenance and Repair (contd)

- Number the tubes 1 through the total number used on the detector.
- Connect high voltage lead to tube #1, accumulate spectra for 1 minute and note peak channel number.
- Repeat the previous step for all other photomultiplier tubes with high voltage connected to only one tube at a time.

CAUTION

- High voltage power supply must be turned off while connecting or disconnecting the high voltage lead.
- Determine which photomultiplier has the lowest gain by noting which one gives a photopeak in the lowest channel.
- Turn the gain potentiometer to the right to determine if the gain can be increased.
- If possible, adjust the gain so that the peak falls in about the same channel as the majority of the other tubes.
- If the adjustment is already at the maximum position, reduce the gain on all the other tubes until they all produce the peak in the same channel as the low gain tube.
- Connect high voltage to all the tubes and the balancing is complete.
- Check resolution.

4.1.4 Determination of Detector Resolution

A scintillation detector's performance is typically stated as a value of pulse height resolution, full width at half maximum (FWHM), for a particular gamma-ray peak.

Although any gamma line may be used, the most usual specified value is for the 662-keV gamma ray from cesium-137. With the source at least 12 inches away from the center face of the detector, accumulate counts until there are at least 5000 counts in the peak channel. Avoid high counting rates that will result in a "dead time" which exceeds 25% on the MCA.

From the resulting spectrum, calculate the resolution by dividing the peak channel into the number of channels comprising the upper half of the peak (see Equation 4.1 and

4.1.4 Determination of Detector Resolution (contd)

Figure 4.3). Resolution values for the large NaI(Tl) detectors should be in the range of 8% to 9% for the 662-keV gamma ray.

$$\text{resolution} = \frac{\text{channel C} - \text{channel A} \times 100}{\text{channel B}} \quad (4.1)$$

FIGURE 4.3. Calculation of Detector Resolution

4.1.5 Diagnosing Detector Problems

Noise in a spectrum is generally defined as the extraneous events counted near the zero-energy end of the spectrum. In scintillation detectors it is nearly always a result of spontaneous emission from the photocathode of the photomultiplier tube and the tube may need to be removed.

It is acceptable for noise to occur in channels corresponding to 0 to 20 keV for the large detectors with multiple tubes. For the thin crystal detectors used for plutonium-239 counting, the acceptable noise level is 0 to 10 keV.

Noise can also appear as discrete peaks at high energies. If unidentified peaks appear in a spectrum that has a peak

4.1.5 Diagnosing Detector Problems (contd)

width narrower than a gamma peak of equal energy, it is certain to be the result of a malfunction of the electronic system. If the peak is the same width as a gamma ray line, look for unshielded sources near the detector.

4.2 PREAMPLIFIERS AND AMPLIFIERS

The section describes the operation of the preamplifiers and amplifiers.

4.2.1 Preamplifiers

The output from a detector is a small charge pulse. It is necessary to precondition the output so that it can be utilized in a linear amplifier system. The linear amplifier system in turn provides the necessary pulse shaping and amplification required for use with the measuring unit. A preamplifier is generally inserted immediately after the detector to provide integration of the charge output of the scintillation/photomultiplier detector or semiconductor detector.

The output of the preamplifier is connected to pulse-shaping main amplifiers. Impedance matching between the detector output and the pulse-shaping and amplifier stage that follow are provided by the preamplifier. Connecting the preamplifier as close to the detector as possible increases the signal-to-noise ratio.

For further details on the operating instruction, refer to the manuals for the specific preamplifiers that are located in the WBC library.

4.2.2 Amplifiers

Main Amplifier

The main amplifier further increases the signal from the preamplifier so that it can be used within the dynamic operating range of the system.

Linear Amplifier

Linear amplifiers are required to ensure that the relationship between the input and output signal is maintained.

To measure individual signals, independent of previous ones, the signal decay time must be reasonably short compared with the input repetition rate in order to reduce pulse pile-up distortion. In addition, to be proportional to the amplitude of the signal from the preamplifier (and therefore the charge from the detector) the duration of the output signals from the amplifier must be longer than the rise time of the input pulse.

4.2.2 Amplifiers (contd)

For further details on the operating instructions, refer to instruction manuals for the specific amplifiers, which are located in the WBC library.

4.3 SPECTROSCOPY EQUIPMENT: THE MULTICHANNEL ANALYZER

The MCA is the basic spectroscopy counting instrument used in the WBC. Because of the MCA's versatility and the facility of operation, it is often used in applications where a scaler or rate meter in combination with a single channel analyzer (SCA) might suffice.

MCA Operation

The MCA converts the pulse received from the amplifier into an equivalent digital number that is stored in memory location which most closely corresponds to the pulse amplitude. The processing time for each pulse is typically 100 μ sec.

Types of MCAs

There are ten different MCAs used at the WBC facilities representing five different models. These range from manually controlled devices to programmable microcomputer-controlled instruments capable of highly automated sequences.

Operation of MCAs

There are five basic steps that are necessary to properly set up and operate the MCAs. These steps are:

- Erase the selected memory.
- Start analyzer acquiring.
- Stop analyzer and be able to recognize that it has timed out.
- Display a portion of the spectrum in sufficient detail to be able to ascertain what channel represents the peak energy.
- Output the spectrum on some permanent medium such as paper tape or a printed page to be able to identify the channel number and the contents of that channel relatively easily.

These steps must be practiced by the WBC technicians until they can be done well. Improper execution of these functions will result in wasted time, unrealistic results, and may destroy valuable acquired data.

4.3.1 MCA Calibration

Before the MCA can be used for either quantitative or qualitative analysis, it must be calibrated to a standard energy scale of pulse height distribution. In other words, it must be adjusted so that each channel represents a predetermined energy range and that a plot of pulse heights versus channel number has a zero intercept.

There are two MCA parameters that can be changed which will allow the MCA to be calibrated for any range of radiation energy desired. The two parameters are gain (either amplifier- or MCA-conversion gain) and the zero-level offset adjustment.

Gain

When the gain is changed, the energy peaks shift to a channel position proportional to the change in gain. If two photopeaks were initially falling in channels 60 and 100, and the gain is doubled, the peaks would then fall in channels 120 and 200. Initially the peaks were separated by 40 channels but after the gain change the peak separation is 80 channels (see Figure 4.4).

FIGURE 4.4. Change in Peak Location with Conversion Gain

Zero Level

In the case of the zero level offset adjustment, the two peaks would shift the same number of channels (see Figure 4.5), and the number of channels between the peaks remain the same. With these two adjustments, the MCA can be calibrated for any energy region or range desired.

Example

As an example for calibration, assume that a setup for an MCA to measure low-energy photons ranging from 0 to 256 keV at 0.5 keV per channel with a zero intercept is desired.

FIGURE 4.5. Change in Peak Location with Zero Level Offset Adjustment

4.3.1 MCA Calibration (contd)

This can be done by using an americium-241 source which emits a 59.5-keV gamma ray and a uranium-235 source which emits a 185.5-keV gamma ray. To calibrate the MCA at 0.5 keV per channel, the 59.5-keV peak needs to center in channel 119 and the 185.5-keV peak needs to center in channel 371.

4.3.2 Example of Adjustment

What change should be made if the 59.5-keV peak falls in channel 126 and the 183.5-keV peak falls in channel 384?

When properly calibrated, the number of channels between the peaks should be 371 minus 119, or 252. In the above situation there are 384 minus 126, or 258 channels. Since there are 6 channels too many between the peaks the first step would be to reduce the gain until 252 channels exist between the peaks. We can reduce the gain until the 185.5-keV peak is in channel 375 and the 59.9-keV peak is in channel 123.

At this point there are 252 channels between the peaks, which is the number desired, but both peaks are 4 channels higher than what is needed. The next step is to change the zero level offset so that the spectrum shifts down by 4 channels and the energy calibration is then complete when the peaks fall in channels 119 and 371.

Some final, very small adjustment in gain or lower level offset may be necessary so that the 2 peaks are precisely centered in the appropriate channel.

5.0 QUALITY ASSURANCE

Whole body counting results are a very important part of an employee's documented work history. The WBC operations must conduct all work with the highest standard of quality commensurate with the requirements of internal dosimetry; cost; employees' time, safety, and comfort; and availability of equipment.

The quality assurance procedures are included in each of the measurement procedures described in Section 3; a summary of the overall quality assurance program as it relates to quality results is presented in this section. All WBC measurements are performed according to Quality Assurance Plan No. O&EP, Revision 4, dated September 11, 1986. This Quality Assurance Plan is included in Appendix B.

5.1 EQUIPMENT CALIBRATION

Two types of basic calibrations--an energy calibration and an efficiency calibration--are made every time the equipment is used, or at least once a day for equipment in daily use.

5.1.1 Energy Calibration

Since all of the measurements are derived from energy spectra, the instrumentation and detectors must be calibrated for energy response so that a unit of energy of the output is exactly proportional to the energy of the radiation detected. At least two points on the energy spectrum, widely separated in energy, are needed for an energy calibration.

For example, the whole body counter is usually calibrated at 20 keV of gamma ray energy per channel of data output, whereas the lung counter is usually calibrated at 0.5 keV per channel.

5.1.2 Efficiency Calibration

After the detectors and instrumentation are calibrated for energy response, they are then calibrated for the primary efficiency response by measuring a National Bureau of Standards (NBS)-traceable, known quantity of a radio-nuclide in a phantom or organ as described in Section 3.

Daily Calibration Checks

The daily check of the efficiency is done with secondary reference sources that have long half-lives and that were measured for standard length of time in a reproducible geometry with respect to the detector at the time of the efficiency calibration. These secondary sources are

5.1.2 Efficiency Calibration (contd)

contained in a matrix which does not change with aging so the geometry or the self-absorption of the source does not change.

A daily measurement of the background is also made. The daily efficiency count and the daily background are stored as retrievable computer data that are dated and accompany the employee measurement spectra data for that day.

If either of the daily efficiency check or background measurement do not fall within the expected limits of variance, the cause must be determined and eliminated before whole body counts are done. If the cause is a malfunctioning detector which must be replaced, a primary efficiency calibration with a phantom may be necessary.

The individual components of the measuring system such as detectors, amplifiers, high voltage supplies, and MCAs are not checked individually for sensitivity or linearity performance unless the total system fails to produce the proper count rate when measuring the standard reference source. If the count rate does not fall within acceptable limits of variability, the failing component is traced and replaced or repaired. Table 5.1 lists the quality assurance checks performed on each counting system.

Quarterly Calibration Checks

At quarterly intervals, the daily background and source efficiency counts are listed, the standard deviations

TABLE 5.1. Summary of Quality Assurance Checks for Counting Systems

<u>Counting System</u>	<u>Frequency of QA Check</u>	<u>Balance Multiple Detectors</u>	<u>Energy Calibration</u>	<u>Secondary Efficiency Calibration</u>	<u>Background-Interval</u>
Preview counter	Daily	Yes	Yes	Yes	Yes-1000 sec
Germanium array lung counter	Daily	Yes	Yes	Yes	Yes-1000 sec
Shadow shield counter	Each use	Yes	Yes	Yes	Yes-10 min
Wound counter	Each use	NA ^(a)	Yes	Yes	Yes-600 sec
Head and liver counter	Each use	Yes	Yes	Yes	NA ^(a)

(a) NA = not applicable

5.1.2 Efficiency Calibration (contd)

calculated, and the listing reviewed for any trends that indicate changes in detector or instrumentation response that need attention. All measurements, whether absolute or relative, are referenced to an NBS-traceable radioactive source measured in a fixed reproducible position.

Frequency of Primary Efficiency Calibrations

Primary efficiency calibrations are only done every 5 or 10 years. However, if the secondary reference source counts indicate a change in the counting efficiency, or if the detector size or resolution changes, or a different geometry is used, then the system must be recalibrated with a NBS-traceable radioactive source in a standard phantom.

5.2 WHOLE BODY COUNTER RECORDS QUALITY ASSURANCE

All WBC measurements must be documented and stored for one year at the WBC. The documentation must be prepared with sufficient detail so that someone skilled in the work can reconstruct the calculation and confirm that energy and efficiency calibrations were performed and maintained on that day.

Fortunately, the natural potassium-40 existing in the body of every person acts as an internal standard of identification of any shifts in energy calibration and also gives a rough indication that the counting efficiency was satisfactory. Only the WBC final results are sent to Radiation Records for permanent record storage.

Records from the balancing of multiple detectors and energy calibration are not kept. The data from the efficiency calibration checks and the background are observed each day to note compliance with established good performance and then stored in the computer each day of its use.

Each quarter these data are listed on hard copy output that is placed in a notebook. These notebooks are located in the library. The data are studied for any trends that might indicate instrumentation or detector problems.

The resolution of detectors is not checked on a daily basis. Any significant change in resolution will result in a loss of counting efficiency and therefore will be discovered during the source count. Periodic checks of resolution and balancing of photomultiplier tubes on detectors with multiple photomultiplier tubes will be done every 6 months for each detector used for in vivo counting. These checks provide valuable information on degradation trends in the detectors.

6.0 WHOLE BODY COUNTER DATA PROCESSING

The WBC facility utilizes a computer for most data processing functions. The following is a list of the eight general functions of the WBC computer:

- reduction of spectra from different sources into a standard format
- combination of descriptive alphanumeric information with the spectra into an easily retrievable record on a data base
- rapid calculation of results and storage of the results on the data base record
- comparison of the alphanumeric record with previously stored records to verify the accuracy of the alphanumeric record
- quick retrieval of records for recalculation
- plotting, printing, or summing of the regions of interest and tabulating results for additional analysis of single or grouped data
- transmission of data to a larger computer for reporting results to the field and permanent storage by records facilities or groups
- derivation of count information for cost accounting: number of counts, count type, and company statistics.

A detailed description of the data processing programs is included in two reports located in the WBC Library: "Whole Body Counter Computer Programming Notes HP 9000/550 Executive Program,"^(a) and "Whole Body Counter Computer Systems Programmers Guide."^(b)

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- (a) PNL internal report by D. M. Nieuwsma prepared for the Whole Body Counter facility, December 6, 1985.
 - (b) PNL internal report by K. K. Johnson prepared for the Whole Body Counter facility, May 28, 1986.

6.1 DATA SOURCES AND FORMAT

Each measurement or "count" done at the WBC represents a spectrum or histogram of the number of events versus the energy as detected by a given detector in a given geometry.

The multichannel analyzers (MCAs) that collect this information are from various manufacturers; therefore, the MCA information output can vary greatly in terms of the headers, the number of bits per word, parity, and other parameters. Spectra can also be entered manually, from magnetic tape, or through links to other computers. Input programs convert data to a uniform format so that all the data, whatever the source, may be handled by the same series of programs.

6.2 RECORD STORAGE

All spectra are assigned a unique serial number and if available, combined with descriptive alphanumeric information. The combination of a spectrum, alphanumeric descriptors, and the calculated results becomes a record that is stored in the computer's data base.

This data base can now be accessed by many different programs to plot, print, calculate, or do any number of statistical analyses. The descriptive information can be verified against previous entries in master files to assure the accuracy of social security numbers, payroll numbers, names, and initials. These data are essential for making results available to authorized parties.

Presently, the results from completed records are sent on the occupational radiation exposure (ORE) data base in a batch mode on about a weekly cycle.

6.3 SUPPORTING PROCESSING FUNCTIONS

Calibration spectra are analyzed to develop factors used by the calculational programs. Daily background and source count spectra are organized and analyzed for quality assurance purposes. Curvefitting and statistical programs reduce data to equations for easier use in computation or to indicate trends such as gradual loss of sensitivity or increases in background levels.

6.4 WEEKLY PROCESSING OF IN VIVO RESULTS

On a weekly basis, in vivo results, spectra, and supporting files are transferred from the "current" processing directory to a "past" directory. Once files have been moved, a rigorous checking routine is performed on the results before a magnetic tape is generated containing the finalized record input to the ORE data base.

Calculations are produced for all non-DOE-contractor measurements, and supporting documentation is provided for all positive examinations or nonroutine requests (unusual exposures, field-evaluator requests, follow-ups). Quick-reference spectra logs which contain the name, date, body/detector code, spectra numbers, and summarized results are also verified for accuracy and appropriate editing of information is performed as required.

Once the thorough checking of supporting data is completed, the recorded results are written to magnetic tape. A detailed listing of all records to be entered to the ORE data base are printed. One copy is sent with the magnetic tape as confirmation for internal dosimetry records accountability with the ORE data base. Another copy is retained at the WBC for future reference.

The number of measurements written to magnetic tape categorized by individual contractor is stored in a permanent file to generate unit costs. Supporting files in the past directory are then deleted after sufficient magnetic backup tapes are produced.

Compiled results, listings, and tapes are given to the senior WBC technician for additional verification. Results are rechecked and then approved by the support staff before the magnetic tape containing the finalized results is delivered to the Radiation Records staff for entry to the ORE data base.

Non-DOE-contractor measurements are typed in a report format and then mailed to the designated company contact. Any data required for future reports are extracted from the weekly listing and the approved calculations are filed.

6.5 CHECKING RESULTS

After the results have been written to magnetic tape for submission to the ORE data base, visual record verification is performed. Results and other pertinent information are quickly scanned to assure that the proper calculation methods were used. Values calculated without computer automation are rechecked for accuracy.

6.5 CHECKING RESULTS (contd)

Whenever errors are discovered, the weekly tape is corrected before submission to the ORE data base. If any errors are detected after the tape is submitted, a letter of correction is sent to the Internal Dosimetry Group requesting that the record be revised and stating the reason for the required change. This letter should be addressed to Internal Dosimetry Specialist, and should contain the following information:

- Measurement identification (name, serial no., date, type, etc.)
- Correct result and data of correction
- Original result
- Reason for change
- Signature

6.6 WHOLE BODY COUNTER ANNUAL REPORT PREPARATION

The WBC manager prepares an annual report summarizing the activities of the routine counting program, research development, special studies, and improvements. The data for this report come from a log that is updated weekly. The following information is required for this document:

1. In Vivo Measurements During the Year (by individual contractor)

<u>Contractor</u>	<u>Whole Body Counts</u>	<u>Lung Counts</u>	<u>Thyroid</u>	<u>Wound</u>	<u>Other</u>	<u>Total</u>
-------------------	--------------------------	--------------------	----------------	--------------	--------------	--------------

2. Number of Incident Cases

3. Incident Case Classification

<u>Type of Count</u>	<u>< MDA</u>	<u>MDA to 10 nCi</u>	<u>>10 nCi</u>
Whole Body			
Lung			
Wound			
Total			

6.7 UNIT COST ACCOUNTING AND SUBMISSION OF CHARGES

Whole body counting charges for all contractors (DOE and non-DOE) are submitted on a monthly basis to PNL cost accounting.

Unit charges are designated by four categories:

Type 101 = Head and Lung Counts

Type 102 = Whole Body Counts

Type 103 = Special/Other Counts (thyroid, liver, wound, ultrasound, lymph, etc.)

Type 104 = Overtime.

Automatic summing of count types is performed by computer for a designated time period for whole body, lung, head, abdomen, knee, throat, hand, special, and other counts.

Summing of group charges into type 101 and type 103 categories is performed manually. Ultrasound, retrocalculations, and overtime charges are recorded in a log book and are then manually added to the final sums. One unit of overtime (type 104) is charged for every hour a technician works.

The final totals are submitted by category to PNL cost accounting by noon of the Thursday before the last Sunday of the month. Copies of the totals are also sent to the financial representative, section manager, and WBC manager. At the beginning of the fiscal year, the financial representative provides work orders for each contractor. The WBC manager is advised of any work order number changes.

Exhibits 6.1 and 6.2 contain examples of the computerized summation and derived cost submission.

Costs are recorded for each contractor on a separate summary from the monthly submission. The fiscal year end totals are given to the financial representative for addition verification. Examples of recorded totals are shown in Exhibits 6.3 and 6.4.

6.8 MONTHLY COUNT SUMMARIES

Daily count totals are recorded in five categories and summed at the end of the month. A letter report is generated from the WBC manager and is sent to the PNL Personnel Dosimetry section manager, the Internal Dosimetry group manager, Radiation Records manager and the DOE contact in Environment Safety and Health Division. An example of the monthly count summary is contained in Exhibit 6.5.

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EXHIBIT 6.1

WEEKLY STATISTICS FROM 5/9 TO 6/17/86

COMPANY	WBC	HEAD	CHEST	ABDOMEN	KNEE	THROAT	HAND	SPECIAL	OTHER	CO TOTAL	
PNL	93	2	23	0	0	0	0	0	0	118	
RHO	337	6	97	0	0	1	5	7	1	453	454 + 10.5 OT = 464.5
HEDL	62	0	39	0	0	1	0	0	0	102	
UNI	238	0	13	0	0	2	0	0	0	253	253 + 1 OT = 254
HEHF	0	0	0	0	0	0	0	0	0	0	
BCSR	1	0	0	0	0	0	0	0	0	1	
JAJ	35	0	0	0	0	0	0	0	0	35	
KAISER	25	0	0	0	0	0	0	0	0	25	
DOE	0	0	0	0	0	0	0	0	0	0	
JAJ SU	0	0	0	0	0	0	0	0	0	0	
EXXON	0	0	14	0	0	0	0	0	0	14	
NEC	0	0	0	0	0	0	0	0	0	0	UL = 1 RHO OT = 11.5 (10.5 RHO) (1 UNC)
WPPSS	0	0	0	0	0	0	0	0	0	0	
ALLIED	0	0	0	0	0	0	0	0	0	0	
PAC NU	2	0	0	0	0	0	0	0	0	2	
OTHERS	0	0	0	0	0	0	0	0	0	0	
TOTAL	793	8	186	0	0	4	5	7	1	1003	1004 + 10.5 OT = 1015.5

WEEKS SUMMED ABOVE INCLUDE

20 = 131 21 = 297 22 = 277 23 = 298

EXHIBIT 6.2

EXAMPLE OF A MONTHLY COST SUBMISSION FOR DOE- AND NON-DOE CONTRACTORS^(a)

WHOLE BODY COUNTER SMALL JOB CENTER
5-19-86 TO 6-17-86

SERVICER - 98039	: TOE 957	JOB TICKET # _____
		NUMBER OF IN VIVO COUNTS
<u>CONTRACTOR</u>	<u>COST CODE</u>	<u>101</u> <u>102</u> <u>103</u> <u>104^(b)</u>
PNL	D7H71 M05706	25 93
RHO	D7H71 C06107	103 337 14 10.5
HEOL	D7H71 A21499	39 62 1
UNC	D7H71 B26976	13 238 2 1
JAJ	D7H71 A66330	35
DOE	D7H71 M17701	
KEH	D7H71 C31916	25
BCS	D7H71 877513	1
HEHF	D7H71 B59203	
U.S. ECOLOGY	D7H71 M17707	
EXXON	D7H71 W01734	14
ALLIED NUCLEAR	D7H71 W05152	
PACIFIC NUCLEAR	D7H71 W05343	2
TELEDYNE WAH CHANG	D7H71 M08166	
PRECISION CASTING	D7H71 W05151	
	TOTALS	<u>194</u> <u>793</u> <u>17</u> <u>11.5</u>
		GRAND TOTAL = <u>1015.5</u>

(a) This is usually a computer-generated form. The numbers entered under the In Vivo Measurement Categories are usually handwritten.

(b) Overtime

EXHIBIT 6.3

FISCAL YEAR END TOTALS OF COSTS FOR ALL DOE AND NON-DOE CONTRACTORS^(a)

	<u>101 Lung and Head</u>	<u>102 WBC</u>	<u>103 Other</u>	<u>104 O.T.</u>	<u>Monthly Total</u>
8-19/9-20-85	189	858	3		1,050
7-15/8-16	160	776	5	4	945
6-24/7-12	95	453	2	16	566
5-17/6-21	157	806	7	2.5	972.5
4-22/5-17	172	693	4	18	887
3-22/4-19	174	729	6		909
2-11/3-22	208	922	5	9	1,144
2-8/1-14	162	621	5	1	789
12-17-84/1-11-85	110	471	4		585
11-12/12-14-84	184	762	9	7.5	962.5
10-15/11-12-84	160	690	26	3.75	879.75
9-15/10-12-84	<u>151</u>	<u>636</u>	<u>5</u>	<u>9.75</u>	<u>801.75</u>
	1922	8417	81	71.5	10,491.5

^(a) This is usually a handwritten form.

EXHIBIT 6.4

FISCAL YEAR END TOTAL COST FOR ONE CONTRACTOR^(a)

	<u>101</u> <u>Lung and Head</u>	<u>102</u> <u>WBC</u>	<u>103</u> <u>Other</u>	<u>104</u> <u>O.T.</u>	<u>Monthly</u> <u>Total</u>
8-19/9-20-85	28	77	1		106
7-15/8-16	17	87			104
6-24/7-12	14	57			71
5-17/6-21	26	116	2		144
4-22/5-17	33	87			120
3-22/4-19	27	105			132
2-11/3-22	38	129	1	0.5	168.5
2-8/1-14	38	102	2	1	143
12-17-84/1-11-85	27	75	3		105
11-12/12-14	26	116	4		146
10-15/11-12	11	106	5		122
9-15/10-12	<u>30</u>	<u>85</u>	<u>1</u>	<u>1.5</u>	<u>117.5</u>
	315	1,142	19	3	1,479

^(a) This is usually a handwritten form.

EXHIBIT 6.5

MONTHLY COUNT SUMMARY

Date May 16, 1986

To J. R. Houston

From H. E. Palmer

Subject In Vivo Count Summary for April 1986

JJ Jech
MJ Sula
File (2)
LB

Date	Whole Body	Add. Pos. Counts	Lung	Wound	Thyroid, Liver & Other Organs	Head	Daily Totals
04-01-86	29		8		1	1	39
04-02-86	34		8				42
04-03-86	28		11				39
04-04-86	31		4			3	38
04-07-86	29		12				41
04-08-86	27		12				39
04-09-86	35		13				48
04-10-86	33		11			2	46
04-11-86	20		2				22
04-14-86	36		11		1		48
04-15-86	30		10	1		2	43
04-16-86	35		12	6	2	2	57
04-17-86	39		13	2	2		56
04-18-86	27		6	1			34
04-21-86	45		6	1		1	53
04-22-86	24		11				35
04-23-86	29		8				37
04-24-86	25		12				37
04-25-86	19		4			1	24
04-28-86	42		9			1	52
04-29-86	33		11			1	45
04-30-86	33		10				43
Delayed Entry*	—	—	—	23	21	5	49
Totals	683		204	34	27	19	967

*Special measurements

hep/cb

cc: G. R. Yesberger - DOE

7.0 MINIMUM DETECTABLE AMOUNT, ACCURACY, AND PRECISION OF IN VIVO MEASUREMENTS

The statistical aspects of in vivo measurements, which are not as precise and as easily determined as those for measuring radioactive sources, are discussed in this section.

7.1 MINIMUM DETECTABLE AMOUNT

The value of the minimum detectable amount (MDA) indicates the ability of the WBC equipment to discern between the count rate from an internally deposited radionuclide and the count rate from the person if he were not internally contaminated.

Because of the variation in body size and shape in the general population, and the variable distribution of radioactivity within the body or organ, the MDA values are given for a uniform distribution in the body or organ for a "Reference Man" (ICRP 1975). The measurement sensitivity values will be less for thinner, smaller people and more for larger people because of differences in self-absorption.

Until the publication of this manual, the MDA values at the WBC were calculated as the equivalent to a count rate that is three times the standard deviation of the estimated background. This method did not give the same MDA that is recommended by Brodsky (1986), and the draft ANSI Standard N13.30 (1985) which uses 4.65 times the standard deviation of the background. This ANSI N13.30 method yields MDAs that are 55% higher than the values determined from 3 standard deviations.

For the measurements made with the germanium planar detectors, low-energy gamma, and x-rays above 25 keV, the photopeak can be visually observed on a plot of the spectrum when an amount equal to 3 standard deviations is present. The use of 4.65 standard deviation is very conservative for these measurements.

For measurements of x-rays below 25 keV with the germanium detectors and for high-energy gamma rays with the NaI(Tl) detectors, the MDA calculated by 4.65σ is probably more appropriate. The MDA values for various radionuclides in the body or organs measured at the WBC facilities are given in Tables 7.1, 7.2, and 7.3.

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TABLE 7.1. Accuracy and Sensitivity for In Vivo Measurements of Common Radionuclides Using Various Numbers of Germanium Planar Detectors

LOW ENERGY PHOTON EMITTERS							
$MDA^{(a)} = \frac{4.65 \sigma}{KT} + \frac{3}{KT}$							
Radionuclide	Photon Energy	Time, sec	Organ	Number of Detectors	95% Confidence MDA or Statistical Error, nCi	10^3 Precision, $^{(b)}$ %	10^3 Estimate of Body Shape and Size Error, %
^{239}Pu	59.5-keV ^{241}Am tag	2000	Lung	6	2.4	10	20
	with 15:1, ^{239}Pu :	2000	Liver	3	2.1	7	20
	^{241}Am ratio $^{(c)}$	3000	Bone	2	5.4	10	20
^{239}Pu	59.5-keV ^{241}Am tag	2000	Lung	6	0.9	10	20
	with 5:1, ^{239}Pu :	2000	Liver	3	0.7	7	20
	^{241}Am Ratio	3000	Bone	2	1.8	10	20
^{239}Pu	17.0- and 20.4-keV	2000	Lung	6	75	20	40
	x-rays from pure	2000	Liver	3	150	20	40
	^{239}Pu , 3 cm CWT $^{(d)}$	3000	Bone	2	75	10	30
		600	Wound	1	0.09	10	20
^{238}Pu	17.0- and 20.4-keV	2000	Lung	6	30	20	40
	X-rays from ^{238}Pu	2000	Liver	3	60	20	40
	3 cm CWT	3000	Bone	2	30	10	30
^{241}Am	59.5 keV	2000	Lung	6	0.18	10	20
		2000	Liver	3	0.15	7	20
		3000	Bone	3	0.36	10	15
		600	Wound	1	0.0015	10	15
^{238}U	93 keV from ^{234}Th	2000	Lung	6	1.8 nCi (5.4 mg)	10	20
^{235}U	183.7 keV	2000	Lung	6	0.12 nCi (0.056 mg)	10	20
^{232}Th	239 keV from ^{212}Pb	2000	Lung	6	0.57	8	15
^{144}Ce	134 keV	2000	Lung	6	0.60	8	15
^{154}Eu	123 keV	2000	Lung	6	0.07	8	15
		3000	Bone	2	0.22	7	15
^{155}Eu	86.5 keV	2000	Lung	6	0.18	10	20
		3000	Bone	2	0.37	7	20
^{210}Pb	46.5 keV	2000	Bone	3	3.0	8	15
^{125}I	27 keV	2000	Thyroid	2	0.004	10	15

(a) See Equation 7.1.

(b) Precision values are for cases where the count rate is high enough that the counting rate error is insignificant compared to the precision error.

(c) This assumed ratio does not mean that this is a commonly found ratio nor does it mean that the ratio of ^{239}Pu to ^{241}Am remains constant as it transfers from lung or wound to liver and bone.

(d) CWT = chest wall thickness.

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TABLE 7.2. Accuracy and Sensitivity for Whole Body Counts in the Preview Counter

$$MDA^{(a)} = \frac{4.65 \sigma}{KT} + \frac{3}{KT}$$

Radionuclide	Gamma Ray Energy, MeV	Counting Time, sec	Organ ^(b)	95% Confidence MDA Statistical Error, nCi	1 σ Precision, (c) %	1 σ Estimate of Body Shape & Size Error, % ^(d)
¹³⁷ Cs- ¹³⁷ Ba	0.662 MeV	200	WB L	3 2.4	5 5	± 10 ± 10
⁵¹ Cr	0.32 MeV	200	WB L	22 18	5 5	± 15 ± 15
⁶⁰ Co	1.17 and 1.33 MeV	200	WB L	3 2.4	5 5	± 10 ± 10
¹³¹ I	0.36 MeV	200	WB L	6 4.5 ^(e)	5 5	± 15 ± 20
⁵⁹ Fe	1.10 and 1.29 MeV	200	WB L	6 4.5	5 5	± 10 ± 10
⁵⁴ Mn	0.84 MeV	200	WB L	3 2.4	5 5	± 10 ± 10
¹⁰⁶ Ru- ¹⁰⁶ Rh	0.51 MeV	200	WB L	12 9	5 5	± 10 ± 10
⁴⁰ K	1.46 MeV	200	WB	15	5	± 10
¹¹⁰ Ag	0.658 MeV	200	WB L	3 2.4	5 5	± 10 ± 10
²² Na	1.28 MeV	200	WB	1.5	5	± 10
²⁴ Na	1.37 and 2.75 MeV	200	WB	0.7	5	± 10
²³² Th	Using ²⁰⁸ Tl 2.61 MeV	200	WB L	2 1.5	5 5	± 10 ± 10
⁶⁵ Zn	1.12 MeV	200	WB L	4.5 3.4	5 5	± 10 ± 10
⁹⁵ Zr- ⁹⁵ Nb	0.724 and 0.756	200	WB L	3 2.4	5 5	± 10 ± 10
¹²⁵ Sb	176 KeV	200	WB L	6 4.5	5 5	
¹⁵⁴ Eu	1.274	200	WB L	4.5 ^(f) 3.4	5 5	± 10 ± 10
¹⁴⁴ Co- ¹⁴⁴ Pr	2.18	200	WB L	100 ^(f) 75	5 5	± 10 ± 10
¹⁴⁰ La	1.596	200	WB L	2 1.5	5 5	± 10 ± 10

(a) See Equation 7.1.

(b) WB = whole body; L = lung.

(c) Precision values are for cases where the count rate is high enough that the count rate error is insignificant compared to the precision error.

(d) Activity in the gastrointestinal tract can give counting rates which vary $\pm 50\%$, depending on the location within the tract.

(e) Lower MDA can be obtained by other methods (see Table 7.3).

(f) Much lower MDA is obtained using 6 germanium planar detector systems (see Table 7.1).

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7.4TABLE 7.3 Accuracy and Sensitivity for Selected In Vivo Measurements

<u>Radionuclide</u>	<u>Photon Energy, MeV</u>	<u>Organ</u>	<u>Detector System</u>	<u>99% Confidence MDA Statistical error, nCi</u>	<u>Precision</u>	<u>Estimate of Body Size and Shape Error</u>
^{131}I	0.36	Thyroid	3-in. x 3-in. NaI(Tl) 35% GeLi	0.030 0.020	$\pm 10\%$ $\pm 10\%$	$\pm 20\%$ $\pm 20\%$
Fission products in wounds	^{137}Cs as an example	Wound	4" x 11 1/2" NaI(Tl) 35% GeLi	0.03 0.016	$\pm 5\%$	$\pm 5\%$
^{60}Co	1.33	Whole body	Two 35% GeLi	5.0	$\pm 5\%$	$\pm 5\%$
^{241}Am	0.595	Axillary lymph node	20-cm ² germanium planar	0.01	$\pm 10\%$	$\pm 20\%$

7.1 MINIMUM DETECTABLE AMOUNT

(contd)

These MDAs are calculated using the ANSI N13.30-recommended formula shown below.

$$MDA = \frac{4.65 \sigma}{KT} + \frac{3}{KT} \quad (7.1)$$

where σ = the standard deviation in the count of an uncontaminated person

K = the calibration factor in appropriate units as counts per unit of time per nCi in the body or organ.

T = the counting time interest used in consistent time units.

7.2 ACCURACY AND PRECISION

The in vivo determination of radioactivity in the body or in an organ is not a highly accurate measurement because of the variable body size, shape, and distribution of radioactivity. Despite these shortcomings, the determinations are as accurate or more accurate than the radiation dose calculations which use the in vivo measurement results. For measurements of radionuclides that are rather uniformly distributed in the body such as potassium-40, cesium-137, and sodium-24, the precision and accuracy is relatively good but varies according to the amount in the body and the counting time. The accuracy and precision values have been estimated from human data such as those described in a study of ^{92m}Nb in the lungs of 9 males and 11 females (Newton et al. 1985; Gunston and Jefferies 1986) and are given in Tables 7.1, 7.2, and 7.3.

Radioactivity that is not uniformly distributed in the body or which changes distribution with time is measured with less precision and accuracy. However, the measurement equipment has been designed to minimize the effects of nonuniform and changing distribution. The estimated values of precision and accuracy are given in Tables 7.1, 7.2, and 7.3.

7.3 REFERENCES

American National Standards Institute (ANSI). 1985. "Performance Criteria for Radiobioassay." Draft ANSI Standard N13.30.

Brodsky, A. 1986. Accuracy and Detection Limits for Bioassay Measurements in Radiation Protection - Statistical Considerations. NUREG-1156 (Draft), U.S. Nuclear Regulatory Commission, Washington, D.C.

Gunston, K. J., and S. J. Jeffries. 1986. Calibration of X-Ray Counters for Assessment of Internal Lung Contamination, with Low Energy X-Ray Emitters, in Women, Part I Measurements Made at AWRE. Final Report to IAEA, Technical Contract 3362/TC. Vienna, Austria.

International Commission on Radiological Protection (ICRP). 1975. "Report of Task Group on Reference Man." ICRP Publication 23, Pergamon Press, New York.

Newton, D., A. C. Wells, S. Mizushita, R. E. Toohey, J. Y. Sha, R. Jones, S. J. Jeffries, H. E. Palmer, G. A. Rieksts, A. L. Anderson and G. W. Campbell. "The Livermore Phantom as a Calibration Standard in Assessment of Plutonium in Lungs." In Proceedings of IAEA Symposium on the Assessment of Radioactive Contamination in Man, pp. 189-199. IAEA-SM-276/01, International Atomic Energy Agency, Austria, Vienna.

APPENDIX A

BROCHURE: "THE HANFORD WHOLE BODY COUNTING CENTER"
(on back cover)

APPENDIX B
QUALITY ASSURANCE PLAN

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QA PLAN

☐ Project ☒ Service Activity

☒ 1830

☐ 1831

Project/Service Activity: Whole Body Counting

Sponsor: DOE, Hanford Contractors and other companies, agencies as requested

Authorized By (DOC. No.): N/A (Service Activity)

QA Requirement Specification:

(Specify) 1. DOE-RL Order 5700.1A, Quality Assurance, as interpreted by PNL-MA-65

2. This QA Plan replaces O&EP-16, Rev. 3

The Sections or selected paragraphs of PNL-MA-65 (as identified by section of paragraph number) designated in this QA Plan are applicable to this Project/Service Activity. Additional information is also provided when useful to provide clarification of the selected requirement.

Approvals:

DATE APPROVED <u>9-10-86</u>	SIGNATURE (QUALITY ENGINEER) J. C. Langford <i>J. C. Langford</i>
DATE APPROVED <u>9/11/86</u>	SIGNATURE (Q.E. MANAGER) D. E. Ryder <i>D. E. Ryder</i>
DATE APPROVED <u>9-10-86</u>	SIGNATURE (PROJECT/ACTIVITY MANAGER) H. E. Palmer <i>H. E. Palmer</i>
DATE APPROVED <u>9-10-86</u>	SIGNATURE (LINE MANAGER) (a) J. R. Houston <i>J. R. Houston</i> (D7H71)

Distribution: (Project QA Files, QAO, and others as appropriate)

J. R. Houston
J. C. Langford
H. E. Palmer
D. E. Ryder
M. J. Sula
QAD c/o G. R. Schmidt
Records c/o H. W. Hunt

(a) Department or Section Manager as designated by Department Policy or the Project Plan Document.

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3.1.6.3 Formal Design Review	0	0	
3.1.6.4 Development Testing	0	0	
3.1.7 Revisions	●	●	
4.1 Procurement—Applies if a purchase requisition is processed (procurement or subcontract)		●	
4.1.1 Procurement/Subcontract Document Preparation and Approval		0	
4.1.2 Source Inspection Activities		0	
4.1.3 Supplier/Subcontractor Selection		0	
4.1.4 Procurement Document Close-Out		0	
5.1 Instructions, Procedures, and Drawings	●	●	
5.1.1 Ident. & Content	●	●	
5.1.2 Transmit of QA Req.	●	0	
5.1.3 Compliance	●	0	

(a)W/C—With clarification presented in this QA Plan

(b)REV—Indicates revision number in which changes were made

QA PLAN INDEX (cont'd)

	<u>Applies</u>	<u>W/C</u>	<u>REV</u>
6.1 Document Control	●	●	
6.1.1 Control of Select Documents	●	●	
6.1.2 Revisions	●	0	
7.1 Identification and Control of Items	●	●	
7.1.1 Identification and Control	●	●	
7.1.2 Traceability	●	●	
8.1 Control of Special Processes	0	0	
8.1.1 Process Controls	0	0	
8.1.2 Process Selection	0	0	
9.1 Performance of Inspections and Tests	●	●	
9.1.1 Receiving Inspection	0	0	
9.1.2 Other Inspections (Nonreceiving)	0	0	
9.1.3 Content of ITI	0	0	
9.1.4 Records, Tagging and Nonconformances	0	0	
10.1 Control of Measuring and Test Equipment	●	0	
10.1.1 Basic Responsibilities	●	0	
10.1.2 Performance Checks	●	●	
10.1.3 Calibration of M&TE	●	●	
10.1.4 Calibration Discrepancy	●	0	
10.1.5 New Equipment	●	0	
10.1.6 Records	●	0	
11.1 Handling, Storage and Shipping	0	0	
11.1.1 General Guidance	0	0	
11.1.2 Special Instructions	●	●	
12.1 Status of Inspection, Test & Operating Condition	0	0	
12.1.1 Status Indication Authorities	0	0	
12.1.2 Status Indication Requirements	0	0	
13.1 Nonconformance & Corrective Action	●	0	
13.1.1 Occurrences	●	0	
13.1.2 Control of Nonconforming Item	●	0	
13.1.3 Corrective Action	●	0	
14.1 QA Records	●	●	
14.1.1 General Guidance	●	0	
14.1.2 QA Record Requirement	●	0	
14.1.3 Laboratory Record Books	●	●	
15.1 Audits — Applies when a project or activity is selected as part of the base for a QA audit.		0	

Additions

● ●

See Parts 3 and 5 of this QA Plan.

1. ORGANIZATION

- 1.1 The Personnel Dosimetry Section of the Health Physics Department is responsible for DOE-RL's Pacific Northwest Laboratory Whole Body Counting Activity. This program provides technical and administrative support to DOE-RL's Hanford site-wide radiation protection services.

Other supporting agencies are listed below:

- BCS Richland, Inc. receives the whole body counting data and organizes it into reports.
- The Radiation Records Service Activity is responsible for the permanent storage of Whole Body Counting Data.

2. QA PROGRAM

This QA Plan applies to the training of whole body counting personnel and the administration of whole body counting services provided for any sponsor.

- 2.1 The Battelle QA Program shall be applied as described in this QA Plan.

- 2.1.3.3 Annual training of staff members shall be documented. This training shall include an annual review of the W.B.C. training manual by each staff member.

3. DESIGN CONTROL AND METHOD REVIEW

- 3.1.2 The activity approach and method is documented in the Work Package. Review and approval by the Activity Manager and the appropriate Section Manager shall be noted by signature and date on the cover page or other means traceable in the Work Package.

- 3.1.3.1(3) This paragraph applies when a sketch or worksheet is used to transmit information to another organization.

- 3.1.7 This section applies when a revision is made to a sketch or worksheet.

In addition:

- Calculations and analysis performed in support of activity results reported to the sponsor shall be documented and traceable from the primary data and its source, through the assumptions and/or interpretations made, to the corresponding calculation and/or reported analysis.

- The accuracy and precision of the measurements shall be determined. This data shall be recorded in a report and delivered on request to the sponsor as part of a performance report.
- Documentation of computer codes used shall include:
 - Identification of the mathematical technique of coded model
 - Assumptions and constraints that apply to the model
 - Definition of input and important variables
 - Data input requirements
 - Input and output variables
 - Users instructions
 - Listing
 - Verification of code model and operation
 - Review and approval of code and documentation

Previously verified codes shall be reviewed by the Activity Manager for adequacy with the activity, as well as adequate documentation (i.e., user's guide/instruction, tests and results). This review shall be documented, and retained as a QA record. A list of all computational computer codes shall be maintained.

- Changes to existing verified activity codes shall be documented as they are made and used in the activity. Documentation shall be maintained by the user of the code and shall include:
 - code title and version
 - changes made (compare original to modification)
 - date
 - persons reviewing and approving the change

Verification shall be performed on changed codes prior to use when the results are expected to be reported to the sponsor.

If a computer is used for analysis or calculations, each computer output containing results to be reported to the sponsor shall be traceable to the:

- computation performed (title or number)
- data set used (input)
- time and date of run
- code model and version used

- Data Control

Data on computer systems shall be protected and controlled by implementation of the following requirements:

- Each computer run reported or used for reporting information in project reports shall have a copy of the output stored as a QA record.
- Data on computer tapes, disks, and other memory devices shall be identified.
- Computer system configuration and software source(s) shall be documented and retained as an activity record.
- The data transferred between computer systems shall be controlled, verified, documented, and retained as an activity record.
- Master copies of computer data on tapes, disks, and other memory devices shall be stored in a secure manner which will protect them from tampering, loss and/or damage.

The above whole body counting data results/records are transferred on a weekly basis to the Radiation Records Group for permanent storage, protection, and control. These records will be available in the Whole Body Counting Group on a temporary basis.

4. PROCUREMENT

4.1 This section applies when a purchase requisition is processed. The applicable parts of Sections 9.1 and 12.1 shall apply if receiving inspection is to be applied to a specific procurement.

5. INSTRUCTIONS, PROCEDURES, AND DRAWINGS

5.1 This section applies and additional information is provided in the following statements.

5.1.1 Activities that require written procedures and/or instructions shall be determined by the Activity Manager. This includes the following procedures:

- Whole Body Counter Manual
- Hewlett-Packard 9000 Manual
- EXEC User Manual
- Radiation Safety Practices and Procedures Training Guide

In addition:

A description of the research procedures and methods actually used or developed shall be recorded in the Laboratory Record Books. (Note: It is only necessary to make reference to established procedures.) Design decisions and related information shall also be recorded in the Laboratory Record Books.

6. DOCUMENT CONTROL

6.1 Documents shall be controlled in accordance with this section and a control list of the distribution of the manuals shall be maintained. This includes, but is not limited to, the procedures identified in 5.1.1 above.

6.1.1.2 Controlled documents shall be reviewed by authorized personnel and approved for use by the task leader and the cognizant line manager. Approvals shall be indicated by signatures and date on the document.

7. IDENTIFICATION AND CONTROL OF ITEMS

7.1 This section applies and additional information is provided in the following statements.

7.1.1 This paragraph applies especially to the identification and control of computational computer items (disks, tapes, print-outs) used for this activity. The controls applied will be documented in procedures as noted in Part 3, In Addition.

7.1.2 Emergency accident evaluations shall be traceable to the computed results (spectral results are not retained as permanent records).

9. INSPECTION AND TEST

9.1 This section applies to the procurement of appropriate measuring and test equipment (M&TE).

10. CONTROL OF MEASURING AND TEST EQUIPMENT

10.1.2 Performance of operational checks and adjustments shall be recorded on the computer records. Note the procedure used, if appropriate. Quarterly reviews of daily measurements are printed and transferred to a Laboratory Record Book.

10.1.3.2 Critical measurements for this activity include radiation measurements and spectral measurements.

10.1.3.3 The measuring and test equipment (M&TE) which have impact upon the accuracy of the data and in this activity are listed below along with their calibration level.

<u>Measuring and Test Equipment</u>	<u>Calibration Level</u>
Multichannel Analyzers	2
NaI (Tl) detectors	2
Phoswick detectors	2
Ge (Li) detectors	2
Intrinsic germanium detectors	2
Analytical balances	1

11. HANDLING, STORAGE, AND SHIPPING

- 11.1.2.1 The handling and storage of sealed radioactive samples require special controls and identification which are described in the Radiation Safety Practices and Procedure Training Guide.

14. QA RECORDS

- 14.1 The Activity Manager shall assure that a file is maintained which contains or references the location of QA Records. These records shall include but are not limited to those identified in Management Guide 4.3 and the following documents:

QA Plan HPD-26
Procurement Documents
Calibration Records
Work Packages
Sketches and Worksheets
Inspection Test Instructions (ITIs)
Radiation Safety Practices and Procedure Training Guide
Personnel Training Documentation
Sample Log Book
Records Plan/Index listing records type, custodian and location

Record retention periods and final disposition shall be in accordance with requirements of the sponsor. The retention and storage of records for this activity are the responsibility of Radiation Records task group.

- 14.1.3 Laboratory Record Books used to record research activity data and results shall be dedicated solely to this activity. Entries in Laboratory Record Books shall be in ink accompanied with the individuals signature and date. Changes shall be made only by a single line drawn through the original entry accompanied with the initials and date by the individual making the change. The reason for the change shall be noted unless obvious. Attachments included in the Laboratory Record Book shall be permanently affixed and identified with the page and book number. Laboratory Record Books shall be used to record the following information:

- Test results and raw data
- Level 2 calibration records
- Calculations
- Description of research procedures and methods used or developed
- Unusual conditions
- Equipment operation checks and maintenance

Note: These Laboratory Record Books shall reference the location of all other data not contained in Laboratory Record Books.

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The Hanford Whole Body Counting Center

Welcome to the Hanford Whole Body Counting Center. Hanford workers who are assigned to areas where radioactive materials are processed or stored may be scheduled for exams at the Whole Body Counting Center. Your examination provides another measure of assurance that the work place is safe and that the controls established to prevent and limit internal radiation exposure are adequate.

What Does the Whole Body Counter Do?

Your examination at the Whole Body Counting Center can detect the presence of very small quantities of gamma-emitting, radioactive materials that may be deposited in your body. For example, detectors at the Whole Body Counting Center can detect smaller quantities of gamma-emitting radioactive materials than the portable survey instruments and portal monitors at your workplace.

When are Exams Scheduled?

If you are a new employee and have formerly worked with or expect to work with radioactive substances, you will probably have an examination at the Whole Body Counting Center before you enter a radiation zone. You may also have an exam whenever a change in your job task or working condition involves a different type or form of radioactive substance. Most people who work in radiation zones at Hanford are examined on an annual basis; these exams establish a normal or "background" value against which future results can be compared. You also would be examined in the unlikely event you accidentally became exposed at work.

Results of most whole body exams are normal, meaning no radioactive substances from the site were detected in the body. However, if an intake is confirmed, additional exams are scheduled to observe the clearance of the material from your body.

What Kinds of Exams are Performed?

Two types of examinations, the whole body count and the lung count, are performed routinely at the Hanford Whole Body Counting Center. The whole body count measures the entire body from head to foot to determine whether any detectable quantity of radioactivity is present. The lung count focuses on the respiratory system. It is designed to detect gamma radiation from americium, plutonium, and uranium, the radionuclides associated with processing nuclear fuels at Hanford.

Your radiation protection group establishes a monitoring schedule for you based on the radiation protection requirements of your specific job. Everyone scheduled for an exam has a whole body count, which takes only three minutes. If you work in the fuels fabrication or separation areas, then you will probably receive a lung count as well as a whole body count.

Many other types of examinations can be performed at the Whole Body Counting Center, but they are reserved for special circumstances.

Preparing for the Exam

Because exam results are an important part of your permanent radiation records, the technician first requests that you put your name, payroll number and other identifying information on a form. About five minutes after you return the form, the technician calls you for your exam.

If you are having a lung count, the technician will ask you to shower and change into coveralls provided in the change rooms. These coveralls are required for the lung count because your personal clothing may have attracted small quantities of naturally occurring radioactivity from the air outdoors. Showers are also necessary prior to all lung counts because surface dust and naturally occurring radioactive particles from radon or thoron are attracted to the hair and skin and

may interfere with the measurement. These interferences may cause a result to be invalid. Since the objective of the exam is to measure radioactive substances deposited within the body, these interferences must be washed off prior to the exam.

The Whole Body Count

For a whole body count, five large stationary detectors have been installed in a lead-shielded booth. Lead shielding is necessary to reduce interference from natural sources of radiation in the environment.

When you step into the whole body counter booth, you are asked to stand upright against the detectors. The technician adjusts the detectors so that your chest is next to the one with the largest diameter. You need to lean against the detectors for about three minutes while electronic instruments and computers process the information they receive from the detectors.

No radiation is given off by these detectors. Instead, the detectors measure gamma rays emitted by radioactive substances deposited in the body. A computer analyzes the detector measurement to ensure that the results of your exam are accurate and reliable.

The final result of your whole body count may not be available immediately because processing takes time. In most cases, the lack of an immediate finding indicates that the result is normal. Your supervisor is informed of the findings and will pass the results to you. These results are maintained in your official permanent records.

The Lung Count

The lung count determines whether any detectable plutonium, americium, or uranium is deposited in your respiratory system. Before the lung count starts, you will lie on a bed and a technician will arrange a set of six individual detectors on your chest. (The position of the detectors is important for the measurement to be accurate.) The exam takes about fifteen minutes.

Because the detectors are very sensitive, the lung count must be performed in a room shielded with thick steel walls. This shielding reduces interference from natural sources of radiation in the environment.

Lung counts take more time for evaluation than whole body counts. In most cases you will know whether your exam was normal before you leave the laboratory, but detailed findings may not be available during your visit. Your supervisor will inform you of the findings and the results will also be in your official permanent records.

Sometimes Exams are Repeated

Occasionally, an exam has to be repeated. For example, a small amount of radioactive material on the skin or clothing can cause a higher than normal reading. This material may be due to naturally occurring radioactive dust particles from radon or thoron that attach to the hair or skin. If you are asked to have a repeat whole body count, the technician will request that you shower, scrub your chest and wash your hair. If the result of the repeat whole body count is normal, the source of activity found in the initial exam is attributed to external contamination.

Although it is unlikely, sometimes an internal deposition of radioactive material is confirmed. Additional examinations may be performed to identify the location of the deposit and the type and quantity of material present.

Follow-up exams may also be scheduled to determine the rate of elimination from the body. Results of these exams and the radiation dose estimates become part of your personal Hanford radiation records and also are made available to your supervisor.

Natural Radioactivity in the Body

Everyone has some internal body radioactivity. Most of it comes from potassium-40, the naturally occurring radioactive isotope of potassium. All plants and animals need potassium to live. An average person contains about 140 grams of potassium of which less than 0.01% is potassium-40.

Sources of Other Radioactive Materials in the Body

Other radioactive materials measured in humans, such as cesium-137 and strontium-90, are not naturally occurring, but are due to fallout from atmospheric weapons testing. Occasionally, small quantities of reactor fission products and radioactive cobalt, manganese and iron are found in workers who have been accidentally exposed while working on reactor piping. The cobalt, manganese and iron make up the stainless steel that very slowly becomes corroded as the reactor operates. Also, if your personal physician has recently prescribed a diagnostic or therapeutic radio-pharmaceutical, it may be detected during your whole body or lung count.

Questions?

If you have any questions regarding the systems used to perform exams or the methods employed to calculate results, please ask one of the technicians to direct you to a member of our professional staff. Our phone number is 376-6102. We will be glad to answer your questions.

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