Advanced Medical Systems, Inc.

Decommissioning Cost Estimate for the London Road Site in Cleveland, Ohio

January, 1995

Revision 0

SEG

SCIENTIFIC ECOLOGY GROUP, INC.

Radiological Engineering & Decommissioning Services

APPENDIX C

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University Hospital of Cleveland	11100 Euclid Avenue Cleveland, OH 44106

Advanced Medical Systems, Inc.

Decommissioning Cost Estimate for the London Road Site in Cleveland, Ohio

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January 1995

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REVISION 0

PROPRIETARY STATEMENT

EXECUTIVE SUMMARY

The Radiological Engineering and Decommissioning Services division of Scientific Ecology Group, Inc., has provided a decommissioning cost estimate for the Advanced Medical Systems, Inc. London Road Site located at Cleveland Ohio under the NRC License No. 34-19089-01. This cost estimate was developed using a systematic approach. Applicable release levels were identified and historical data was reviewed. Specific information regarding structures and equipment was used to estimate waste volumes and remediation costs.

Itemized costs were determined, including costs for manpower and equipment resources, packaging, shipping and burial activities, and the performance of final status surveys for buildings and structures. The estimated decommissioning cost is $1,795,612 in terms of 1995 dollars. This estimate is for budgetary purposes only and is not a proposal or cost estimate for Scientific Ecology Group, Inc., to perform decommissioning work.

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1.0 INTRODUCTION

1.1 Purpose

The Radiological Engineering and Decommissioning Services (RE&DS) division of Scientific Ecology Group, Inc. (SEG) has prepared this document for the purpose of providing a decommissioning cost estimate for the Advanced Medical Systems London Road Site. The cost estimate includes only those activities and cost factors required to remove residual radioactivity to levels which will permit release of the site for unrestricted use in accordance with the NRC guidelines in, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material.*

Costs associated with the demolition and removal of non-contaminated equipment or structures are not included in this cost estimate. An actual date to perform decommissioning has not been projected as portions of the facility will continue to be used. The cost estimate provided by this report is in terms of 1995 dollars. This estimate is intended to be used for funding and budgetary purposes and does not constitute proposal or cost estimate for SEG to perform work.

1.2 Scope

The scope of this report is to present the estimated costs derived for decommissioning the Advanced Medical Systems London road Site. The specific areas and systems covered by this estimate include:

- Hot Cell, First Floor
- Decontamination Room, First Floor
- Isotope Shop Area, First Floor
- High Level Waste Storage Room, First Floor
- Airlock, First Floor
- Clean Equipment Room, Second Floor
- HEPA Systems Room, Second Floor

- Waste Storage Room, basement
- Clean Area, basement
- Waste Water Hold-Up Tank Room (WHUT), basement

This estimate has been prepared to support the requirements of 10 CFR 70, *Domestic Licensing of Special Nuclear Material*, and Regulatory Guide 1.159, *Assuring the Availability of Funds For Decommissioning Nuclear Reactors*. This estimate addresses activities related to the removal of hardware, structural materials, and miscellaneous materials as necessary to reduce levels of residual radioactivity to below the guideline values specified in the NRC *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of License for Byproduct, Source, or Special Nuclear Material.*

Decommissioning costs are directly related to the degree of remediation required and the amount of radioactive waste generated. The extent of remediation is based on radiological data, proven decontamination processes and experience with similar projects. The volume of radioactive wastes generated were determined from facility drawings, equipment sizes, radiological data, and proven volume reduction processes. Costs associated with the performance of final status surveys were estimated based on the size of the various areas being decommissioned and their prior radiological history.

The cost estimate for London Road Site utilizes a combination of unit price estimates and task-based estimates to arrive at a total cost for decommissioning all areas. The unit cost methodology is modeled after the method used in the *Means Building Construction Cost Data*. The decommissioning work is first divided into units of work, such as removing 2-inch pipe and then the unit of cost per foot of pipe is multiplied by the feet of pipe to arrive at the cost. A similar method is used for decontamination work, such as decontaminating concrete floor to a depth of 1/4 inch. The unit of cost per square foot of concrete floor area is multiplied by the square feet of floor area to arrive at the cost. The estimate includes the craft labor, supervision, health physics support, waste disposal, materials and equipment necessary to actually perform this task. Other work is priced using the task based methodology which is modeled after the method used by PNL (Pacific Northwest Laboratory) to prepare the estimates presented in NUREG/CR-1756, *Technology Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors*, March 1982. The work is divided into tasks such as decontaminating a hot cell using robot operated decontamination equipment, and then an estimate or vendor price quote is obtained for each task. The various costs derived from the two methods are combined and a project schedule is developed which defines the duration and man loading for the project. The schedule and man-loading information is used in the development of on site project management costs, travel and living costs, equipment rental costs, home office support costs, and owner oversight costs.

1.3 Discussion

The following assumptions and bases were utilized in developing the cost estimate.

- The building will remain in place after decommissioning.
- The Co^{60} source inventory in the facility will be shipped to other sites as part of the decommissioning.
- All contaminated equipment will be removed for disposal.
- The soil under the building has been sampled and is un-contaminated.
- All equipment, electrical boxes, conduit, pipes and ducts in contaminated rooms are assumed to be contaminated.
- The interior partition wall framing studs and wall board in contaminated rooms are assumed to be contaminated.
- The decommissioning of the WHUT room will not take place until the year 2018 to allow decay of the Co^{60} activity to a manageable level.
- Contaminated equipment not decontamination onsite will be shipped to a volume reduction facility for processing prior to disposal.
- Radioactive waste will be disposed of at the Midwest Compact disposal site in Ohio. The compact disposal site has not been selected as yet.

2.0 GENERAL SITE DESCRIPTION

The Advanced Medical Systems Site at London Road in Cleveland, Ohio, was used to produce Co^{60} and Cs^{137} sources for medical applications.

The Advanced Medical Systems Site is located northeast of Cleveland, Ohio at 1020 London Road. This is a small site as shown in Figure 2-1, and only part of the site was involved with radioactive material handling and storage. The remainder of the site is used for normal warehouse operations.

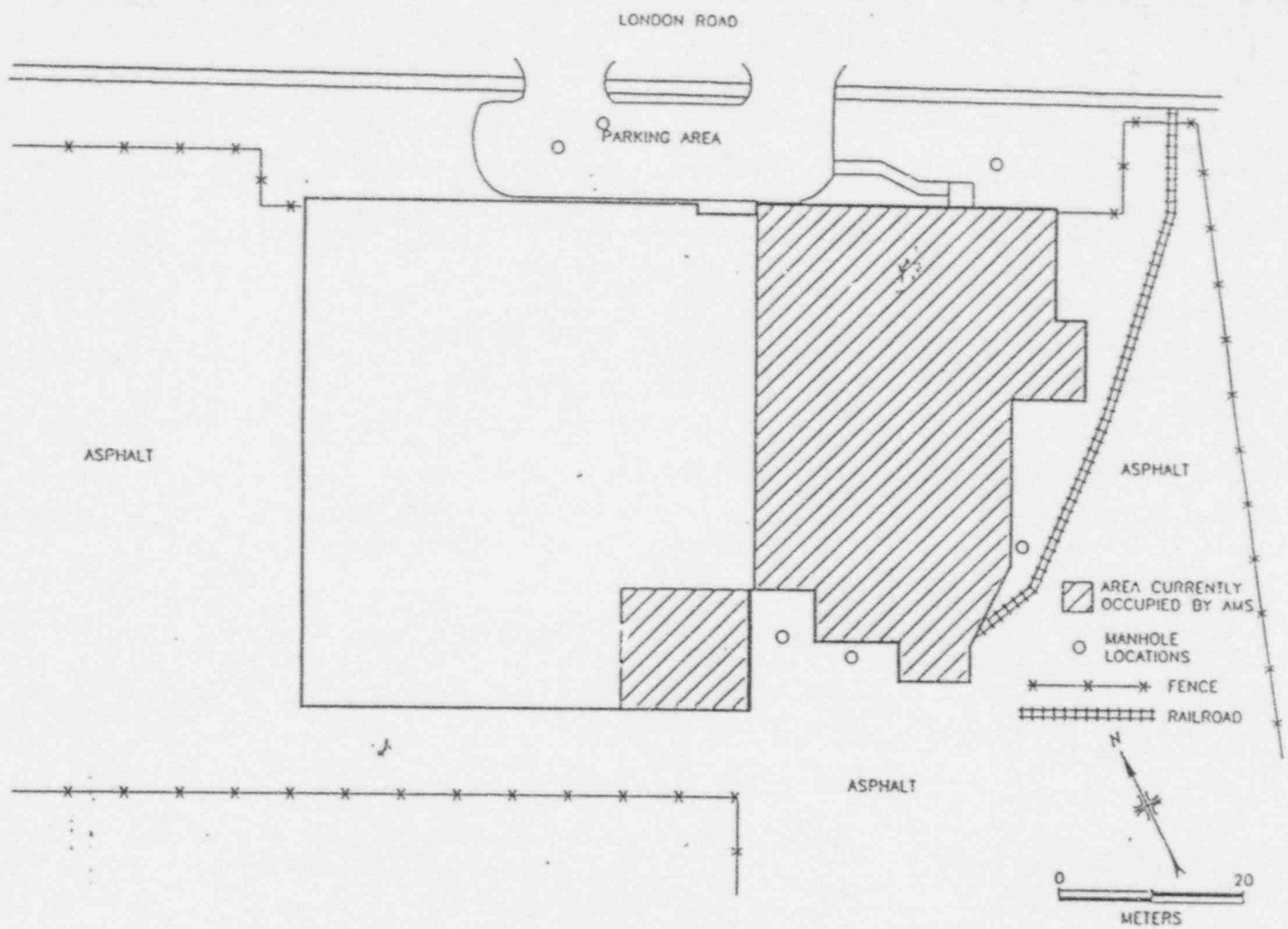


Figure 2-1
Advanced Medical Systems London Road Site

3.0 RADIOLOGICAL CONDITIONS

The Advanced Medical Systems Site in Cleveland, Ohio, was visited in September of 1994 to gather physical facility and nuclear data for this site. Site drawings, photographs and drawings of facility buildings, and radiological data for affected areas were obtained. On site staff members were interviewed to determine radiological history of affected areas and the site in general.

The remediation decisions, survey decisions and waste volume estimates in this report were based on available information. Conservative assumptions were made based upon historical use information, the condition of the area and the experience of the contractor with similar decommissioning projects.

The radiological conditions, related historical information, and the bases for remediation decisions are provided for the various affected areas below.

3.1 Radionuclides of Concern at the London Road Facility

The radioactive materials of concern at this site are Co^{60}, Cs^{137}, and Depleted Uranium (DU). The current inventory of Co^{60} is approximately 70,000 Curies at this facility, this inventory will be removed as part of the decommissioning. The Co^{60} was fabricated into sealed sources which were used in cancer therapy equipment. The current inventory of Cs^{137} is zero. The Cs^{137} was fabricated into sealed sources for industrial and research use. The current inventory of DU is approximately 2,500 kilograms, this inventory will be removed as part of the decommissioning. The DU is used in source heads for shielding and their is no reason to suspect DU contamination in the area because the DU was not processed or machined at this site. The acceptable surface contamination levels are as given in *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material, August 1987.* These acceptable levels for Co^{60} and Cs^{137} are less than 5,000 dpm/100 cm^2 average for fixed activity, less than 15,000 dpm/100 cm^2 maximum for fixed activity, and less than 1,000 dpm/100 cm^2 for removable activity. The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively. The acceptable soil concentration limits are as given in *Federal Register Vol. 57, No. 34, February 20, 1992 / Notices, "Order Establishing Criteria and Schedule for Decommissioning the Bloomsburg Site", Attachment 3.* These acceptable levels are 8 pCi/gram for Co^{60} and 15 pCi/gram for Cs^{137}.

The radiological condition of the facility was ascertained from Advanced Medical Systems records. Current survey records were obtained for the restricted areas and prior survey records for all other areas at the site. A summary of the survey data is provided in Appendix A.

3.2 Hot Cell

The hot cell was designed and equipped to encapsulate large sources of medical therapy and industrial radiography. The cell is six feet square and has 5-1/2 foot thick concrete walls and a four foot thick floor and ceiling. There is a stainless steel floor pan in the cell and 1/4 inch thick steel wall plates 11 foot tall. The cell has a six foot wide 42 ton hinged door at the rear. Numerous small access ports are located on the front and side faces of the cell, and a 20 inch square port opens from each side. There is a 60 inch thick glass and zinc bromide window at the cell front. Remote handling is accomplished with a pair of manipulators and a 2 ton overhead crane. Every item of equipment in the cell and every item in the cell structure is removable. A sketch of the first floor of the building including the hot cell is shown in Figure 3-1.

The hot cell contained approximately 12,400 curies of Co^{60} when the site was visited in September of 1994 including approximately 5,500 curies in a stuck storage plug in the cell floor. There was a shipping cask in the cell which was being prepared to ship some of the cobalt inventory off site. The dose rates within the cell are approximately 12 R/hr with certain hot spots exceeding 12 R/hr. The Co^{60} sources will be decontaminated and shipped offsite as part of the decommissioning.

3.3 Isotope Shop

The isotope shop is located on the first floor next to the hot cell and is shown in a sketch of the first floor area in Figure 3-1. The isotope shop area has a concrete floor, ceiling, and interior walls, the exterior walls are painted brick. Co^{60} sources were transported around this area in shielded containers such as the "transfer monster" which was used to move sources from the "storage garden" to the hot cell. The "transfer monster" is expected to still be on site at the time of decommissioning but all other transfer and shipping shields are expected to have been removed. The shop also contains a hood setting on a table, a second table, a sink, an old trash compactor, a 3 ton overhead hoist with trolley, a wall cabinet and a Tow Motor. The Tow Motor is an electric fork lift where the operator stands behind it to operate it. The isotope shop also contains the "storage garden" and irradiation facility. The dose rates in the isotope shop average about 1 mR/hr with a maximum of 10 mR/hr. The contamination levels average about 100,000 dpm/100 cm^2 with a maximum of 188,000 dpm/100 cm^2.

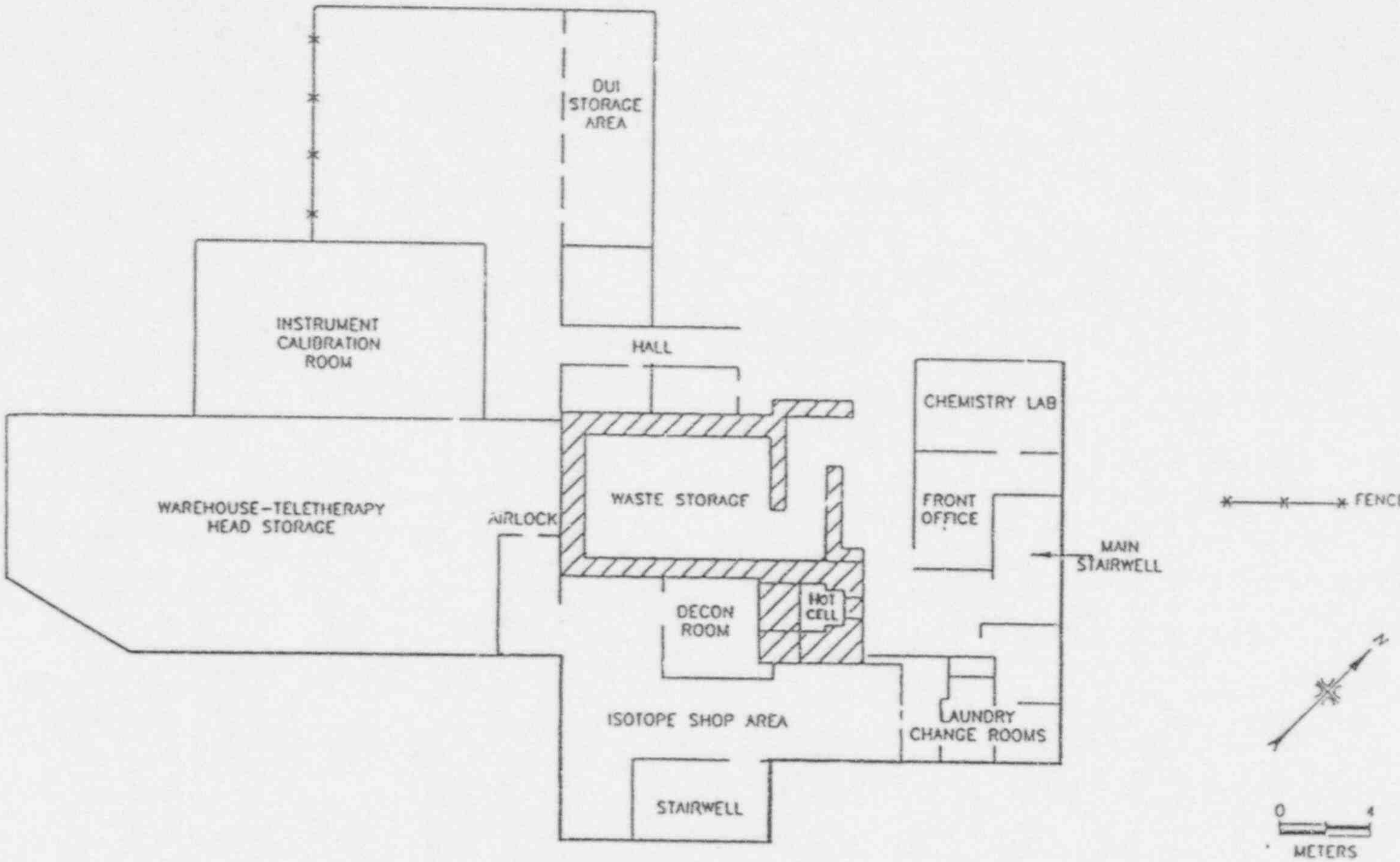


Figure 3-1
AMS Facility First Floor

The "storage garden" and irradiation facility is located in the southwest corner of the building and contains vertical tubes in a six foot square well extending from the first floor level to the basement level. An L-shaped shield around the well in the basement level is provided by two sand filled shield rooms which are accessible through man-holes in the first floor. The high density concrete walls containing the sand shield are two feet thick. There are 54 storage tubes in the "storage garden" rectangular array. The tubes are in a 7 x 9 array with the center nine spaces left open. The center space is fitted wit an irradiation plug which can handle objects up to 8-1/2 inches square by 12 inches high. The storage tubes terminate in a metal container through which cooling air is drawn from the room through the "storage garden" to the HEPA exhaust system. The "storage garden" contains about 2,900 curies of Co^{60}.

There is stairwell from the back of the isotope room to the basement area. This stairwell is contaminated with dose rates of less than 1 mR/hr and contamination levels averaging about 10^6 dpm/100 cm^2.

3.4 Decontamination Room

The decontamination room is located in the behind the hot cell and at the side of the Isotope Shop as shown in a sketch of the first floor area in Figure 3-1. The decontamination shop area has a concrete floor and walls. The room provides space enough for opening the hot cell door into the ventilation controlled space of the decontamination room. The room is equipped with water outlets and a "hot" floor drain used during decontamination operations. In addition there is vault in one corner of the room that contains some items from the hot cell and lead blankets. There are also some large lead shield beams in one corner of the room. This area is contaminated and has dose rates averaging greater than 10 mR/hr and smearable contamination levels averaging about 3 x 10^6 dpm/100 cm^2.

3.5 High Level Waste Storage Room

The High Level Waste Storage Room Area is located next to the hot cell on the first floor as shown in a sketch of the first floor area in Figure 3-1. This room has concrete floors, walls and ceiling. There are 24 drums of waste stored in the room along with 21 used HEPA filters, a small cart, portable cabinet and wall cabinets. This area has dose rates averaging about 400 mR/hr and contamination levels averaging about 75 dpm/100 cm^2 with a maximum contamination level of 100 dpm/100 cm^2. The area in front of the shield wall in this room is a storage area for various items containing Depleted Uranium.

3.6 Clean Equipment Room

The clean equipment room is located on the second floor as shown in a sketch of the second floor area in Figure 3-2. This room has concrete floors, walls and ceiling and contains all the facility service equipment except for the HEPA ventilation equipment. There are two items of contaminated equipment in the room, an air supply blower and the exhaust stack sampling system. This area has dose rates averaging less than 1 mR/hr and a maximum dose rate of 30 mR/hr on a wall adjoining the HEPA equipment room. Contamination levels averaged about 170 dpm/100 cm^2 with a maximum contamination level of 190 dpm/100 cm^2.

3.7 HEPA Equipment Room

The HEPA equipment room is located on the second floor as shown in a sketch of the second floor area in Figure 3-2. This room has concrete floors, walls and ceiling and contains the facility HEPA ventilation equipment. There is a large HEPA exhaust blower with four 2 x 2 HEPA filters in a housing that services all isotope areas except the hot cell. In addition there is a small HEPA exhaust blower with one 2 x 2 HEPA filter in a housing that services the hot cell. This room also contains an abandoned emergency power generator, the hoist motor for the hot cell hoist, and a wood "A" frame with a small manually operated hoist attached. This area has dose rates averaging about 60 mR/hr with a maximum dose rate of 2,000 mR/hr on the exhaust duct from the hot cell. Contamination levels averaged about 11,000 dpm/100 cm^2 with a maximum contamination level of 17,000 dpm/100 cm^2.

3.8 Dry Waste Storage Room

The dry waste storage room is located in the basement as shown in a sketch of the basement area in Figure 3-3. This room has concrete floors, walls and has a drum storage area along one wall with a temporary shielding wall erected between storage area and the main part of the room. The room contains 17 waste drums, a large shop table with vise, and a 55 gallon waste holding tank. The bottom of the stairwell from the isotope room contains 2 floor buffers and 2 mops with buckets. The mop buckets are stored against a wall with a lead sheet in front of them. There also over 500 high density concrete blocks in the room that were placed against the walls to the WHUT room to reduce dose rates. This area has dose rates averaging about 7 mR/hr with a maximum general dose rate of 50 mR/hr. One drum behind the storage shield has a drum with a contact dose reading of about 1,000 R/hr. Contamination levels averaged about 900,000 dpm/100 cm^2 with a maximum contamination level of 2,100,000 dpm/100 cm^2.

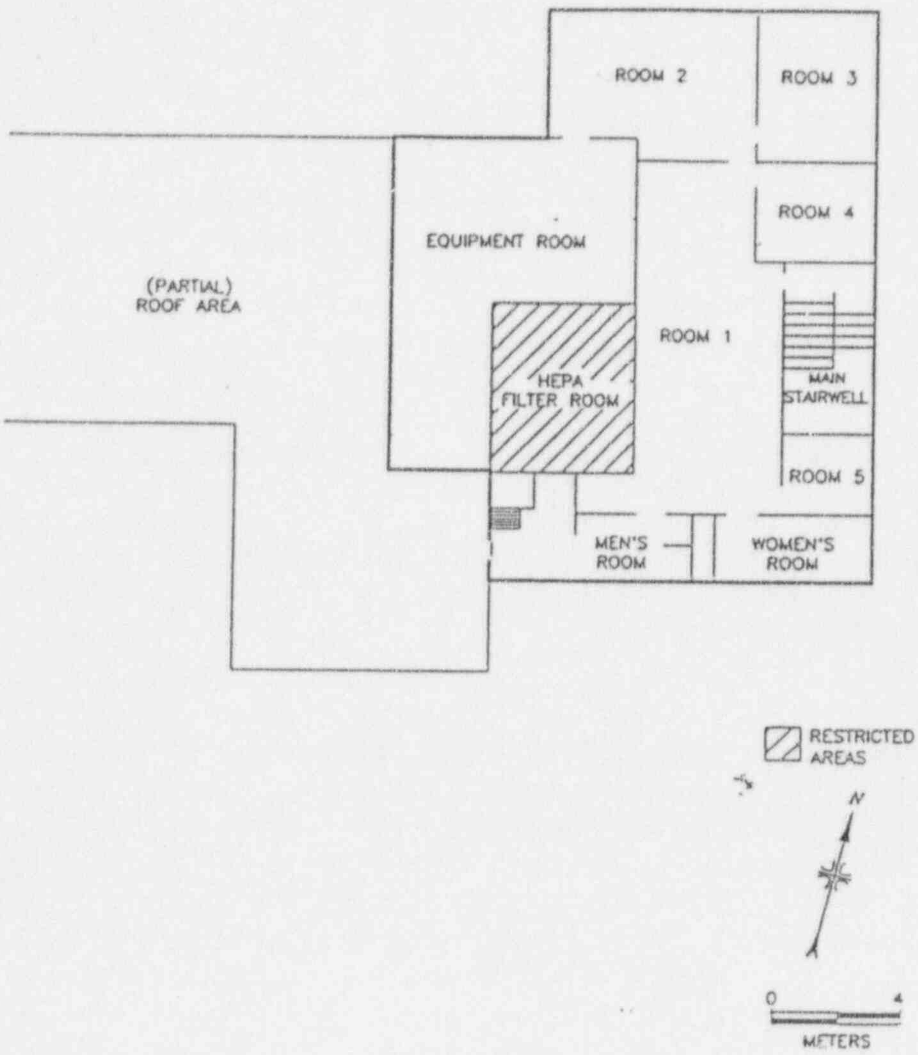


Figure 3-2
AMS Facility Second Floor

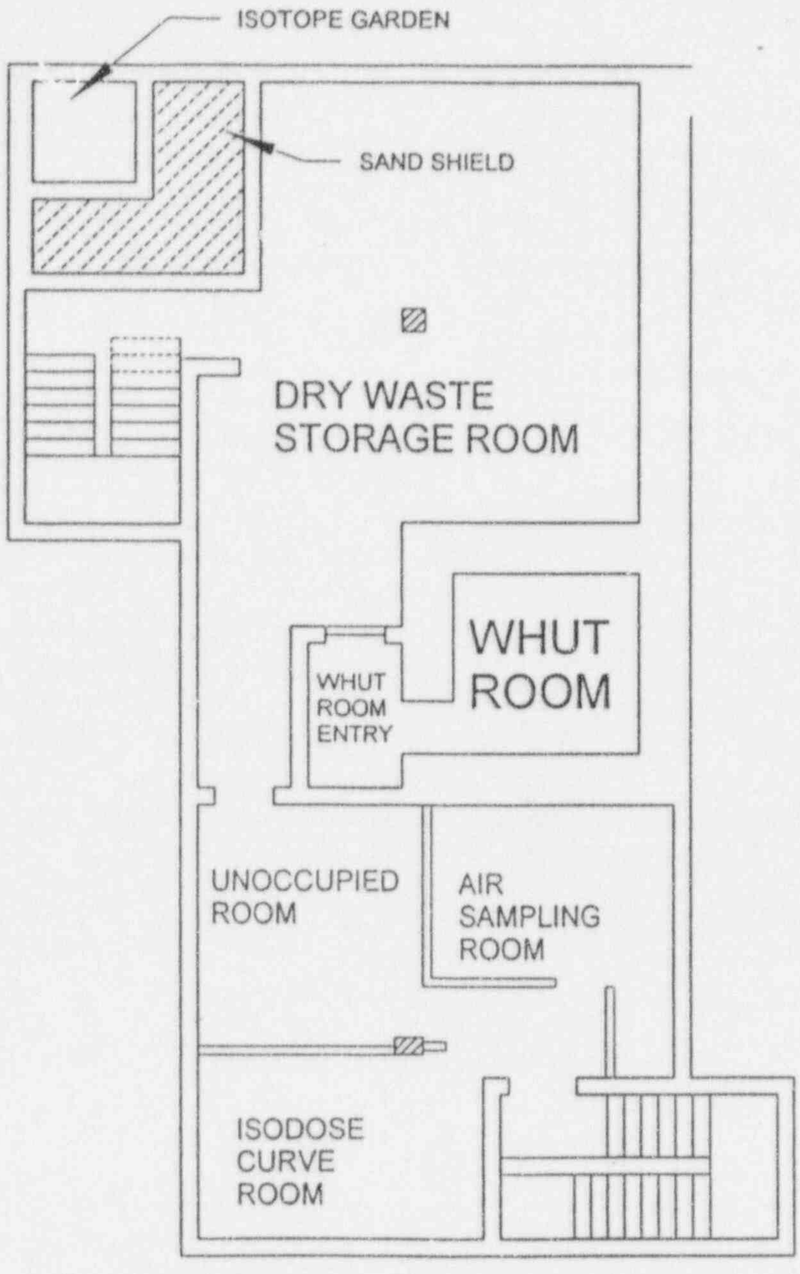


Figure 3-3
AMS Facility Basement

3.9 WHUT Room

The Waste Hold-Up (WHUT) room is located in the basement directly under the hot cell as shown in a sketch of the basement area in Figure 3-3. This room has concrete floors, walls and ceiling. The room walls are three foot thick to provide shielding for the room contents. There is an entry room that contains an abandoned drum compactor. The WHUT room contains 100 and 500 gallon waste receiving tanks, two small ion exchange columns, a table for the ion exchange columns and about 1 inch of sediment uniformly distributed on the floor. This information was taken form the report *Remedial Actions for the Waste Hold Up Tank Room*, NSS, 8 February, 1988. This document also reported that the dose rate from one of the tanks was approximately 2000 R/hr and that smears taken of the floor sediment each produced a dose rate of 1.5 R/hr at 1 centimeter. This area has dose rates estimated to average about 250 R/hr with a maximum dose rate of 2,000 R/hr.

3.10 Basement Clean Side

The basement clean side is located on the east side of the basement next to the WHUT room. It consists of three rooms, the Air Sampling Room, the ISODOSE Curve Room, and the Unoccupied Room. The rooms have concrete floors, ceiling, and exterior walls. The interior walls are standard 2 x 4 wood framed walls with a painted drywall surface. These rooms contain a large plastic tank, an air sampler pump, large metal shelves holding ISODOSE Curves, wooden shelf supports, a sink with metal cabinet, two chairs, and two steel doors. There are 45 high density concrete blocks in the unoccupied room to provide additional shielding from the WHUT room. This area has dose rates averaging about 1 mR/hr with a maximum dose rate of 20 mR/hr in the Unoccupied room. Contamination levels averaged about 1,250 dpm/100 cm^2 with a maximum contamination level of 3,410 dpm/100 cm^2.

3.11 Miscellaneous Areas

The miscellaneous areas at the London road site do not individually contribute significantly to the cost of decommissioning. These areas are summarized in table 3-1.

Table 3-1
AMS London Road Site Miscellaneous Areas

Area	Area Construction Materials	Contaminated Equipment Description	Average Dose Rate mR/hr	Average Activity Level dpm/100 cm²
Air Lock	Concrete floor and interior walls, metal ceiling and exterior walls.	Power cord for Isotope room Tow Motor, 30 concrete shield blocks, and a utility cart.	<1	7,600
Isotope Warehouse	Concrete floor, concrete block and clay brick walls, and metal ceiling.	Old hot cell shield window.	1	128
Former Chemistry Lab	Concrete floor, clay brick walls, and metal ceiling.	None	<0.1	<1,170
Hot Cell Control Room	Concrete floor walls and ceiling.	None	<0.1	<1,170
First Floor Office Areas	Concrete floor and ceiling, and standard drywall.	None	0.1	<1,170
Isotope Shop Locker Room	Concrete floor and ceiling, clay brick and standard drywall.	None	<0.1	1000
Instrument Calibration Room	Concrete floor, clay brick and standard drywall, and metal ceiling.	None	<0.1	<710
Caged Storage Area	Concrete floor, concrete block and clay brick walls, and metal ceiling.	None	1	128
Second Floor Office Areas	Concrete floor and ceiling, clay brick and standard drywall.	None	0.1	1,200
Sewers	Iron pipe in buildings	None	0.84	___
Outdoor Areas	Mostly paved with some natural soil areas.	None	0.028	0.8 pCi/g

4.0 ESTIMATION METHODS

The estimated cost to decommission the licensed areas at the Advanced Medical Systems, Inc., London Road Site is $1,795,612. This section of the cost estimate report provides an overview of the considerations and factors that influenced the decommissioning cost estimate. Table 4-1 provides a summary of the cost associated with each area of the London Road Site.

Table 4-1
Decommissioning Cost Summary - Advanced Medical Systems, London Road

Operation	Man-hours	Labor Plus Travel & Living	Waste Processing & Shipping	Equipment Contracts & ***Supplies	Asbestos Waste Shipping & Disposal	Radwaste Shipping & Disposal	Total Cost
Hot Cell	529	$31,782	$6,111	$30,036		$3,402	$71,331
Isotope Shop	2,448	$147,043	$32,787	$9,162	$920	$10,932	$200,844
Decontamination Room	562	$33,750	$66,850	$2,324		$6,203	$109,127
High Level Waste Storage Room	534	$32,093	$14,342	$3,099		$8,640	$58,173
Clean Equipment Room	53	$3,206	$1,605	$448		$382	$5,641
HEPA Equipment Room	1,078	$64,720	$10,503	$5,765	$766	$10,368	$92,123
Dry Waste Storage Room	1,371	$82,328	$17,581	$5,794	$1,380	$16,553	$123,635
WHUT Room	1,093	$65,642	$18,962	$264,024	$153	$23,429	$372,210
All Other Areas	1,691	$101,569	$18,319	$8,048		$20,300	$148,236
Ship Sources Offsite	64	$4,640		$43,891			$48,531
Building Release Surveys	497	$42,706					$42,706
Outdoor Release Surveys	143	$12,257					$12,257
Planning, Training, Mobilization	624	$26,832					$26,832
Survey Documentation & Report	240	$13,702					$13,702
Contractor Home Office Oversight	385	$29,260					$29,260
AMS Oversight & Licensing	880	$66,880					$66,880
NRC Verification Survey							$15,000
TOTALS	12,193	$758,409	$187,060	$372,591	$3,219	$100,211	$1,436,489
			25% CONTINGENCY				$359,122
				GRAND TOTAL			$1,795,612

4.1 Cost Modifying Factors

There are modifying factors that significantly affect the overall cost for remediation. One of these factors is an adjustment for personnel protection requirements since various levels of personnel protection equipment will be required for remediation work. The degree of protection required depends upon the extent of contamination and specific activities to be performed in a given area. As the level of personnel protection increases, so does the impact on individual productivity and task duration. Adjustments were made to account for the implementation of personnel protective measures where applicable. A description of standardized levels of personnel protection, along with the associated impacts is provided in Table 4-2. The net impact is normalized over an 8 man-hour period.

Table 4-2
Personnel Radiological Protection Summary

Protection Level	Description	Task Impact Summary
Level D, used in uncontaminated areas only.	Hard hats, safety glasses and safety shoes. Respiratory protection and protective clothing are not required to perform work.	No lost time or worker time adjustment is necessary.
Level D (modified), used in areas potentially contaminated.	Hard hats, safety glasses, safety shoes and protective clothing are required, however respiratory protection is not required.	Approximately 15 minutes to don and remove protective clothing accounts for a 3% lost-time adjustment.
Level C, used in areas of elevated airborne activity.	Hard hats, safety shoes and a full face respirator are required in addition to protective clothing.	A 65 minute lost-time adjustment (14%) consists of the following factors: • Safety meeting - 5 min • Don/remove protective clothing - 30 min • Breaks - 30 min A worker's productivity is decreased by 15% due to wearing the full face respirator. Combining this 15% lost time adjustment with the 14% lost-time adjustment yields a net adjustment of approximately 29% or all tasks will take twice as long as Level D work.

The volume of radwaste requiring treatment and disposal can be a very significant modifying factor due to the high cost for radwaste disposal. For the Advanced Medical Systems decommissioning, the radwaste processing, shipping, and disposal costs are about 20% of the total decommissioning cost. Radwaste volume estimates are discussed in detail in the following section.

4.2 Radwaste Volume Estimates

The radwaste volume estimates are key to developing accurate decommissioning costs. Burial costs are based on waste volume and shipping costs are based on waste volume and weight. Spreadsheets were used to estimate the required volumes and weights. A summary of contaminated waste volumes and asbestos waste volumes is presented in Appendix B sheet B-1.

To address structural materials, the spreadsheet incorporated floor and wall dimensions, determined from drawings and direct measurements, along with the percent of the area contaminated. From this information, the volume of rubble for disposal was calculated. Table 4-3 presents a summary of the radwaste volumes calculated for the various areas of the Advanced Medical Systems Site.

Table 4-3
Unprocessed Waste Volume Summary for Advanced Medical Systems

Area Description	Bulk Waste Volume (ft^3)	Concrete Volume (ft^3)	Hardware & Demolition Volume (ft^3)	Lead Volume (ft^3)	Asbestos Volume (ft^3)
Hot Cell		1	337		
Isotope Shop		8	516		35
Decontamination Room		12	147	11	
High Level Waste Storage Room		0	319		
Clean Equipment Room		0	65		
HEPA Equipment Room		15	571		28
Dry Waste Storage Room		16	371		52
WHUT Room	14	14	660		9
Miscellaneous Areas	338	5	656	1	
TOTALS	352	70	3,642	12	123

4.3 Radwaste Disposal Costs

A significant portion of the overall decommissioning cost is generally attributed to the burial of radioactive and asbestos waste. The cost for disposal of radioactive waste was estimated to be \$181 per cubic foot, and low level asbestos waste was estimated to be \$150 per cubic foot at Envirocare in Utah.

The costs to transport waste for disposal are based on a transport distance of 250 miles to an unspecified Midwest Compact site in Ohio. It is assumed that only full loads of waste are transported, that a 40 foot Sea/Land container is the limiting volume and that 44,000 pounds is the limiting weight. The transport charge is $650 per load.

The cost to transport waste the central volume reduction facility in Oak Ridge Tennessee are based on a transport distance of 520 miles at a rate of $2.65 per mile. The costs to transport volume reduced waste for disposal are based on a transport distance of 500 miles from Oak Ridge Tennessee to an unspecified Midwest Compact site in Ohio.

The unit disposal cost factors are listed in Appendix B, sheet B-4.

4.4 Remediation Methods

The goal in choosing remediation methodologies is to select the minimum cost option to accomplish a task. There are many factors which need to be considered when selecting a methodology such as equipment cost, support equipment costs, material and chemical costs, the generation of secondary waste volumes (waste in addition to the removed contaminated material), processing rates, labor requirements, and applicability to various tasks. These factors were utilized in selecting the optimum methods for use at Advanced Medical Systems. The decontamination processes analyzed are summarized in Table 4-4. This table shows the decontamination methodology used, application information, the process cost per square foot of area decontaminated, and the amount of secondary waste generated. These unit factors are applied to specific areas or equipment requiring remediation to determine the most cost effective process.

Table 4-4
Decontamination Methodology Comparison

Methodology	Application	Nominal Penetration depth (in)	Process Rate (ft²/hr)	Crew Size	Total Process Cost ($/ft²)	Secondary Waste Volume (ft³/1000 ft²)
McDonald U-5 Scabbler	Floor concrete	0.25	150	2.0	$0.335	
McDonald U-5 Scabbler	Floor concrete	0.5	75	2.0	$0.575	
McDonald 3WCD Scabbler	Wall concrete	0.125	30	2.0	$1.248	
Blastrac 10D Shot Blaster	Floor concrete	0.063	750	1.1	$0.191	0.26
Blastrac 10D Shot Blaster	Floor concrete	0.125	375	1.1	$0.224	0.26
LTC 10-60Pn Special Vacuum Blaster	All surfaces	0.031	70	1.3	$0.574	0.26
LTC 10-60Pn Standard Vacuum Blaster	All surfaces	0.063	40	1.3	$0.834	0.26
EDCO CPU-10C Floor Plane	Floor concrete	0.50	93	2.0	$0.578	
EET Chemical Decon	Concrete		15	2.0	$10.000	6.68
Hands-on decon	Non-Porus surfaces		150	1.0	$0.162	8.33

4.5 Radwaste Volume Reduction Costs

The volume reduction processes analyzed for use at Advanced Medical Systems are summarized in Table 4-5. This table shows the volume reduction methodology used, application information, transportation charges, the process cost per unit weight or volume, and the total process cost per unit volume. These unit factors are applied to specific items of equipment requiring disposal to determine the most cost effective process.

Table 4-5
Volume Reduction Methodology Cost Information

VR Methodology	Applicability	Transport Container Type	Total Transport Cost ($)	Volume Reduction Factor	Waste Bulk Density (lb/ft³)	VR Process Charge Rate	Total VR Cost ($/ft³)
Super Compaction	Dry active waste	B-25	$10,378	6	20	$0.95	$24.29
Super Compaction	Metal Equipment	B-25	$9,478	6	25	$0.95	$29.12
Super Compaction	Metal Equipment	Custom	$6,778	4	75	$0.95	$90.08
Asbestos Compact	Asbestos	B-25	$10,378	6	20	$1.45	$34.29
Incineration	DAW	B-25	$10,378	100	20	$3.70	$79.29
Metal Melt	Metal (20 lb/ft³)	Custom	$9,478	Note 1	20	$1.95	$56.55
Metal Melt	Metal (75 lb/ft³)	Custom	$9,478	Note 1	75	$1.95	$163.80
Metal Melt	Metal (200 lb/ft³)	Custom	$4,528	Note 1	200	$1.95	$411.56
Lead Brick Decon	Lead Brick	Custom	$6,778	Note 1	650	$1.75	$1,156.33
Wood Incineration	Wood	B-25	$6,778	100	50	$2.00	$105.76

1. These processes recycle the processed material so there is no waste for disposal.

4.6 Unit Costs

There are a number of unit factors used to generate this cost estimate. They are listed here so project costs can be updated when required and the effects of changing units costs can be evaluated.

Table 4-6
Decommissioning Estimate Unit Cost Factors

Unit Cost Factor	Unit Cost Rate	Units
Radioactive Waste Disposal	$181.00	cubic foot
Waste Transportation to Midwest Compact	$650	trip
Waste Transportation to Oak Ridge for Volume Reduction	$2.65	mile
Asbestos Disposal Cost at Envirocare in Utah	$150	cubic foot
B-25 Waste Disposal Container	$450	each
Project Manager	$76	hour
Radiation Safety Officer	$45*	hour
Senior Radiological Engineer	$70	hour
HP Instrument Technician	$39	hour
HP Technician	$18*	hour
Decontamination Specialist	$18*	hour
Airfare	$562	round trip
Car Rental (one)	$22*	day
Per Diem	$116	day

*These costs provided by AMS who will provide there personnel and equipment.

4.7 Final Surveys

Final survey cost estimates are based on the methodology presented in NUREG/CR-2241, *Technology and Cost of Termination Surveys Associated With Decommissioning of Nuclear Facilities* (February 1982). This methodology requires the determination of the number of sample points for the various areas being surveyed and the type of survey being performed. The time to perform each of these surveys is determined, and the product of these two items is the labor time to perform the surveys. Equipment and material cost to perform the surveys is added along with staff support costs to determine a total cost. The survey requirements are based on (Draft) NUREG/CR-5849, *Manual for Conducting Radiological Surveys in Support of License Termination* (June 1992). A spreadsheet was developed which incorporates facility dimensions, labor rates and support cost ratios to estimate the final survey cost. The facility survey labor estimate is summarized in Appendix B, Sheet B-10 and the open land and miscellaneous area survey labor estimate is summarized in Appendix B, Sheet B-11.

5.0 DESCRIPTION OF THE DECOMMISSIONING SCENARIO

Decommissioning of the Advanced Medical Systems London Road site requires that residual radioactive materials be removed from the site to allow termination of the NRC license for this location. For the purposes of this cost estimate, once buildings, structures and soils are remediated to releasable limits, no further decontamination or demolition is required.

The following areas are considered in this cost estimate because they contain radioactive material or have previously contained radioactive material.

5.1 Hot Cell

The hot cell is six feet square and has 5-1/2 foot thick concrete walls and a four foot thick floor and ceiling. There is a stainless steel floor pan in the cell and 1/4 inch thick steel wall plates 11 foot tall. The cell has a six foot wide 42 ton hinged door at the rear. The cell will initially be used for the decontamination and shipping of the Co^{60} sources offsite. Approximately 60% of the sources will be shipped to a facility in California and 40% to a facility in Maryland. In order to accomplish this task, the cell will need to be partially decontaminated to allow handling of the sources without contaminating them. The existing Co^{60} sources in the cell will be moved out of the cell using the AMS cask and the "Transfer Monster". The cell will then be decontaminated by first vacuuming the cell using a remote HEPA system entering the cell through the rear cell door. The HEPA vacuum will be fitted with a shielded prefilter which will retain most of the removed Co^{60}. The vacuuming will be followed by chemical decontamination to remove the remaining surface contamination from the cell. The Hot cell lathe, welding machine, and weighing scale, will then be manually removed and shipped for volume reduction and disposal. Careful monitoring will be performed during this process to minimize exposure to hot spots that may be exposed during equipment removal. The sources will then be returned to the cell where they will be cleaned up using a chemical decontamination process. After verification of decontamination they will be shipped to the facilities in California and Maryland using the AMS cask. The remaining equipment in the hot cell, the hoist, hoist trolley, table, and manipulators will then be manually removed and shipped for volume reduction and disposal. The cell door will then be removed to allow decontamination of inaccessible parts of the door and door drive mechanism. The ventilation duct will be removed in conjunction with removal of the ductwork from adjacent areas. The hot cell will be surveyed as an affected area as part of the decommissioning.

5.2 Isotope Shop Area

The isotope shop is a 680 square foot area with concrete floor, ceiling, and interior walls, the exterior walls are painted brick. The hood, tables, sink, old trash compactor, 3 ton overhead hoist with trolley, wall cabinet, and Tow Motor will be removed and shipped for volume reduction and disposal. The shop floor will be decontaminated using a Blastrac vacuum shot blaster, the walls and ceiling will be decontaminated by manual wipe down. The isotope shop overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be removed and shipped for volume reduction and disposal. The isotope shop will be surveyed as an affected area as part of the decommissioning.

The "storage garden" and irradiation facility is located in the southwest corner of the isotope shop and contains 54 vertical tubes in a six foot square well extending from the first floor level to the basement level. All cobalt sources will have been removed from the hot cell prior to the start of decommissioning work. The "storage garden" tubes and spaces will be removed and shipped for volume reduction and disposal. The interior concrete walls and floor of the "storage garden" will be decontaminated using a vacuum blast unit. The "storage garden" will be surveyed as an affected area as part of the decommissioning.

The stairwell at the back of the Isotope room is constructed of steel with concrete steps. The steps have steel top edges which have a history of contamination in the joint areas. The steel top edges will be removed and shipped for volume reduction and disposal. The stairs will be decontaminated using a vacuum blast unit. The equipment under the stairs, two floor buffers, two buckets, two mops, and a lead sheet will be sent for volume reduction and disposal. The stairwell will be surveyed as an affected area as part of the decommissioning.

5.3 Decontamination Room

The decontamination room is a 135 square foot area with concrete floor, walls and ceiling. This is a high dose rate area and it will be decontaminated by first vacuuming the room and contents using a robotic HEPA system. The HEPA vacuum will be fitted with a shielded prefilter which will retain most of the removed Co^{60}. The vacuuming will be followed by robotic CO_2 blasting to remove accessible hot spots from the room and contents. The robot will be used to transfer hot items from the room and shielded vault to a shielded container for shipping for volume reduction and disposal. The wood blocks, shields and vault will then be manually removed and shipped for volume reduction and disposal. Careful monitoring will be performed during this process to minimize exposure to hot spots that may be exposed during equipment removal. The decontamination room overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be removed and shipped for volume reduction and disposal. The decontamination room will be surveyed as an affected area as part of the decommissioning.

5.4 High Level Waste Storage Room

The High Level Waste Storage Room Area is a 560 square foot area with concrete floors, walls and ceiling. The various shields containing Depleted Uranium (DU) in the front portion of the room will be removed from site as part of the decommissioning. There is no cost included for removal of the DU items as they have a significant value that will offset shipping costs to another location. The 24 drums of waste in the room are significant dose sources and they will be removed using a shielded forklift and moved to a shielded van and shipped for volume reduction and disposal. The 21 used HEPA filters in the room are significant dose sources and they will be moved to shielded containers using the robot and the containers will be moved with a shielded forklift to a shielded van and shipped for volume reduction and disposal. The other equipment in the room including the small cart, portable cabinet and wall cabinets will then be removed and surveyed for unrestricted release. The room floor, walls and ceiling, overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be cleared using a HEPA vacuum cleaner prior to being surveyed for release. The high level waste room will be surveyed as an affected area as part of the decommissioning.

5.5 Clean Equipment Room

The clean equipment room is a 727 square foot area with concrete floors, walls and ceiling. The contaminated air supply blower and the exhaust stack sampling system will be removed, packaged and shipped for volume reduction and disposal. The contaminated air supply blower is large and heavy and it will be sectioned, moved to the roof through a door and removed from the roof with a crane. Minor decontamination of the area will be done using manual wipe down. The clean equipment room will be surveyed as an unaffected area as part of the decommissioning. The contaminated equipment areas and the adjacent areas will be surveyed as affected areas as part of the decommissioning.

5.6 HEPA Equipment Room

The HEPA equipment room is a 240 square foot area with concrete floors, walls and ceiling. This is a high dose rate area and it will be decontaminated by first vacuuming the room and contents using a robotic HEPA system. The HEPA vacuum will be fitted with a shielded prefilter which will retain most of the removed Co^{60}. The vacuuming will be followed by robotic CO_2 blasting to remove accessible hot spots from the room and contents. Temporary shield blankets will be placed over and in front of remaining high dose areas such as the HEPA filters and vent ducts from the hot cell. The HEPA filters will be manually removed and packaged for shipment for volume reduction and disposal. The vent from the hot cell will be opened at the floor level using extension tools and the interior of the duct vacuumed using the robotic HEPA system. The HEPA exhaust blowers,

ductwork, and exhaust stack on the roof will be sectioned and packaged for shipping for volume reduction and disposal. The remaining equipment in the room including the abandoned emergency power generator, the hoist motor for the hot cell hoist, and a wood "A" frame with a small manually operated hoist attached will be removed manually and packaged for shipping for volume reduction and disposal. The duct from the room floor to the hot cell will be removed and packaged for shipping for volume reduction and disposal. The room floor will be decontaminated using a Blastrac vacuum shot blaster, the walls will be decontaminated by using scabbling, and the ceiling will be decontaminated using vacuum grit blasting. The room overhead lights, piping, conduit, and electrical boxes will be removed and shipped for volume reduction and disposal. The HEPA equipment room will be surveyed as an affected areas as part of the decommissioning.

The entry to the HEPA equipment room is a 132 square foot area with concrete floors, walls and ceiling. The portable HEPA filter unit will be used during the decommissioning project to maintain ventilation control and air quality. The ventilation control tent will be packaged for shipping for volume reduction and disposal. The entry area floor will be decontaminated using a Blastrac vacuum shot blaster, the walls and ceiling will be decontaminated by manual wipe down. The HEPA equipment room entry area will be surveyed as an affected areas as part of the decommissioning.

5.7 Dry Waste Storage Room

The dry waste storage room is a 752 square foot room with concrete floors, walls and ceiling. The room will first be HEPA vacuumed to pick up loose contamination. The 17 drums of waste in the room are significant dose sources and they will be moved using a shielded manual drum lift to a floor opening under the isotope shop. The drums will then be hoisted into the isotope shop and moved with a shielded forklift into a shielded van and shipped for volume reduction and disposal. The other equipment in the room including a large shop table with vise, and a 55 gallon waste holding tank will then be manually removed and shipped for volume reduction and disposal. The 650 high density concrete blocks in the room will be removed and shipped off site for decontamination and disposal. The room floor will be decontaminated using a Blastrac vacuum shot blaster, the walls will be decontaminated using a vacuum grit blaster, and ceiling will be decontaminated by manual wipe down. The room overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be removed and shipped for volume reduction and disposal. The dry waste storage room will be surveyed as an affected area as part of the decommissioning.

5.8 WHUT Room

The decommissioning of the WHUT room will not take place until the year 2018 to allow decay of the Co^{60} activity to a manageable level. The Waste Hold-Up (WHUT) room, including entry area, is a 162 square foot area with concrete floors, walls and ceiling. This is a high dose rate area due to sediment on the floor, in pipe traps, and in the waste holding tanks. As a result it will be decontaminated by first using a robot to remove debris from the room to a shielded shipping container and then vacuuming the floor and contents using a robotic HEPA system. The HEPA vacuum will be fitted with a shielded prefilter which will retain most of the removed Co^{60}. The vacuuming will be followed by robotic CO_2 blasting to remove adhered sediment and accessible hot spots from the room and contents. Temporary shield blankets will be placed over and in front of remaining high dose areas such as the waste holding tanks. The other equipment in the room including an abandoned drum compactor, two small ion exchange columns, and a table for the ion exchange columns, will be manually removed and shipped for volume reduction and disposal. The 100 and 500 gallon waste receiving tanks will be flushed with water that is recirculated through a high efficiency shielded filtration system to remove the sediment and Co^{60} activity. The spent filters, and hold up tanks will then be packaged and shipped for volume reduction and disposal. The room floor will be decontaminated using a concrete plane, the walls will be decontaminated using concrete scabbling equipment, and ceiling will be decontaminated by a vacuum grit blaster. The room overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be removed and shipped for volume reduction and disposal. The WHUT room will be surveyed as an affected area as part of the decommissioning.

5.9 Basement Clean Side

The basement clean side consists of three rooms, Air Sampling Room, ISODOSE Curve Room and Unoccupied Ro[illegible] with a total area of 550 square feet. The floors, ceiling, and exterior walls a[illegible]crete. The interior walls are standard 2 x 4 wood framed walls with a painte[illegible] wall surface. The rooms will first be HEPA vacuumed to pick up loose contamination The equipment in the rooms, a large plastic tank, an air sampler, large metal shelves, wooden shelf supports, ISODOSE Curves, sink with metal cabinet, two chairs, and two steel doors will be manually removed and shipped for volume reduction and disposal. The 45 high density concrete blocks in the unoccupied room will be removed and shipped off site for decontamination and disposal. The floors will be decontaminated using a Blastrac vacuum shot blaster the walls and ceiling will be decontaminated by manual wipe down. The overhead lights, piping, conduit, electrical boxes, and ventilation ductwork will be removed and shipped for volume reduction and disposal. The basement clean side will be surveyed as affected areas as part of the decommissioning.

5.10 Miscellaneous Areas

The miscellaneous areas at the London road site do not individually contribute significantly to the cost of decommissioning and are therefore presented in less detail than the previous areas. These remediation work for these areas is summarized in table 5-1.

Table 5-1
AMS London Road Site Miscellaneous Area Remediation

Area	Size of Area and Construction Materials	Equipment Removed for Volume Reduction & Disposal	Remediation Methods	Area Survey Category
Air Lock	320 ft², concrete floor & interior walls, metal ceiling & exterior walls.	Power cord for Isotope Room Tow Motor, 30 concrete shield blocks, and a utility cart	Blastrac for floor	Affected
Isotope Warehouse	4,668 ft², concrete floor, concrete block and clay brick walls, and metal ceiling.	Old hot cell shield window	None	Affected
Former Chemistry Lab	220 ft², concrete floor, clay brick walls, and metal ceiling.	None	None	Unaffected
Hot Cell Control Room	170 ft², concrete floor walls and ceiling.	None	None	Unaffected
First Floor Office Areas	4,600 ft², concrete floor and ceiling, and standard drywall.	None	None	Unaffected
Isotope Shop Locker Room	91 ft², concrete floor and ceiling, clay brick and standard drywall.	None	None	Affected
Instrument Calibration Room	988 ft², concrete floor, clay brick and standard drywall, and metal ceiling.	None	None	Affected
Caged Storage Area	1,564 ft², concrete floor, concrete block and clay brick walls, and metal ceiling.	None	None	Affected
Second Floor Office Areas	1,513 ft², concrete floor and ceiling, clay brick and standard drywall.	None	None	Affected
Sewers	121 lineal feet, iron pipe in buildings.	None	Chemical Decontamination	Affected
Outdoor Areas	Mostly paved with some natural soil areas.	None	None	Unaffected

6.0 REFERENCES

6.1 NRC, *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material*, April 1993.

6.2 Code of Federal Regulations, 10 CFR 70, *Domestic Licensing of Special Nuclear Material*

6.3 NRC Regulatory Guide 1.159, *Assuring the Availability of Funds For Decommissioning Nuclear Reactors*

6.4 NRC, February 20, 1992, Federal Register Vol. 47, No. 34, *Order Establishing Criteria and Schedule for Decommissioning the Bloomsburg Site, Attachment 3.*

6.5 NUREG/CR-1756, *Technology Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors*, March 1982

6.6 Means Building Construction Cost Data, 52nd Annual Edition, 1994, R.A. Means Company, Inc.

6.7 ORAU 89/B-145, April 1989, Oak Ridge Associated Universities, P.R. Cotten and G.L. Murphy, *Radiation Survey of the Advanced Medical Systems, Inc., London Road Facility, Cleveland, Ohio*

APPENDIX A

Radiological Data

- A-1, Radiological Data for Buildings
- A-2, Radiological Data for Outdoor Areas

Appendix A-1
ADVANCED MEDICAL SYSTEMS SURVEY DATA

AREA	DOSE RATE MAX AREA (mR/hr)	DOSE RATE AVG AREA (mR/hr)	TOTAL β-γ CONTAMINATION MAX FLOOR (dpm/100 cm^2)	TOTAL β-γ CONTAMINATION AVG FLOOR (dpm/100 cm^2)	SMEARABLE β-γ CONTAMINATION MAX FLOOR (dpm/100 cm^2)	SMEARABLE β-γ CONTAMINATION AVG FLOOR (dpm/100 cm^2)
Exterior Structure	0.07	0.07				
Exterior Structure Roof	14.00	2.46				
Isotope Warehouse Exterior Structure	0.06	0.05				
Isotope Warehouse Roof	0.15	0.03	110	46		
Front Stairwell [#2] (1988 data)	0.10	0.10	<710	<710	15	<6
Chemistry Lab [126] (1988 data)	0.10	<0.1	1,200	<1170	18	<6
Test Cell Control Room [123] (1988 data)	0.10	<0.1	1,500	<1170	<6	<6
Office [118] (1988 data)	0.10	0.10	1,200	<1170	7	6
Lobby Stairwell [#3] (1988 data)	<0.1	<0.1	<710	<710	6	<6
Hot Cell (1988 Data)	>20,000	3,000				
Isotope Hot Shop	10.00	1.00	187,560	98,335		
Isotope Hot Shop Source Storage Garden	2.00	<1	269,230	269,230		
Isotope Hot Shop Clean Locker Room (1988 data)	0.30	<0.1	1,700	1,000	<6	<6
Isotope Hot Shop Shower Room (1988 data)	<0.1	<0.1	100,000	1,000	49	10
Isotope Hot Shop Toilet Room (1988 data)	<0.1	<0.1	<710	<710	---	---
Isotope Hot Shop Dirty Locker Room (1988 data)	2.10	0.90	300,000	1,000		
Decon Room		>10	1,199,150	1,199,150	3,000,000	
Isotope Shop Stairwell [#1]	<1	<1	949,900	310,893		
High Level Waste Storage Room	400	400	100	75		
Airlock	1	<1	15,050	7,590		
Isotope Warehouse	50	1	160	128		
Instrument Calibration Room (1988 data)	<0.1	<0.1	<710	<710	<6	<6
Caged Storage Area (1987 data)					1,790	134

Data from "Radiation Survey of the Advanced Medical Systems, Inc. London Road Facility, Cleveland Ohio", Oak Ridge Associated Universities, ORAU 89/B-145, P. Cotten and G. Murphy, April 1989.

Appendix A-1

ADVANCED MEDICAL SYSTEMS SURVEY DATA

	DOSE RATE		TOTAL β-Γ CONTAMINATION		SMEARABLE β-Γ CONTAMINATION	
AREA	MAX AREA (mR/hr)	AVERAGE AREA (mR/hr)	MAX FLOOR (dpm/100 cm²)	AVERAGE FLOOR (dpm/100 cm²)	MAX FLOOR (dpm/100 cm²)	AVERAGE FLOOR (dpm/100 cm²)
Women's Room (1988 data)	0.10	0.10	<710	<710	10	<6
Second Floor Office Room 1 (1988 data)	0.20	0.10	2,700	1,500	9	<6
Second Floor Office Room 2 (1988 data)	0.10	0.10	2,700	1,350	35	11
Second Floor Office Room 3 (1988 data)	0.10	0.10	1,300	1,200	<6	<6
Second Floor Office Room 4 (1988 data)	0.10	0.10	<1,170	<1,170	7	<6
Second Floor Office Room 5 (1988 data)	0.10	0.10	<710	<710	<6	<6
Clean Equipment Room [207]	30.00	<1.0	190	167		
Men's Room (1988 data)			18,000	8,900	<6	<6
HEPA Equipment Room Entry Area (1988 data)			130,000	30,500	23	10
HEPA Equipment Room [206]	2,000	60	17,170	10,920		
Air Sampling Room [B2]	<1.0	<1.0	150	150		
ISODOSE Curve Room	<1.0	<1.0	210	210		
Unoccupied Room	20	10	3,410	3,410		
Dry Waste Storage Room [B-5]	50	7.17	2,116,280	853,523		
WHUT Room [B3], (1987 Data)	2,000,000	250,000				
WHUT Room Entry [B3] (1987 Data)	250,000	150,000			1.8 R/hr	[illegible].05 R/hr
Sewer Manhole - 1 each	3.00	0.84				

Data from "Radiation Survey of the Advanced Medical Systems, Inc. London Road Facility, Cleveland Ohio", Oak Ridge Associated Universities, ORAU 89/B-145, P. Cotten and G. Murphy, April 1989.

Appendix A-2

ADVANCED MEDICAL SYSTEMS OUTDOOR SURVEY DATA

No.	AREA	DOSE RATE Contact (μR/hr)	DOSE RATE at 1 meter (μR/hr)	RADIONUCLIDE CONCENTRATIONS Co-60 (pCi/g)	Cs-137 (pCi/g)
1	Blocked Entrance Door on East Side of Building	72	310	2.2	2.2
2	Approx 7 m from the East Side on Old RR Tracks	18	18	0.1	0.3
3	13 m South & 10 m East of NE Corner of Bldg	16	18	0.3	0.2
4	21 m South & 5 m East of NE Corner of Bldg	26	37	2.5	0.4
5	North of Drain on East Side of Bldg	134	310	<0.1	0.1
6	6 m East & 41 m South of NE Corner of Bldg	21	26	<0.1	0.3
7	52 m South & 5 m East of NE Corner of Bldg	14	14	1.3	0.4
8	2.5 m North from SE Corner of Bldg, Against Wall	11	11	2.3	0.4
9	At NE Corner of Bldg	9	9	<0.1	0.5
10	West Side of Sidewalk at Main Entrance Door	10	10	0.6	0.5
11	In Shrub Bed at West side of Front Driveway	7	8	0.2	0.8
12	NW Corner of Bldg at Fence Corner Nearest fo Sidewalk	7	7	<0.1	0.3

tes:

. Data from "Radiation Survey of the Advanced Medical Systems, Inc. London Road Facility, Cleveland Ohio", Oak Ridge Associated Universities, ORAU 89/B-145, P. Cotten and G. Murphy, April 1989.

2. A higher dose rate at 1 meter distance than on contact indicates that the source is shine from the structure and not from radioactive material in the soil.

APPENDIX B

Cost Calculation Sheets for Advanced Medical Systems

- B-1, Contaminated and Asbestos Waste Volume Summaries
- B-2, Contaminated Waste Disposal Cost
- B-3, Asbestos Waste Disposal Cost
- B-4, Waste Shipping Container Cost, Unit Disposal Cost Factors, and Waste Disposal Summary
- B-5, Volume Reduction Transportation Summary
- B-6, Building Area Survey Labor Estimate
- B-7, Open Land Areas Survey Labor Estimate
- B-8, Estimated Midwest Compact Burial Charges
- B-9, Hot Cell Decontamination Special Process Charges
- B-10, WHUT Room Decontamination Special Equipment Costs
- B-11, AMS Cobalt-60 Source Decontamination and Shipping Costs
- B-12, Project Instrumentation Costs

APPENDIX B-1

ADVANCED MEDICAL SYSTEMS CONTAMINATED WASTE VOLUME SUMMARY

	Area Description	Reduced Hardware Volume (ft^3)	Decon Waste Volume (ft^3)	Removed Concrete Volume (ft^3)	Generated Waste Volume (ft^3)	Total Waste Volume (ft^3)
1	Hot Cell	10.0	3.1	0.6	5	19
2	Isotope Shop	28.3	16.9	7.9	7	60
3	Decon Room	0.1	15.5	11.5	7	34
4	High Level Waste Storage Room	42.7	1.8	0.0	3	48
5	Clean Equipment Room	0.1	0.0	0.0	2	2
6	HEPA Equipment Room	19.4	15.5	15.1	7	57
7	Dry Waste Storage Room	54.6	17.7	15.7	3	91
8	WHUT Room	8.7	22.8	14.3	83	129
9	All Other Areas	70.4	29.2	5.0	7	112
	TOTALS:	234	123	70	124	551

ADVANCED MEDICAL SYSTEMS

ASBESTOS WASTE VOLUME SUMMARY

	Area Description	Asbestos Volume (ft^3)
1	Hot Cell	
2	Isotope Shop	6
3	Decon Room	
4	High Level Waste Storage Room	
5	Clean Equipment Room	
6	HEPA Equipment Room	5
7	Dry Waste Storage Room	9
8	WHUT Room	1
9	All Other Areas	
	TOTAL:	21

APPENDIX B-2

ADVANCED MEDICAL SYSTEMS CONTAMINATED WASTE DISPOSAL COST

	Area Description	Reduced Hardware Disposal Cost	Decon Waste Disposal Cost	Removed Concrete Disposal Cost	Generated Waste Disposal Cost	Total Waste Disposal Cost
1	Hot Cell	$1,810	$561	$109	$905	$3,385
2	Isotope Shop	$5,122	$3,059	$1,430	$1,267	$10,878
3	Decon Room	$18	$2,806	$2,082	$1,267	$6,172
4	High Level Waste Storage Room	$7,729	$326	$0	$543	$8,598
5	Clean Equipment Room	$18	$0	$0	$362	$380
6	HEPA Equipment Room	$3,511	$2,806	$2,733	$1,267	$10,317
7	Dry Waste Storage Room	$9,883	$3,204	$2,842	$543	$16,471
8	WHUT Room	$1,575	$4,127	$2,588	$15,023	$23,313
9	All Other Areas	$12,742	$5,285	$905	$1,267	$20,200
	TOTALS:	$42,408	$22,173	$12,688	$22,444	$99,713

ADVANCED MEDICAL SYSTEMS CONTAMINATED WASTE PACKAGING & SHIPPING COST

	Area Description	Reduced Hardware Volume (ft^3) ($)	Decon Waste Volume (ft^3) ($)	Removed Concrete Volume (ft^3) ($)	Generated Waste Volume (ft^3) ($)	Total Waste Volume (ft^3) ($)
1	Hot Cell	$9	$3	$1	$5	$17
2	Isotope Shop	$26	$15	$7	$6	$54
3	Decon Room	$0	$14	$10	$6	$31
4	High Level Waste Storage Room	$39	$2	$0	$3	$43
5	Clean Equipment Room	$0	$0	$0	$2	$2
6	HEPA Equipment Room	$18	$14	$14	$6	$51
7	Dry Waste Storage Room	$49	$16	$14	$3	$82
8	WHUT Room	$8	$21	$13	$75	$116
9	All Other Areas	$64	$26	$5	$6	$101
	TOTALS:	$212	$111	$63	$112	$498

APPENDIX B-3
ADVANCED MEDICAL SYSTEMS
ASBESTOS WASTE DISPOSAL COST

Area Description		Asbestos Waste Cost ($)
1	Hot Cell	$0
2	Isotope Shop	$900
3	Decon Room	$0
4	High Level Waste Storage Room	$0
5	Clean Equipment Room	$0
6	HEPA Equipment Room	$750
7	Dry Waste Storage Room	$1,350
8	WHUT Room	$150
9	All Other Areas	$0
TOTAL:		$3,150

ADVANCED MEDICAL SYSTEMS
ASBESTOS WASTE PACKAGING & SHIPPING COST

Area Description		Asbestos Waste Cost ($)
1	Hot Cell	$0
2	Isotope Shop	$20
3	Decon Room	$0
4	High Level Waste Storage Room	$0
5	Clean Equipment Room	$0
6	HEPA Equipment Room	$16
7	Dry Waste Storage Room	$30
8	WHUT Room	$3
9	All Other Areas	$0
TOTAL:		$69

APPENDIX B-4

ADVANCED MEDICAL SYSTEMS WASTE SHIPPING CONTAINER COST

	Area Description	Waste Volume (ft^3)	B-25 Waste Containers (Ea.)*	Waste Container Cost ($)
1	Hot Cell	19	0	$86
2	Isotope Shop	66	1	$304
3	Decon Room	34	0	$157
4	High Level Waste Storage Room	48	0	$218
5	Clean Equipment Room	2	0	$10
6	HEPA Equipment Room	62	1	$285
7	Dry Waste Storage Room	100	1	$459
8	WHUT Room	130	1	$596
9	All Other Areas	112	1	$512
	TOTALS:	**572**	**6**	**$2,626**

* *Fractional containers used for cost calculations.*

ADVANCED MEDICAL SYSTEMS UNIT DISPOSAL COST FACTORS

Estimated radwaste disposal rate for Midwest Compact :	$181.00	per cubic foot
Estimated asbestos waste rate for Enviriocare in Utah :	$150	per cubic foot
Estimated transport rate to Midwest Compact :	$24	per cubic yard
Estimated transport rate to Midwest Compact :	$650	per load
Estimated mileage rate to Midwest Compact :	$2.65	per mile
Estimated transport distance to Midwest Compact :	250	miles
Estimated average waste density to Midwest Compact :	60	lb/cubic foot
Estimated transport rate to Envirocare in Utah :	$89	per cubic yard
Estimated transport rate to Envirocare in Utah :	$2,927	per load
Estimated transport distance to Enviriocare in Utah :	1,825	miles
Estimated mileage rate to Enviriocare in Utah :	$2.65	per mile
Estimated average waste density to Envirocare in Utah :	30	lb/cubic foot
Truck transport waste weight limit :	44,000	pounds
Estimated cost of used B-25 shipping containers :	$450.00	each

ADVANCED MEDICAL SYSTEMS WASTE DISPOSAL SUPPORT LABOR ESTIMATE

	Area Description	B-25 Waste Containers (Ea.)	Radioactive Waste Shipments (Ea.)	Waste Shipment Labor (man-hr)
1	Hot Cell	0.2	0.0	0.3
2	Isotope Shop	0.7	0.1	0.9
3	Decon Room	0.3	0.0	0.5
4	High Level Waste Storage Room	0.5	0.0	0.6
5	Clean Equipment Room	0.0	0.0	0.0
6	HEPA Equipment Room	0.6	0.1	0.8
7	Dry Waste Storage Room	1.0	0.1	1.4
8	WHUT Room	1.3	0.1	1.8
9	All Other Areas	1.1	0.1	1.5
	TOTALS:	**6**	**0**	**8**

Estimated waste loading operator time :	4	hr per load
Estimated HP Tech time per rad or mixed waste load :	4	hr per load
Estimated HP shipper time per rad or mixed waste load :	8	hr per load
Estimated clean waste shipping volume limit :	1176	ft^3 per load
Estimated radwaste shipping volume limit :	12	B-25 Boxes

APPENDIX B-5

ADVANCED MEDICAL SYSTEMS VR WASTE TRANSPORT SUMMARY

input Loc. code	Original Contaminated Volume (ft^3)	B-25 Waste Containers (ea.)	Waste Container Cost ($)	Radioactive Waste Shipments (ea.)	Waste Shipment Labor (man-hr)
1.70	327	3.3	$1,499	0.3	4.4
1.71	415	4.2	$1,905	0.4	5.6
1.73	52	0.5	$239	0.0	0.7
1.77	0	0.0	$0	0.0	0.0
1.78	136	1.4	$626	0.1	1.9
1.79	14	0.1	$63	0.0	0.2
1.80	308	3.1	$1,416	0.3	4.2
1.81	9	0.1	$41	0.0	0.1
1.82	234	2.4	$1,074	0.2	3.2
1.85	52	0.5	$239	0.0	0.7
2.16	64	0.6	$292	0.1	0.9
2.20	0	0.0	$0	0.0	0.0
2.21	11	0.1	$49	0.0	0.1
2.22	550	5.6	$2,525	0.5	7.5
3.10	130	1.3	$599	0.1	1.8
3.11	113	1.2	$518	0.1	1.5
3.12	18	0.2	$83	0.0	0.2
3.13	343	3.5	$1,576	0.3	4.7
3.15	630	6.4	$2,891	0.5	8.6
3.16	9	0.1	$40	0.0	0.1
4.12	42	0.4	$193	0.0	0.6
Total	3,455	35	$15,866	2.9	47

.PPENDIX B-6

.DVANCED MEDICAL SYSTEMS SURVEY COST ESTIMATE FOR BUILDINGS

AREA	WIDTH (ft)	LENGTH (ft)	HEIGHT (ft)	SURFACE AREA FLOOR (m²)	LOWER WALLS (m²)	UPPER WALLS (m²)	CEILING (m²)	ROOF (m²)	TOTAL (m²)	FLOOR + L. WALL SURVEY CODE	U. WALL CEILING SURVEY CODE	FLOOR + L. WALL SURVEY POINTS	U. WALL + CEILING SURVEY POINTS	ROOF SURVEY POINTS	TOTAL SMEAR POINTS	DIRECT SURVEY LABOR (hrs)
Main Bldg Exterior Structure	50.0	70.0	29.0		146	500		325	972	1	4	30	30	30	90	5
Research Bldg Exterior Structure	58.0	83.0	29.0		169	579		432	1,181	1	4	30	30	30	90	[illegible]
Isotope Warehouse Exterior Structure	60.0	83.0	14.5		174	211		463	848	1	4	30	30	30	90	[illegible]
Main Warehouse Exterior Structure	60.0	87.0	14.5		191	232		541	964	1	4	30	30	30	90	5
Main Entrance Hallway [128]	9.0	19.0	14.0	16	34	39	16		105	1	4	30	30		60	4
Front Stairwell [#2]	8.5	16.5	39.5	13	30	153	13		210	1	4	30	30		60	4
Front Office [127]	12.5	17.0	14.0	20	36	41	20		116	1	4	30	30		60	4
Chemistry Lab [126]	12.0	18.5	14.0	21	37	42	21		121	1	4	30	30		60	4
Test Cell and Radiography Control Room [123]	5.0	34.0	14.0	16	48	54	16		133	1	4	30	30		60	4
Research Area [120]	35.0	51.0	14.0	166	105	119	166		555	1	4	30	30		60	4
Office [118]	9.0	11.0	14.0	9	24	28	9		70	1	4	30	30		60	4
Office [119]	9.0	11.0	14.0	9	24	28	9		70	1	4	30	30		60	4
Corridor [103]	6.0	81.0	14.0	45	106	120	45		317	1	4	30	30		60	4
Dark Room [117]	7.0	11.0	14.0	7	22	25	7		61	1	4	30	30		60	4
Short Hall [111]	7.5	12.0	14.0	8	24	27	8		67	1	4	30	30		60	4
Womens Lounge & Toilet [116]	11.0	13.0	14.0	13	29	33	13		89	1	4	30	30		60	4
Janitors Closet [114]	5.0	5.5	14.0	3	13	15	3		32	1	4	30	30		60	4
Pipe Space [140]	2.0	11.0	14.0	2	16	18	2		38	1	4	30	30		60	4
Mens Toilet [113]	10.5	11.0	14.0	11	26	30	11		77	1	4	30	30		60	4
Library [112]	11.0	16.8	14.0	17	34	38	17		107	1	4	30	30		60	4
Lobby [102]	20.2	29.0	14.0	54	60	68	54		237	1	4	30	30		60	4
Lobby Closet [105]	4.0	8.0	14.0	3	15	17	3		37	1	4	30	30		60	4
Lobby Closet [106]	2.0	5.0	14.0	1	9	10	1		20	1	4	30	30		60	4
Lobby Closet [104]	2.5	5.0	14.0	1	9	10	1		22	1	4	30	30		60	4
Lobby Stairwell [#3]	9.0	15.0	29.0	13	29	100	13		154	1	4	30	30		60	4
Main Warehouse	81.0	88.0	14.5	662	206	249	662		1,780	1	4	30	30		60	4
Women's Room	7.0	15.0	14.5	10	27	32	10		79	1	4	30	30		60	4
Room 1	14.5	39.0	14.5	53	65	79	53		249	1	4	30	30		60	4
Room 2	16.5	25.5	14.5	39	51	62	39		191	1	4	30	30		60	4
Room 3	11.0	16.5	14.5	17	34	41	17		108	1	4	30	30		60	4
Room 4	10.0	11.0	14.5	10	26	31	10		77	1	4	30	30		60	4
Room 5	10.0	13.0	14.5	12	28	34	12		86	1	4	30	30		60	4
Clean Equipment Room [207] - part A	19.0	27.5	14.5	49	57	69	49		222	1	4	30	30		60	4
Clean Equipment Room [207] - part B	12.0	17.0	14.5	19	35	43	19		116	1	4	30	30		60	4
TOTALS				1,318	1,940	3,175	1,318	1,760	9,511			1,020	1,020	120	2,160	124

Notes: *Room number codes from Drawing 635, Sheet A-1, Rev 2, McGeorge-Hargett & Associates*

ᵖPENDIX B-6

)VANCED MEDICAL SYSTEMS SURVEY COST ESTIMATE FOR BUILDINGS

AREA	WIDTH (ft)	LENGTH (ft)	HEIGHT (ft)	SURFACE AREA FLOOR (m²)	LOWER WALLS (m²)	UPPER WALLS (m²)	CEILING (m²)	ROOF (m²)	TOTAL (m²)	FLOOR + L. WALL SURVEY CODE	U. WALL CEILING SURVEY CODE	FLOOR + L. WALL SURVEY BLOCKS	FLOOR + L. WALL SURVEY POINTS	U. WALL + CEILING SURVEY POINTS	ROOF SURVEY POINTS	GAMMA SURVEY or SMEAR POINTS	DIRECT SURVEY LABOR (hrs)
ɔt Cell	8.0	10.0	14.0	8	20	22	8		53	1	4	25	38	30		55	4
ɔtope Hot Shop	10.3	32.5	14.5	31	52	63	31		178	1	4	83	125	30		113	6
ɔtope Hot Shop	13.3	26.0	14.5	32	48	58	32		170	1	4	80	120	30		110	6
ɔtope Hot Shop Source Storage Garden	8.0	9.7	14.5	7	22	26	7		62	1	4	29	43	30		59	4
ɔtope Hot Shop Clean Locker Room	8.0	9.7	14.5	7	22	26	7		62	1	4	29	43	30		59	4
ɔtope Hot Shop Shower Room	6.5	8.0	14.5	5	18	21	5		49	1	4	23	34	30		53	3
ɔtope Hot Shop Toilet Room	5.7	13.0	14.5	7	23	28	7		64	1	4	30	44	30		60	4
ɔtope Hot Shop Dirty Locker Room	7.0	13.0	14.5	8	24	29	8		71	1	4	33	49	30		63	4
econ Room	9.0	15.0	14.5	13	29	35	13		90	1	4	42	63	30		72	4
ɔtope Shop Stairwell [#1]	9.0	17.0	25.0	14	32	89	14		149	1	4	46	69	30		76	5
igh Level Waste Storage Room	16.0	35.0	14.5	52	62	75	52		241	1	4	114	171	30		144	8
irlock	10.0	32.0	14.5	30	51	62	30		173	1	4	81	121	30		111	6
ɔtope Warehouse	80.0	77.8	14.5	433	168	203	433		1,238	1	4	601	902	95		697	37
ıstrument Calibration Room	26.0	38.0	14.5	92	78	94	92		356	1	4	170	255	30		200	11
aged Storage Area	34.0	46.0	14.5	145	98	118	145		506	1	4	243	364	39		282	15
emporary Waste Storage Area [SW corner]	9.0	24.0	14.5	20	40	49	20		129	1	4	60	90	30		90	5
ten's Room	7.0	13.5	14.5	9	25	30	9		73	1	4	34	51	30		64	4
EPA Equipment Room Entry Area	11.0	12.0	14.5	12	28	34	12		86	1	4	40	60	30		70	4
EPA Equipment Room [206]	15.0	16.0	11.5	22	38	28	22		111	1	4	60	90	30		90	5
ir Sampling Room [B2]	13.6	14.8	10.5	19	35	21	19		93	1	4	53	60	30		83	5
SODOSE Curve Room	10.8	16.8	10.5	17	34	20	17		88	1	4	51	76	30		81	5
noccupied Room	11.5	14.5	10.5	16	32	19	16		82	1	4	47	71	30		77	5
ry Waste Storage Room [B-5], part A	24.0	26.0	10.5	58	61	37	58		213	1	4	119	178	30		149	8
ry Waste Storage Room [B-5], part B	8.0	16.0	10.5	12	29	18	12		71	1	4	41	62	30		71	4
iquid Waste Holding Tank (WHUT) Room [B3]	10.5	11.0	10.5	11	26	16	11		63	1	4	37	55	30		67	4
VHUT Room Entry [B3]	5.5	8.5	10.5	4	17	10	4		36	1	4	21	32	30		51	3
ource Storage Garden Sand Shield [B6]	5.5	19.5	10.5	10	30	18	10		69	1	4	40	61	30		70	4
ource Storage Garden [B6]	6.0	6.0	10.5	3	15	9	3		30	1	4	18	30	30		50	3
ewer Manhole - 1 each	4.0	4.0	12.0	1	10	8	1		21	1	4	11	30	30		50	3
ewer Catch Basins - 7 each	2.0	2.0	8.0	0	5	1	0		7	1	4	5	30	30		50	23
TOTALS				1,097	1,170	1,269	1,097	0	4,633			2,267	3,439	975	0	3,267	207
GRAND TOTALS				2,415	3,110	4,444	2,415	1,760	14,144				4,459	1,995	120	5,427	331

otes: *Room number codes from Drawing 635, Sheet A-1, Rev 2, McGeorge-Hargett & Associates*

Appendix B-7

ADVANCED MEDICAL SYSTEMS OPEN LAND & MISCELLANEOUS SURVEY LABOR ESTIMATE

UNAFFECTED OPEN LAND AREAS

SURFACE	AREA	WIDTH (ft)	LENGTH (ft)	WIDTH (m)	LENGTH (m)	WIDTH (blocks)	LENGTH (blocks)	AREA (m²)	SURVEY BLOCKS	100% SCANS	100% PLAN SAMPLE POINTS	100% GAMMA SURVEY POINTS	10% SURVEY LABOR (hrs)
Paved/Grass	Front of Building To London Road	30.0	132.5	9.1	40.4	1	5	369	5	5	30	5	7
Paved/Grass	South of Building & Across Railroad Tracks	90.0	170.0	27.4	51.8	3	6	1,421	18	18	30	18	8
Paved/Grass	North of Building to Mandalay Avenue	160.0	250.0	48.8	76.2	5	8	3,718	40	40	30	40	11
Paved/Grass	Rear South of Building to Easement	140.0	220.0	42.7	67.1	5	7	2,861	35	35	30	35	10
Paved/Grass	Rear North of Building to Easement	70.0	250.0	21.3	76.2	3	8	1,626	24	24	30	24	9
	TOTALS							9,994	122	122	150	122	44

SEWER PIPE SURVEY

BUILDING	AREA	DIAMETER (in)	LENGTH (ft)	SURVEY RATE (ft/hr)	CREW SIZE	SURVEY LABOR (hrs)
Hot Cell	12" V.S.P. Sewer Line parallel to Bldg Front	12.0	185	40	2	9
Hot Cell	15" V.S.P. Sewer to 58" Brick Main in Street	15.0	55	40	2	3
Hot Cell	10" V.S.P. Sewer Main Under Building	10.0	215	40	2	11
Hot Cell	6" V.S.P. Sewer Laterals Under Building	6.0	100	40	2	5
Hot Cell	4" V.S.P. Sewer Laterals Under Building	4.0	120	40	2	6
	TOTALS		675	200	10	34

GRAND TOTAL : 78

Appendix E-6

ESTIMATED MIDWEST COMPACT BURIAL CHARGE BASED ON CURRENT BARNWELL RATES FOR AN UNSHIELDED LSA WASTE SHIPMENT

USER INPUT DATA SECTION

CASK SHIPMENT (Y/N)	PACKAGE WEIGHT (LBS)	TOTAL CURIES	PACKAGE VOLUME (FT^3)	SHIELDED SHIPMENT (Y/N)?	SNM SHIPMENT (Y/N)?	SNM QUANTITY (g)	BIOLOGICAL WASTE SHIPMENT (Y/N)
N	3600	0.5	98	N	N	0	N

SITE SET-UP REQUIRED (Y/N)?	IRRADIATED HARDWARE SHIPMENT (Y/N)	UNSHIELDED SHIPMENT WITH H-3 or C-14 (Y/N)?	STATE CODE (Two Letters)	CLASS B/C LINER SHIPMENT (Y/N)	CLASS B/C DRUM SHIPMENT (Y/N)?	CLASS B/C OVERPACK SHIPMENT (Y/N)
N	N	N	OH	N	N	N

BARNWELL FEE CALCULATION DATA

CASK HANDLING CHARGE – (Minimum $3,000)	$3,000	per cask
SNM SURCHARGE –	$10.00	per gram
BARNWELL SURCHARGE –	2.4%	
SITE SETUP CHARGE – (Minimum $17,600)	$17,600	per shipment

SOUTHEAST COMPACT RATES

STANDARD VOLUME CHARGE –	$152.00	per cubic foot
BIOLOGICAL WASTE VOLUME CHARGE –	$167.00	per cubic foot
SNM VOLUME CHARGE –	$152.00	per cubic foot
BASE DISPOSAL CHARGE =	***$152.00***	***per cubic foot***
STABILIZATION & CLOSURE CHARGE –	$12.60	per cubic foot
MINIMUM SHIPMENT CHARGE –	$1,000.00	per shipment
IRRADIATED HARDWARE SURCHARGE –	$15,000.00	per liner overpack

WEIGHT SURCHARGE RANGES & COSTS

0 TO 1,000 LBS	—
1,000 TO 5,000 LBS	$1,250
5,000 TO 10,000 LBS	—
10,000 TO 20,000 LBS	—
20,000 TO 30,000 LBS	—
30,000 TO 40,000 LBS	—
40,000 TO 50,000 LBS	—
< 50,000 LBS	—
SURCHARGE:	$1,250

SHIELDED SHIPMENT CURIE SURCHARGE RANGES & COSTS

0 TO 5 CURIES	—
5 TO 15 CURIES	—
15 TO 25 CURIES	—
25 TO 50 CURIES	—
50 TO 75 CURIES	—
75 TO 100 CURIES	—
100 TO 150 CURIES	—
150 TO 250 CURIES	—
250 TO 500 CURIES	—
500 TO 1000 CURIES	—
> 1,000 CURIES	—
SURCHARGE:	$0

CLASS B/C WASTE SURCHARGES :

Large Liners (82" dia x 79" ht, max)	$12,500	per liner
Overpacks (33" dia x 79" ht, max)	$6,000	per overpack
55-Gal Drum (25.5" dia x 36" ht, max)	$1,500	per drum
SURCHARGE	$0	per cubic foot

SPECIFIC BURIAL FEE CALCULATIONS

COMPACT: **Midwest** COMPACT STATUS CODE: **3** **MW Compact Member**

BASE DISPOSAL CHARGE –	$155.65	per cubic foot
SITE STABILIZATION AND CLOSURE FUND –	$12.60	per cubic foot
TOTAL VOLUME CHARGE –	**$168.25**	**per cubic foot**
RADWASTE VOLUME –	98	cubic feet
RADWASTE VOLUME CHARGE –	$16,488.30	
CURIE SURCHARGE –	$0.00	
WEIGHT SURCHARGE –	$1,250.00	
CASK USE SURCHARGE –	$0.00	
SNM SURCHARGE –	$0.00	
SITE SETUP SURCHARGE –	$0.00	
CLASS B/C WASTE SURCHARGE –	$0.00	
IRRADIATED HARDWARE OVERPACK SURCHARGE –	$0.00	

TOTAL BURIAL FEE -- $17,738.30

TOTAL ($ / FT^3) -- $181.00

Cost basis for the Midwest Compact is based on the fact that a disposal site has not been chosen and that no disposal rates for the site have been quoted. This estimate uses July 1, 1994 Barnwell rates.

Appendix B-9

AMS HOT CELL DECONTAMINATION SPECIAL PROCESS CHARGES

Semi-Remote Decontamination Using Moveable Shields,

Remote Tools Robotics and Chemical Cleaning

Chemical Cleaning Duration	4	weeks	
Cost Category	*Rate*	*Unit*	*Cost*
Mobilization of Chemical Cleaning Contractor	$5,000	each	$5,000
Remote Handling Equipment & Shield	$4,700	per week	$18,800
Chemical Cleaning Waste Product Solidification	$3,200	per week	$3,200
TOTAL			**$27,000**

APPENDIX B-10

AMS WHUT ROOM DECONTAMINATION SPECIAL EQUIPMENT CHARGES

Remote Decontamination Using Robotics and Blast Cleaning

CO2 Blast Cleaning Cost

CO2 Blast Cleaning Duration	4	weeks	
Cost Category	*Rate*	*Unit*	*Cost*
Mobilization of CO2 Blast Cleaning Equipment*	$22,000	each	$22,000
CO2 Blast Cleaning Equipment Lease*	$8,000	per week	$32,000
Ventillation Equipment Lease*	$34,000	each	$34,000
Remote Handling Equipment & Shield*	$4,700	per week	$18,800
CO2 Blast Cleaning Procedure*	$1,500	each	$1,500
Liquid Nitrogen*	$2,415	per week	$9,660
Fuel*	$1,200	per week	$4,800
HEPA Filters*	$1,000	per week	$4,000
Technician Labor (3 techs)*	$5,355	per week	$21,420
TOTAL			**$148,180**

W.H.U.T. ROOM DECONTAMINATION ROBOTICS SUPPORT

WHUT Room Cleaning Duration	4	weeks	
Cost Category	*Rate*	*Unit*	*Cost*
Mobilization of Robotics Equipment	$10,700	each	$10,700
Robotics Unit	$66,500	each	$66,500
Robotics Tools	$10,700	each	$10,700
Technician Labor	$5,355	per week	$21,420
TOTAL			**$109,320**

**** Costs based on a price quote by Hot Cell Services***

Appendix B-11

AMS COBALT 60 SOURCE DECONTAMINATION AND SHIPPING

Decontamination Using Existing Manipulators and Chemical Cleaning

Shipping via existing AMS cask and comercial carrier

COBALT 60 SOURCE DECONTAMINATION

Co-60 Source Decontamination Duration	1	weeks	
Cost Category	***Rate***	***Unit***	***Cost***
Mobilization of Chemical Cleaning Contractor	$5,000	each	$5,000
Decontamination Chemical & Equipment Costs	$1,500	each	$1,500
Remote Decontamination Labor	$4,500	per week	$4,500
Chemical Cleaning Waste Product Solidification	$500	each	$500
TOTAL			**$11,500**

COBALT 60 SOURCE SHIPPING

	No.	Curies	
Co-60 Source Shipments to Maryland	2	27,650	
Co-60 Source Shipments Valecetos	3	42,350	
Allowable curies per shipment in cask		13,830	
Cost Category	***Rate***	***Unit***	***Cost***
Mobilization of Shipping Cask	$1,137	one time	$1,137
Labor to Load Cask & Prepare for Shipping	$2,080	per load	$10,400
Shipping distance to Maryland	716	miles	
Shipping distance to GE Valectos and return	4,970	miles	
Cask Transportaion Rate per mile	$1.56	mile	
AMS Cask Lease Rate	$0	per day	
Cask Lease Days for Maryland Shipments	2	days	
Cask Lease Days for GE Valectos Shipments	11	days	
Shipping cost to Maryland			$2,234
Shipping cost to GE Valectos			$23,260
TOTAL			**$37,031**

ppendix B-12
MS PROJECT INSTRUMENTATION COSTS
ONDON ROAD FACILITY
ECOMMISSIONING COST ESTIMATE

TN, Sales Tax = 8.75% W/O Roane Co. = 6.00%

OTAL PROJECT
DURATION (months): 7
Average Onsite Staff: 8

ITEM	RADIATION-PROTECTION INSTRUMENTATION FOR DECOMMISSIONING	LEASE PERIOD Inst-mo	LIFE IN YEARS	LIFE IN MONTHS	UNIT PRICE	TN TAX	UNIT COST	UNIT LEASE RATE	TASK RENTAL
	Instrumentation provided at monthly rental rate								
1	EBERLINE - PORTABLE ALPHA COUNTER MODEL / SAC-4:	1	1	12	$3,380	$246.82	$3,627	$302	$302
2	EBERLINE - PORTABLE BETA COUNTER MODEL / BC-4:	7	1	12	$2,607	$200.45	$2,808	$234	$1,638
3	EBERLINE - PORTABLE ION CHAMBER INSTRUMENT MODEL R02:	7	1	12	$945	$82.65	$1,027	$86	$599
4	BURK'S - HV-1 HIGH VOLUME AIR SAMPLERS W/ SAMPLE HEAD:	6	1	12	$750	$65.63	$816	$68	$408
5	BURK'S - LV-1 LOW VOLUME AIR SAMPLERS W/ SAMPLE HEAD:	12	1	12	$680	$59.50	$740	$62	$740
6	LUDLUM - MODEL 12 FRISKER WITH 44-9 PROBE & HARD CASE:	7	1	12	$653	$57.16	$710	$59	$414
7	LUDLUM - MODEL 19 MICRO R METER WITH HARD CASE:	7	1	12	$867	$75.86	$943	$79	$550
8	LUDLUM - FLOOR MONITOR CART W/ O PROBE MODEL 239-1F FOR USE WITH 2350 MONITOR:	8	1	12	$2,155	$173.29	$2,328	$194	$1,552
9	LUDLUM - FLOOR MONITOR CART W/ O PROBE MODEL 239-1F FOR USE WITH CM7A CONTAMINATION MONITOR:	7	1	12	$1,572	$137.53	$1,709	$142	$997
10	LUDLUM - MODEL 2350 WITH KEYPAD, BARCODE READER, HEADPHONES, HARD CASE AND THE FOLLOWING DETECTORS: 43-68 100 cm2 GAS PROPORTIONAL DETECTOR; 43-5 ALPHA SCINTILLATION DETECTOR; 44-2 HIGH ENERGY GAMMA SCINTILLATION DETECTOR; 44-40 SHIELDED GM PAKCAKE DETECTOR; 43-37, 550 cm2 GAS PROPORTIONAL DETECTOR	15	1	12	$3,660	$263.60	$3,924	$327	$4,905
11	LUDLUM - PORTABLE FRISKER MODEL 177 W/ 44-9 PROBE & HARD CASE:	7	1	12	$739	$64.67	$804	$67	$469
12	NE TECHNOLOGY CM7A ALPHA/BETA FRISKER W/ DP5HA PROBE & STAND:	7	1	12	$4,184	$295.05	$4,479	$373	$2,613
13	TENNELEC - LB5100W-2080- III PC BASED ALPHA/BETA COUNTING SYSTEM:	7	3	36	$31,244	$1,918.62	$33,162	$921	$6,448
14	RADIO INTERCOM WITH THROAT AND RESPIRATOR MICROPHONE:	6	1	12	$1,500	$131.25	$1,631	$136	$816
	Instrumentation Sources Provided at Monthly Rental Rate								
15	EFFICIENCY DETERMINATION SOURCE FOR MODEL 2350:	7	1	12	$325	$28.43	$353	$29	$206
16	NaI DETECTOR CHECK SOURCES FOR MODEL 2350:	7	1	12	$45	$3.98	$49	$4	$29
17	CALIBRATION SOURCE FOR MODEL CM7A CONTAMINATION MONITOR:	7	1	12	$1,919	$159.14	$2,078	$173	$1,212
18	ALPHA/BETA COUNTER, BC-4 & SAC-4 6ea SOURCE SET:	7	1	12	$4,600	$319.99	$4,920	$410	$2,870
19	PORTABLE FRISKER 4ea SOURCE SET:	7	1	12	$1,306	$114.25	$1,420	$118	$828
	SUBTOTAL HEALTH PHYSICS INSTRUMENTATION:				$63,131	$4,398	$67,529		$27,596

AMS TRAINING PROGRAM

ACADEMIC

TAB 1	General Policy Statements
	Instructors
TAB 2	Basic Radiation Safety Training Manual
TAB 3	Supplemental Radiation Safety Manual

PRACTICAL

TAB 4	Class 2 Service Engineer Program
TAB 5	Class 1 Service Engineer Program
TAB 6	Isotope Technician Program
TAB 7	Isotope Handler Program
TAB 8	Annual Refresher Training

EXAMINATION POLICY

Copies of exmainations, quizzes, and answers will not be distributed to students prior to test.

After the exams are graded, they may be redistributed to the students for review; however, the exams will be collected and all copies retained by AMS for documentation purposes in the individual's C.V. files.

If retesting of a student is required, the format and questions will be altered before the next test. Revised tests will be at least equivalent to previous examinations.

TEXTS

The primary text utilized in the Basic Radiation Safety course is found after TAB 2. This text will be supplemental with the manual found after TAB 3.

AUDIO/VISUAL PRESENTATIONS

AMS intends to videotape all classroom and laboratory presentations, if possible. These videotapes may be edited and utilized for student review and refresher training. They are not intended to be used as primary training sessions.

INSTRUCTORS

The training program outlines, which are part of this manual, refer to instructors by job title or classification. The present qualified individuals who will be utilized as instructors are listed below by job title or classification. The credentials of these individuals follow:

Radiation Safety Officer	Robert Meschter
Engineering/Production Manager	Edward Svigel
Isotope Handler	Stephen J. Haddock

Qualified service engineers, used as instructors, shall have 6-12 months on-the-job experience and must be evaluated and approved by the RSO and Isotope Committee prior to becoming instructors.

EXPERIENCE ADDENDUM

ROBERT MESCHTER

I am familiar with the process and gamma sources used. I have provided radiation monitoring and surveillance during radiographic operations and know the 10 CFR 20 requirements specifically for posting and barricading areas during the operations. I can calculate dose rates and exposures based on source strength, distance, and time. Other nuclear experience includes radiological environmental sampling and analysis, knowledge of radon sampling, and operation and calibration of radiation measuring instruments such as G-M detectors, ion chambers, solid and liquid scintillators, etc.

Nuclear experience also includes "nuclear decontamination", or more specifically defined as those processes and methods for removing unwanted material from surfaces and equipment. My experience in this area includes the operation of liquid abrasive systems employing glass bead or cutting abrasives, CO_2 pellet blasting, Freon and other degreasing systems, ultra-sonics, ultra-high pressure water cleaning systems, and other solvent and chemical cleaning processes.

My nuclear background includes two (2) years chemistry laboratory experience. Primary duties in this area involved the operation of a water purification plant (Graver and Pennfield systems) and all sampling and analysis to insure Grade "A" demineralized water. Laboratory testing of samples included the measurement of chlorides, fluorides, conductivity, turbidity, dissolved oxygen, silica, suspended solids, pH, etc. Lab duties also included preparation of reagents and standards and the use of strong acids, caustics, and specialty chemicals such as Hydrazine. Measuring and test equipment experience includes pH meters, ion specific meters, Mettler balance, photometers, hydrometer, conductivity cells, etc. Electronic test equipment experience includes multimeters, oscilloscopes, Meggar and load banks. I also have general knowledge of electricity.

More specifically, my experience is:

Knowledge of 10 CFR Part 19 (§ 19.12) requirements and application sections of Part 20 (§§ 20.1101(a) and 20.1101), 33 (§ 33.13) and 35 (§ 35.21). Was involved in the development and provided Part 19 Radiation Safety instruction to radiation workers while employed at various nuclear power plants.

Hold an Associate of Science Degree in Radiological Health Technology. Have a broad working knowledge of Health Physics principles, practices, and regulations. Routinely reviewed ongoing procedures, proposed procedures, equipment at other facilities and Advanced Medical Systems. Recommended necessary changes for the safe use of radioactive materials and radiation producing devices.

Cognizant of potential airborne/surface contamination hazards when using unsealed sources. Aware that metallic cobalt forms oxides when exposed to air and will result in both airborne and surface contamination. Routinely conducted contamination (dry swipe) surveys and air-monitoring and provided instruction to workers on internal radiation protection, potential contamination risks, contamination control, and protection options.

Knowledge of 10 CFR Subpart H intent and requirements, Part 20 Appendix B derived limits, the ALARA concept, and contents of Advanced Medical Systems' Respiratory Protection Program. Received regular training covering respiratory protection in the workplace and included types of respirators, suitability, protection factors, permissible practice, Respiratory Protection Programs, and applicable regulations (OSHA 29 CFR 1910.134 and NIOSH/MSHA 30 CFR Part 11).

Knowledge of contamination hazards, contamination control, internal radiation protection, and decontamination procedures. Routinely provided instruction to workers and subordinates on the proper use, maintenance, and disposal of protective clothing: lab coats, disposable gloves/booties, and anti-c suits.

Knowledge of internal radiation protection, hood design and air cleaning devices. Routinely evaluated hoods at Livermore Laboratories for use with radioactive gases, vapors, and particulates; measured face velocities and determined air transport velocities; determined the effectiveness of, replaced, and disposed of rough and high efficiency (HEPA) filters; operated and maintained the glove box at various nuclear facilities.

Knowledge of 10 CFR Part 20 (Subpart K and Appendix F) and external and internal radiation protection. Involved in the planning and operation of the Perry Nuclear Power Plant Waste Storage Facility. Prepared procedures for the safe collection, transport, treatment (compaction of solidification), storage, and packaging for transfer to an authorized agent. Routinely supervised and was involved in the collection, transport, treatment, storage, packaging, and disposal of radioactive wastes at various nuclear plants.

Knowledge of organization, management, regulatory, and operational aspects of a Radiation Safety Program operating a Type A broad license. Knowledge of RSO/Radiation Safety Office's responsibilities and functions.

RESUME

ROBERT MESCHTER

EXPERIENCE

- 1994 - Advanced Medical Systems, Inc.; Radiation Safety Officer
  - Complete authority and responsibiity for the Isotope facility at 1020 London Road
  - Responsible for Radiation Safety
  - Responsible for regulatory compliance
  - Rewrote ISP Manual and participated in the rewrite of the Emergency Plan
  - Chairperson of the Isotope Committee
  - Member of the Management Committee and Safety Committee

- 1984 to 1993 - employed by the Cleveland Electric Illuminating Company at the Perry Nuclear Power Plant as a Senior Engineering Technician. Health Physics and other related duties during the past nine years included (but not limited to) engineering analysis and evaluations, project economic and cost benefit analysis, preparation of procurement specifications, bid proposal evaluations, procedure writing, correspondence preparation, emergency planning, regulatory issues review, technical and program reviews, and work crew supervision as assigned.

- 1975 to 1984 - employed in the commercial nuclear power industry in a variety of Health Physics and other related positions including health and safety technician, chemistry technician, consultant and engineering technician; member of American Nuclear Society and Health Physics Society (specific employers and dates available on request).

- The nuclear plants I have obtained training and experience at are as follows:
  - Duke Power, Oconee Nuclear Plant
  - Lawrence Livermore Laboratory
  - PSE&G, Salem Nuclear Plant
  - Jersey Central Power & Light, Oystercreek Nuclear Plant
  - Boston Edison, Pilgrim Nuclear Plant
  - Carolina Power & Light, HB Robison Nuclear Plant
  - TVA, Browns Ferry Nuclear Plant
  - SMUD, Rancho Seco Nuclear Plant
  - Connecticut Yankee, Haddam Neck Nuclear Plant
  - Alabama Power, Farley Nuclear Plant
  - LP&L, Waterford 3 Nuclear Plant

- Vietnam War Era Veteran, U.S. Navy, 1967 to 1972 - Honorable Discharge.

EDUCATION

- Associate of Science Degree in Radiological Health Technology, Central Florida Community College, 1975 - Graduated with Honors (GPA 3.9).

- Other training includes nuclear systems, engineering economics, Kepner-Trego Problem Solving and Decision Making, personal development, management and supervision, TQM, and various short technical seminars.

- Computer skills include work processing, Lotus spread sheet, 20/20 spread sheet, and the use of industry specific calculational computer codes. Former training in COBOL and FORTRAN languages.

DATE: January, 1995

CV for Edward L. Svigel
Engineering Manager
Advanced Medical Systems, Inc.
121 North Eagle Street
Geneva, OH 44041

I. Primary Function: To manage and supervise Engineering and related departments. Mechanical and electrical design of medical equipment to include R&D, test and evaluation, Quality Control and GMP compliance.

II. Organizational Relationship:

A. Reports to: General Manager

B. Manages: R&D, Manufacturing Department, Quality Control Department and draftsmen

C. Works with: Isotope Department, Service Department, Purchasing Department and Materials Control

III. Education:

A. B.M.E. - Gannon College - 1970

B. Communication/Electronics Staff Officers School - 1971

IV. Employment History:

Diamond Shamrock	1963-1965 Drafting
True-Temper - Central Engineering	1970-1976 Research Engineer
U.S. Army Signal Corps	1971-1973 Signal Officer
True-Temper Corporation	1976-1977 Plant Engineer
Gould/Engine Parts Division	1978-1982 Machine Design Engineer
Advanced Medical Systems, Inc.	1982-Present Engineering Manager

V. Previous Experience:

A. Design and development of fiberglass hammer handles, tennis racquets.

B. Design and development of automatic golf shaft straightening machine.

C. Project engineer for installation of Reverse Osmosis System.

D. Energy Conservation Engineer and Coordinator.

E. Supervisor of plant draftsmen and Quality Control technicians.

F. Supervision of Army Battalion Communications Radio Relay Section.

V. Previous Experience (Continued):

G. Deputy Chief of Fort Bliss Education Television Division - U.S. Army.

H. Project Engineer for purchase and installation of Carbon Absorption unit.

I. Designed, specified and purchased plating room equipment.

J. Supervised and coordinated rebuilds of elevator plating machines.

K. Designed special tools for use in areas of high radiation.

L. Supervised and coordinated GMP Program on medical equipment.

M. Coordinated and managed capital equipment purchases and moves.

N. Supervised the construction of 34 Cobalt units and 2 simulators.

O. Initiated ECO procedure per Title 21 and AMS Q.C./GMP Program.

STEPHEN J. HADDOCK
1170 East 337th Street
Eastlake, OH 44095
(216) 953-3966

WORK EXPERIENCE:

ADVANCED MEDICAL SYSTEMS, INC. - CLEVELAND, OHIO

Isotope Handler and Technician (May 1991 to Present)

Health Physics responsibilities included the following:
*Licensed on USNRC #34-19089-01 as a sealed source handler and Isotope Technician; assisted Radiation Safety Officer in all aspects of the facility's operation.
*Exposure to contaminated areas with contamination ranging from 100,000-200,000 dpm/100cm^2 throughout the room.
*Health physics support in high radiation areas with an accessible dose rates of 1-3 R/hr.
*Extensive hot cell maintenance and manipulator use experience.
*Transfer and handling of special by-product material with activities ranging from 2,000-9,000Ci Co^{60} and potential exposure of 3,000-10,000 Roentgens/hr. @ 1 meter.
*Equipment maintenance and calibration.
*Packaging radioactive waste.
*Shipping and receiving of radioactive material.
*Assisted in developing a Decommissioning Plan and Emergency Pre-Plan.
*Assisted in developing and implementing plan for replacement of HEPA filter system and for hot cell upgrades, repairs and maintenance.
*Responsibilities also included source fabrication; basic radiation safety for the facility; associated maintenance routines for Picker-AMS Cobalt-60 Teletherapy equipment; source transfers and shipments; physical inventorying of sealed sources and basic daily procedures of operation for the facility under AMS and Nuclear Regulatory Commission guidelines.

COYNE-KANGESSER - CLEVELAND, OHIO

Facility Coordinator (February 1990-May 1991)

Managed 15 employees, which involved hiring, payroll, termination and scheduling of personnel as well as marketing functions. Responsible for customer complaints, billing and deposits. Position included a high degree of confidentially and customer contact.

WORK EXPERIENCE: (Cont'd)

BALDWIN-WALLACE COLLEGE - BEREA, OHIO (1982-1986)

Athletic Trainer (1982-1986)

Part-time as a student athletic trainer with the Athletics Department. Duties included all facets of injury assessment including emergency procedures, first-aid including physical therapy and preventative procedures. Assisted doctors with field emergencies and physicals.

EDUCATION:

BALDWIN-WALLACE COLLEGE - BEREA, OHIO (1982-1986)

Bachelor of Arts--Health including 60 Credit Hours in Science Related Class and 58 Credit Hours in Teaching Related Classes
3.0 GPA in His Major

HONORS:

Dr. Robert H. Lechner Memorial Service Award

Recipient in 1984, 1985 and 1986. Awarded for outstanding service at Baldwin-Wallace College.

Baldwin-Wallace College Four-Year Honorary Letterman for Athletic Training from 1982 to 1986.

BASIC RADIATION THEORY
AND
SAFETY PROCEDURES

COURSE SYLLABUS
(Broad)

Topic	Time (Hours)
Mathematics Review	1
Basic Radiation Physics	6
Radiation Detection and Measurements	4
Biological Effects of Radiation	2
Radiation Protection Standards	2
Protection Against External Exposures	3
Protection Against Internal Exposures	3
Shipping and Receiving Radioactive Material	1
Emergency Procedures and Response	.5
Quizzes/Examinations	2-3

LABORATORY EXERCISES

Survey Meter Use and Care	1.5
Calibration of Survey Meters including Demonstration of Shielding and Distance	1.5
Radiation Measurements and Contamination Monitoring	1
Packaging, Shipping, and Receiving Radioactive Material	4

TRAINING RECORD

STUDENT NAME:______________________

UNIT #	COURSE IDENTIFICATION	NO. HOURS	STUDY AIDE	LOCATION & DATE ATTENDED	TESTING RESULTS	STUDENT SIGNATURE	INSTRUCTOR SIGNATURE
LAB 1	Survey Meter Use & Care						
LAB 2	Calibration of Survey						
	Meters, Shielding &						
	Distance						
LAB 3	Radiation Measurements &						
	Contamination Monitoring						
LAB 4	Packaging, Shipping, &						
	Receiving Radioactive						
	Material						

Isotope Committee Review Date:______________

Comment:____

____

Member Officer Signature:______________________

RADIATION SAFETY TRAINING

FOR

ADVANCED MEDICAL SYSTEMS PERSONNEL

I. Basic Radiation Physics

Atomic and Nuclear Structure
Ionization - Isotopes
Radioactivity

- Decay Process
- Types of Emissions
- Half-Life
- Curie
- Decay Formula - Use of Decay Tables

Properties of Alpha, Beta Particles, Gamma Rays, X-rays, and Neutrons
Interaction of Radiation with Matter
Radiation Dosimetry

- Definition of Terms (Roentgen, RAD, REM)
- Exposure Rate - Dose Rate
- Specific Gamma-Ray Constant
- Inverse Square Law
- Calculations

Background Radiation
Characteristics of Co-60 and Cs-137 Sealed Sources

II. Biological Effects of Radiation

Cells and Radiosensitivity
Somatic Effects

- Acute Exposures
- Chronic Exposures

Genetic Effects
Factors Affecting Biological Damage
Case Histories

III. Radiation Detection

Principles

Ionization Method
Scintillation Method
Thermoluminescence
Photographic Film Dosimetry

Instrumentation

GM Survey Meters
Pocket Dosimeters
TLDs/Film Badges
Detectors Used at AMS

Instrument Calibration
GM Saturation

IV. Radiation Protection Standards

History
Regulatory Agencies
NRC License
10 CFR Parts 19, 20, and 30
Regulatory Guides
ANSI Standards
Exposure Guides
Bioassay Program

V. Radiation Protection

Principles of Radiation Safety

ALARA Principle
Time, Distance, Shielding
Personnel Monitoring
Radiation Measurements
Instrument Calibrations
Required Postings

Receiving, Handling, Storage of Sealed Sources
Source Installation
Routine Use of Source in Device
Leak Testing Sealed Sources
Source Exchange
Source Inventory/Accountability
Packaging and Shipping Sources
Emergency Procedures
Stay Time Calculation
Shielding Calculation
Activity Calculations

VI. Hands on Activities

Each of the following procedures will be demonstrated by the instructor. In turn, each participant will be required to demonstrate their ability to perform the procedure properly:

Leak Testing Sealed Sources
Packaging Sealed Sources for Shipment
Use of a Survey Meter Including Care and Calibration
Air Monitoring
Contamination Monitoring

RELATIVE STRENGTHS OF

FORCES IN NATURE

Nuclear Force	1
Electromagnetic Force	10^{-2}
*Weak Force	10^{-13}
Gravitational	10^{-39}

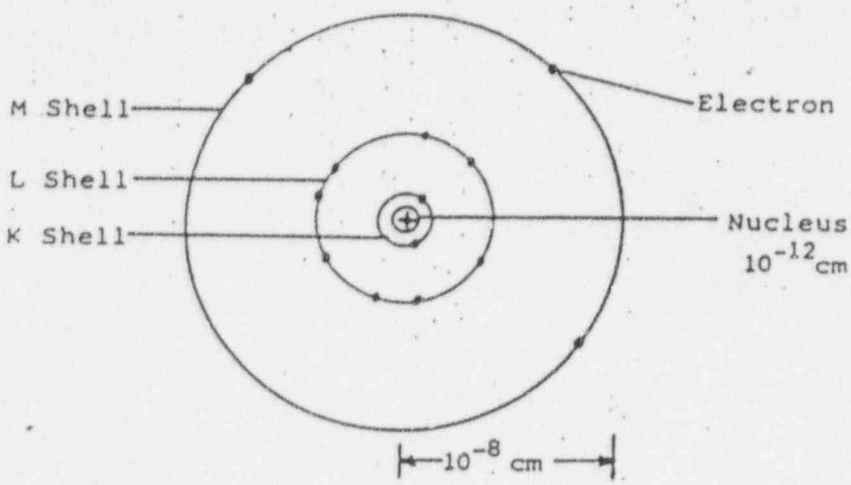
*weak force - an interactive force between the constituents of beta decay

Force = mass x acceleration

Work or Energy "ability to do work" = force x distance

An electron in orbit around the nucleus has potential energy due to being immersed in an electric field (the positive protons in the nucleus and the negative electrons in the electron orbits). It also has Kinetic energy because it is moving (has velocity). The total energy which holds the electron in orbit is the binding energy. To remove an electron from an atom, you must give it enough energy (work) to overcome its binding energy.

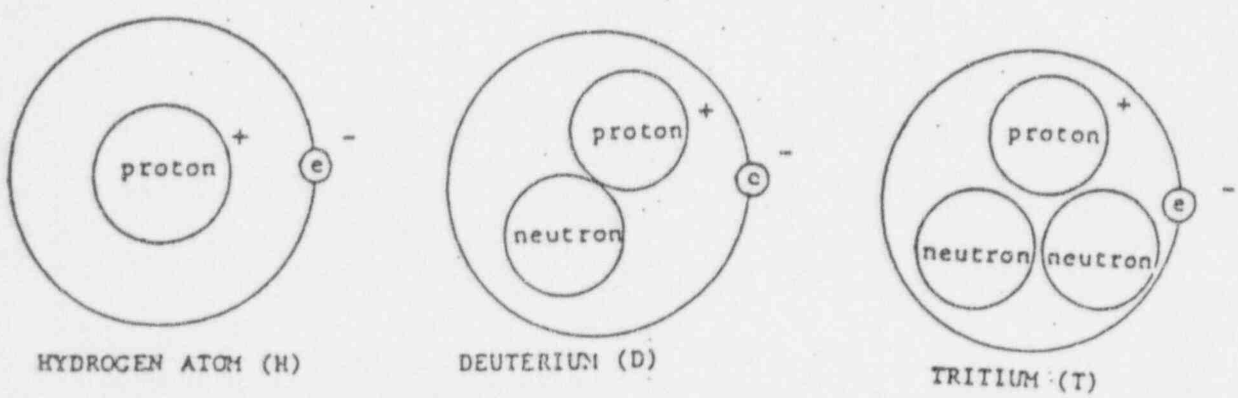
BOHR'S ATOMIC MODEL



1 inch = 2.54 cm

10^{-8} cm = .00000001 cm

$= \frac{1}{250,000,000}$ inch



CURRENT CONVENTION

FOR

ELEMENTAL NOTATION

$$^{A}_{Z}X$$

Where: X = chemical symbol

Ex: Co - Cobalt
Cs - Cesium

Z = atomic number

= number of protons and number of electrons for neutral atoms (net charge = 0)

Ex: $^{60}_{27}Co$

27 protons and 27 electrons

A = atomic mass

= number of protons and neutrons (nucleons) in the nucleus

Accordingly,

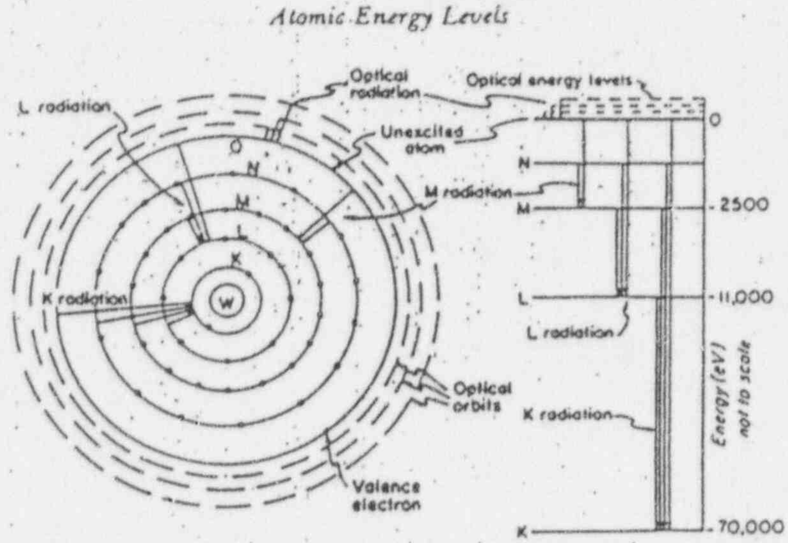
A - Z = number of neutrons in the nucleus

Ex: $^{60}_{27}Co$

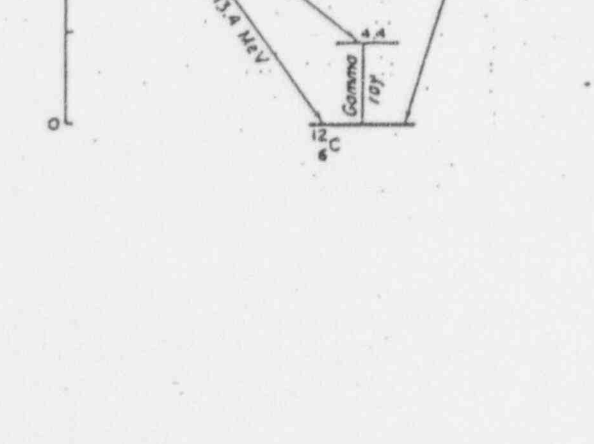
60 nucleons (neutrons and protons)

A - Z = 60 - 27 = 33 neutrons

ATOMIC ENERGY LEVELS

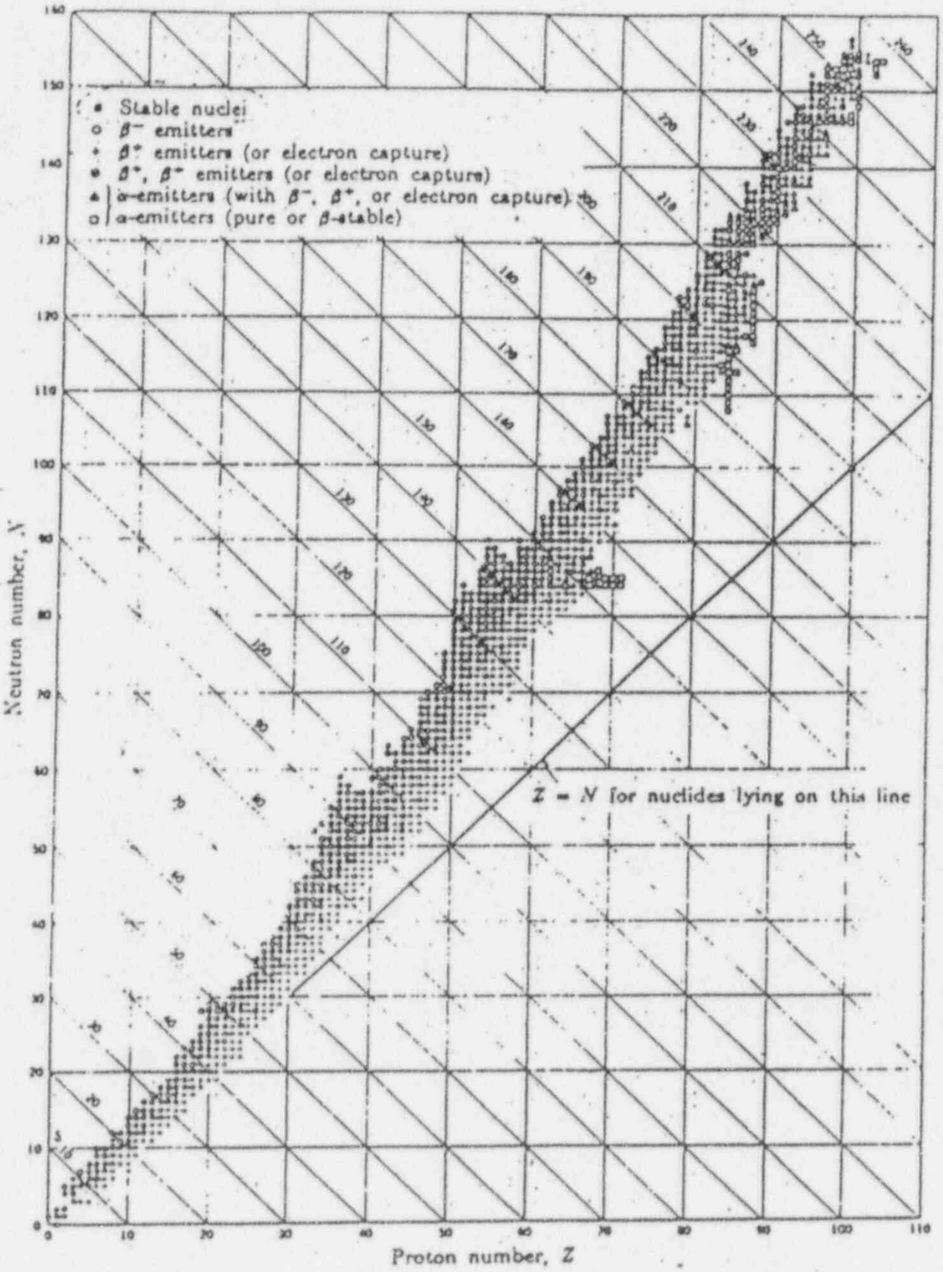


NUCLEAR ENERGY LEVELS



Energy level diagram for carbon 12.

CHART OF NUCLIDES



A plot of neutron number N versus proton Z for all all known nuclei, stable and unstable. A curve through the stable nuclei starts with N/Z = 1 for low-A nuclei and reaches a value of N/Z - 1.6 for high-A nuclei.

REF 1

RADIOACTIVITY

The <u>Curie</u> - A measure of radioactivity equivalent to 37 billion disintegrations per second. (Ci)

1 millicurie (mCi) = one thousandth of a curie

1 microcurie (uCi) = one millionth of a curie

The <u>Becquerel</u> - A measure of radioactivity equivalent to 1 disintegration per second. (Bq)

<u>Unit Conversions</u>

ACTIVITY		
1 terabecquerel	= 1 TBq	= 27 curies
1 gigabecquerel	= 1 GBq	= 27 millicuries
1 megabecquerel	= 1 MBq	= 27 microcuries
1 kilobecquerel	= 1 kBq	= 27 nanocuries
1 becquerel	= 1 Bq	= 27 picocuries

ACTIVITY		
1 kilocurie	= 1 kCi	= 37 terabecquerels
1 curie	= 1 Ci	= 37 gigabecquerels
1 millicurie	= 1 mCi	= 37 megabecquerels
1 microcurie	= 1 µCi	= 37 kilobecquerels
1 nanocurie	= 1 nCi	= 37 becquerels

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	<u>giga</u>	G
10^{6}	<u>mega</u>	M
10^{3}	<u>kilo</u>	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	<u>centi</u>	c
10^{-3}	<u>milli</u>	m
10^{-6}	<u>micro</u>	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Advanced Medical Systems

Device Nominal Activity: ______ Ci

______ Bq

RADIOACTIVE DECAY

$A_{final} = A_{initial} \times e^{-(\lambda \times t)}$

A = activity

$\lambda = \dfrac{.693}{\text{half-life}}$

t = decay period

e = base for natural log

$= 2.71828\ldots$

$\log_e x = y$

$e^y = x$

for ^{60}Co, the half-life ($t_{1/2}$) = 5.3 years

Example: What is the activity of a 5000 curie (Ci.) ^{60}Co sealed source after 15.9 years?

$A_{final} = 5000\text{Ci.} \times e^{-(.693/5.3 \text{ years} \times 15.3 \text{ years})}$

$= 5000\text{Ci.} \times e^{-2.079}$

$= 5000\text{Ci.} \times .125$

$= 625 \text{ Ci.}$

UNIVERSAL DECAY TABLE (REF 5)

The accompanying table can be used to determine the fraction of activity remaining of any radionuclide, from 0.001 half-life to 1.00 half-life. To use the table complete the following:

1. Divide elapsed time by the known physical half-life of the radionuclide under consideration ($t \div T_{1/2}$).
   NOTE: the same time unit must be used in each instance.

2. Use this answer (to three significant figures) in locating the percent of original activity remaining. The first two significant figures are listed on the vertical column at the left of the table; the third significant figure is listed on the horizontal across the tope of the table.

3. Multiply original activity by this percentage figure to obtain amount remaining.

Example: What is the strength of a 10 mCi ^{131}I source after 2 days?

1. $t \div T_{1/2} = 2 \div 8.1 = 0.247$

2. Fraction remaining from decay table = 0.84265

3. 10 mCi × 0.84265 = 8.43 mCi

Activity remaining for $t \div T_{1/2}$ from 0 to 1.00

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
	1.00000	.99931	.99861	.99792	.99723	.99654	.99585	.99516	.99447	.99378
.01	.99309	.99240	.99172	.99103	.99034	.98966	.98897	.98829	.98760	.98692
.02	.98623	.98555	.98487	.98418	.98350	.98282	.98214	.98146	.98078	.98010
.03	.97942	.97874	.97806	.97739	.97671	.97603	.97536	.97468	.97400	.97333
.04	.97265	.97198	.97131	.97063	.96996	.96929	.96862	.96795	.96728	.96661
.05	.96594	.96527	.96460	.96393	.95326	.96259	.96193	.96126	.96059	.95993
.06	.95926	.95860	.95794	.95727	.95661	.95595	.95528	.95462	.95396	.95330
.07	.95264	.95198	.95132	.95066	.95000	.94934	.94868	.94803	.94737	.94671
.08	.94606	.94540	.94475	.94409	.94344	.94278	.94213	.94148	.94083	.94017
.09	.93952	.93887	.93822	.93757	.93692	.93627	.93562	.93498	.93433	.93368
.10	.93303	.93239	.93174	.93109	.93045	.92980	.92916	.92852	.92787	.92723
.11	.92659	.92595	.92530	.92466	.92402	.92338	.92274	.92210	.92146	.92083
.12	.92019	.91955	.91891	.91828	.91764	.91700	.91637	.91573	.91510	.91447
.13	.91383	.91320	.91257	.91193	.91130	.91067	.91004	.90941	.90878	.90815
.14	.90752	.90689	.90626	.90563	.90501	.90438	.90375	.90313	.90250	.90188
.15	.90125	.90063	.90000	.89938	.89876	.89813	.89751	.89689	.89627	.89565
.16	.89503	.89440	.89379	.89317	.89255	.89193	.89131	.89069	.89008	.88946
.17	.88884	.88823	.88761	.88700	.88638	.88577	.88515	.88454	.88393	.88332
.18	.88270	.88209	.88148	.88087	.88026	.87965	.87904	.87843	.87782	.87721
.19	.87661	.87600	.87539	.87478	.87418	.87357	.87297	.87236	.87176	.87115
.20	.87055	.86995	.86934	.86874	.86814	.86754	.86694	.86634	.86574	.86514
.21	.86454	.86394	.86334	.86274	.86214	.86155	.86095	.86035	.85976	.85916
.22	.85857	.85797	.85738	.85678	.85619	.85559	.85500	.85441	.85382	.85323
.23	.85263	.85204	.85145	.85086	.85027	.84968	.84910	.84851	.84792	.84733
.24	.84675	.84616	.84557	.84499	.84440	.84382	.84323	.84265	.84206	.84148
.25	.84090	.84031	.83973	.83915	.83857	.83799	.83741	.83683	.83625	.83567
.26	.83509	.83451	.83393	.83335	.83278	.83220	.83162	.83105	.83047	.82989
.27	.82932	.82874	.82817	.82760	.82702	.82645	.82588	.82531	.82473	.82416
.28	.82359	.82302	.82245	.82188	.82131	.82074	.82017	.81960	.81904	.81847
.29	.81790	.81734	.81677	.81620	.81564	.81507	.81451	.81394	.81338	.81282
.30	.81225	.81169	.81113	.81057	.81000	.80944	.80888	.80832	.80776	.80720
.31	.80664	.80608	.80552	.80497	.80441	.80385	.80329	.80274	.80218	.80163
.32	.80107	.80051	.79996	.79941	.79885	.79830	.79775	.79719	.79664	.79609
.33	.79554	.79499	.79443	.79388	.79333	.79278	.79223	.79169	.79114	.79059
.34	.79004	.78949	.78895	.78840	.78785	.78731	.78676	.78622	.78567	.78513
.35	.78458	.78404	.78350	.78295	.78241	.78187	.78133	.78079	.78025	.77970
.36	.77916	.77862	.77809	.77755	.77701	.77647	.77593	.77539	.77486	.77432
.37	.77378	.77325	.77271	.77218	.77164	.77111	.77057	.77004	.76950	.76897
.38	.76844	.76791	.76737	.76684	.76631	.76578	.76525	.76472	.76419	.76366
.39	.76313	.76260	.76207	.76154	.76102	.76049	.75996	.75944	.75891	.75838
.40	.75786	.75733	.75681	.75628	.75576	.75524	.75471	.75419	.75367	.75315
.41	.75262	.75210	.75158	.75106	.75054	.75002	.74950	.74898	.74846	.74794

Activity remaining for $t \div T_{1/2}$ from 0 to 1.00

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.42	.74742	.74691	.74639	.74587	.74536	.74484	.74432	.74381	.74329	.74278
.43	.74226	.74175	.74123	.74072	.74021	.73969	.73918	.73867	.73816	.73765
.44	.73713	.73662	.73611	.73560	.73509	.73458	.73408	.73357	.73306	.73255
.45	.73204	.73154	.73103	.73052	.73002	.72951	.72900	.72850	.72799	.72749
.46	.72699	.72648	.72598	.72548	.72497	.72447	.72397	.72347	.72297	.72247
.47	.72196	.72146	.72096	.72047	.71997	.71947	.71897	.71847	.71797	.71747
.48	.71698	.71648	.71598	.71549	.71499	.71450	.71400	.71351	.71301	.71252
.49	.71203	.71153	.71104	.71055	.71005	.70956	.70907	.70858	.70809	.70760
.50	.70711	.70662	.70613	.70564	.70515	.70466	.70417	.70368	.70320	.70271
.51	.70222	.70174	.70125	.70076	.70028	.69979	.69931	.69882	.69834	.69786
.52	.69737	.69689	.69641	.69592	.69544	.69496	.69448	.69400	.69352	.69304
.53	.69255	.69208	.69160	.69112	.69064	.69016	.68968	.68920	.68873	.68825
.54	.68777	.68729	.68682	.68634	.68587	.68539	.68492	.68444	.68397	.68349
.55	.68302	.68255	.68207	.68160	.68113	.68066	.68019	.67971	.67924	.67877
.56	.67830	.67783	.67736	.67689	.67642	.67596	.67549	.67502	.67455	.67408
.57	.67362	.67315	.67268	.67222	.67175	.67129	.67082	.67036	.66989	.66943
.58	.66896	.66850	.66804	.66757	.66711	.66665	.66619	.66573	.66526	.66480
.59	.66434	.66388	.66342	.66296	.66250	.66204	.66159	.66113	.66067	.66021
.60	.65975	.65930	.65884	.65838	.65793	.65747	.65702	.65656	.65611	.65565
.61	.65520	.65474	.65429	.65384	.65338	.65293	.65248	.65203	.65157	.65112
.62	.65067	.65022	.64977	.64932	.64887	.64842	.64797	.64752	.64707	.64662
.63	.64618	.64573	.64528	.64483	.64439	.64394	.64349	.64305	.64260	.64216
.64	.64171	.64127	.64082	.64038	.63994	.63949	.63905	.63861	.63816	.63772
.65	.63728	.63684	.63640	.63596	.63552	.63508	.63464	.63420	.63376	.63332
.66	.63288	.63244	.63200	.63156	.63113	.63069	.63025	.62982	.62938	.62894
.67	.62851	.62807	.62764	.62720	.62677	.62633	.62590	.62546	.62503	.62460
.68	.62417	.62373	.62330	.62287	.62244	.62201	.62157	.62114	.62071	.62028
.69	.61985	.61942	.61900	.61857	.61814	.61771	.61728	.61685	.61643	.61600
.70	.61557	.61515	.61472	.61429	.61387	.61344	.61302	.61259	.61217	.61174
.71	.61132	.61090	.61047	.61005	.60963	.60921	.60878	.60836	.60794	.60752
.72	.60710	.60668	.60626	.60584	.60542	.60500	.60458	.60416	.60374	.60332
.73	.60290	.60249	.60207	.60165	.60123	.60082	.60040	.59999	.59957	.59915
.74	.59874	.59832	.59791	.59750	.59708	.59667	.59625	.59584	.59543	.59502
.75	.59460	.59419	.59378	.59337	.59296	.59255	.59214	.59173	.59132	.59091
.76	.59050	.59009	.58968	.58927	.58886	.58845	.58805	.58764	.58723	.58682
.77	.58642	.58601	.58561	.58520	.58479	.58439	.58398	.58358	.58317	.58277
.78	.58237	.58196	.58156	.58116	.58075	.58035	.57995	.57955	.57915	.57875
.79	.57834	.57794	.57754	.57714	.57674	.57634	.57594	.57554	.57515	.57475
.80	.57435	.57395	.57355	.57316	.57276	.57236	.57197	.57157	.57117	.57078
.81	.57038	.56999	.56959	.56920	.56880	.56841	.56801	.56762	.56723	.56683
.82	.56644	.56605	.56566	.56527	.56487	.56448	.56409	.56370	.56331	.56292
.83	.56253	.56214	.56175	.56136	.56097	.56058	.56019	.55981	.55942	.55903
.84	.55864	.55826	.55787	.55748	.55710	.55671	.55632	.55594	.55555	.55517
.85	.55478	.55440	.55402	.55363	.55325	.55287	.55248	.55210	.55172	.55133
.86	.55095	.55057	.55019	.54981	.54943	.54905	.54867	.54829	.54791	.54753
.87	.54715	.54677	.54639	.54601	.54563	.54525	.54488	.54450	.54412	.54374
.88	.54337	.54299	.54261	.54224	.54186	.54149	.54111	.54074	.54036	.53999
.89	.53961	.53924	.53887	.53849	.53812	.53775	.53737	.53700	.53663	.53626
.90	.53589	.53552	.53514	.53477	.53440	.53403	.53366	.53329	.53292	.53255
.91	.53218	.53182	.53145	.53108	.53071	.53034	.52998	.52961	.52924	.52888
.92	.52851	.52814	.52778	.52741	.52705	.52668	.52632	.52595	.52559	.52522
.93	.52486	.52449	.52413	.52377	.52340	.52304	.52268	.52232	.52196	.52159
.94	.52123	.52087	.52051	.52015	.51979	.51943	.51907	.51871	.51835	.51799
.95	.51763	.51727	.51692	.51656	.51620	.51584	.51548	.51513	.51477	.51441
.96	.51406	.51370	.51334	.51299	.51263	.51228	.51192	.51157	.51121	.51086
.97	.51051	.51015	.50980	.50945	.50909	.50874	.50839	.50803	.50768	.50733
.98	.50698	.50663	.50628	.50593	.50558	.50523	.50488	.50453	.50418	.50383
.99	.50348	.50313	.50278	.50243	.50208	.50174	.50139	.50104	.50069	.50035
1.00	.50000									

RADIOACTIVE DECAY MODES

ALPHA DECAY - approximately 160 known radionuclides

- occurs primarily in heavier elements
- the disintegrating nucleus emits an alpha particle (α) which essentially is a helium nucleus

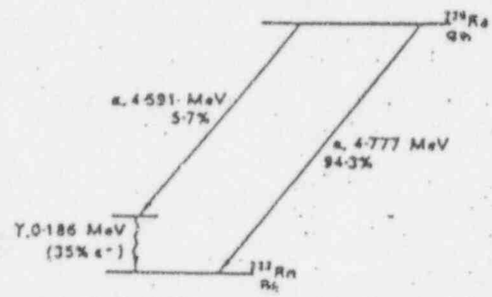
$${}^{4}_{2}He^{2+}$$

Symbolically noted as:

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He^{2+} + \text{Kinetic Energy of } \alpha \text{ particle}$$

Example:

$${}^{228}_{90}Th \longrightarrow {}^{224}_{88}Ra + {}^{4}_{2}He^{++} + \text{Kinetic Energy}$$



Radium-226 transformation (decay) scheme.

BETA DECAY - approximately 1000 artificially produced

- lie above (β^-) and below (β^+ or E.C.) stability curve
- the disintegrating nucleus seeks nuclear stability by emitting a beta particle or capturing an orbital electron
- 3 types

Negatron Emission	-	β^-
Positron Emission	-	β^+
Electron Capture	-	E.C.

Negatron Decay

Negatron (β^-) decay occurs when an electron is created in and emitted from the nucleus

Symbolically noted as:

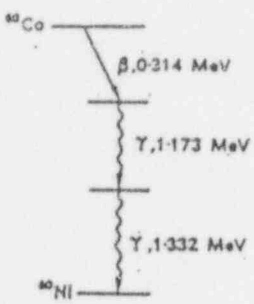
$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e\ (\beta^-) + \bar{\nu}\ \text{(antineutrino)} $$

caused by:

$$ n \longrightarrow p + \beta^- + \bar{\nu}\ * $$

*the neutrino was discovered when observed beta energies were continuous and not discreet

Example:

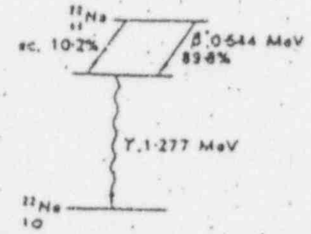


Positron (B^+) Decay

Positron decay occurs when a positron is created and emitted from the nucleus

$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e(B^+) + \nu \text{ (neutrino)} $$

Example:



Sodium-22 transformation (decay) scheme.

A positron is a unique creature in that it annihilates with an electron to form two .51 MeV photons.

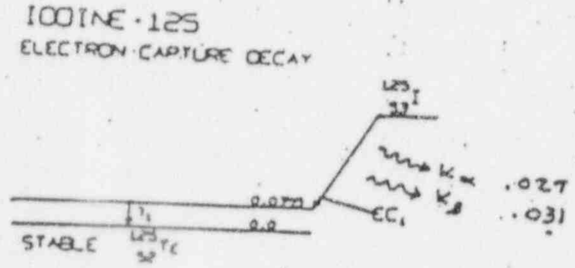
Electron Capture or K-Capture

- the disintegrating nucleus seeks nuclear stability by capturing an orbital electron
- $p + {}^{0}_{-1}e \longrightarrow n$

Symbolically noted as:

$$ {}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}Y + K_{x\text{-ray}} $$

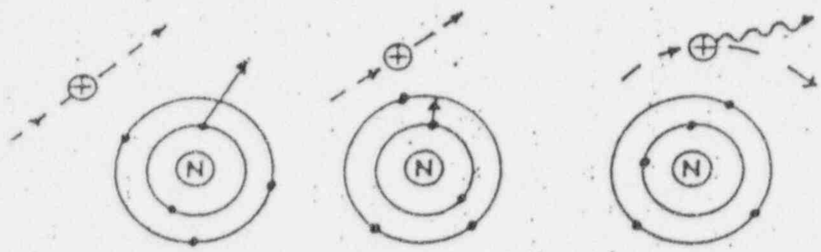
Example:



RADIATION INTERACTIONS

WITH MATTER

<u>Charged Particle</u>



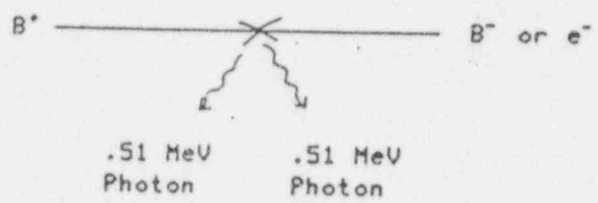
IONIZATION: Removal of electron

EXCITATION: Raising of electron

BREMSSTRAHLUNG: Electromagnetic radiation released

Energy Loss Mechanism

<u>B^+ (Positron-Electron Annihilation)</u>



Rules of Thumb

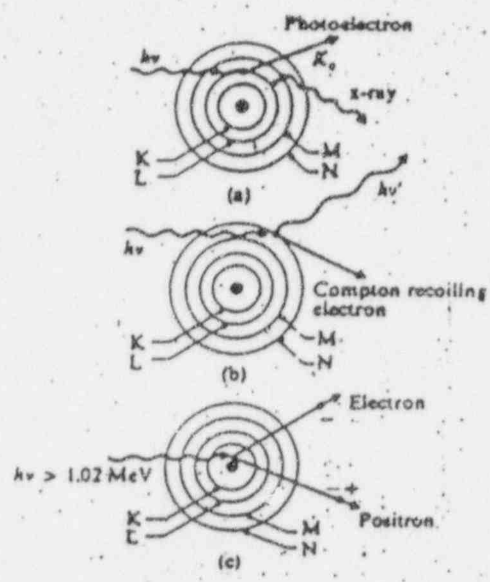
1. Alpha particles up to 7.5 MeV are stopped in the dead layer of normal skin.

2. Beta particles will penetrate about 4 meters in air per MeV of energy.

3. Beta particles will penetrate about 0.5 cm in soft tissue per MeV of energy.

4. Beta particles up to 70 keV are stopped in the dead layer of normal skin.

Photon - An electromagnetic wave with no charge and no mass (x-rays and gamma rays).



The three processes by which x and gamma rays most often interact with matter.

(a) Photoelectric process: the incident photon is absorbed by one of the inner electrons. The resulting photoelectron leaves its orbital. The vacancy created is filled by an outer electron jumping in, with simultaneous emission of x-ray.

(b) Compton process: the incident gamma ray interacts with one of the outer electrons and transfers a part of its energy to this electron.

(c) Pair production: the incident photon converts into an electron-positron pair in the coulombic field of the nucleus. THe positron annihilates with an electron.

NOTE: The probability of a particular type of interaction is related to the photon energy and the atomic number (density) of the target material.

Figure 3-5. Cloud chamber photograph of alpha, beta, and gamma ray tracks. (J.B. Hoag *Electron and Nuclear Physics*, courtesy D. Van Nostrand Co.) (H4)

RADIATION DOSIMETRY UNITS

Roentgen (R) (exposure) - A measure of electrical charge distribution in air

- 2.58×10^{-4} $Coulombs/Kg_{(air)}$

RAD (dose) - A measure of energy deposition in a medium by exposure to radiation.

- 100 $ergs/gm_{(medium)}$

- .877 $Rads_{(air)}$ = 1.0 $Roentgen_{(air)}$

- .877 $Rads_{(air)}$ = .95 $Rads_{(soft\ tissue)}$

REM - A unit of radiation dose related to radiation protection.

- rem = Rad x Quality Factor

- The Quality Factor is related to the L.E.T. (Linear Energy Transfer) and the R.B.E. (Relative Biological Effectiveness).

Type of Radiation	Q.F.
X, B, gamma	1
thermal neutrons	2.2
fast neutrons	10
alpha particles	20

For X, B, and gamma: 1 R = 1 RAD = 1 rem for radiation protection purposes

RADIATION DOSIMETRY

FOR ^{60}CO AND ^{137}CS SOURCES

- Nominal Activity ^{60}Co Device 5000 Ci

- Gamma Constant

^{60}Co - 1.32 $\frac{R}{Ci\text{-}hr}$ at 1m ______ $\frac{R}{Ci\text{-}hr}$ at 1cm

^{137}Cs - 0.33 $\frac{R}{Ci\text{-}hr}$ at 1 m

Example: What is dose rate at 1 meter from a 4700 Ci ^{60}Co point source?

$$1.32 \frac{R}{Ci\text{-}hr} \times 4700 \text{ Ci} = 6204 \text{ R/hr}$$

If distance is decreased to 1/2 meter, what would the dose rate be?

6204 R/hr @ 1 m. (initial)

? @ 1/2 m. (final)

use:

$DR_{final} = DR_{initial} (r_i/r_f)^2$ where r is the distance from the source

$DR_{final} = 6204 \text{ R/hr} \times (1/.5)^2$

$= 6204 \text{ R/hr} \times (4)$

$= 24816 \text{ R/hr}$

SUMMARY OF AVERAGE ANNUAL PER CAPITA

DOSES TO WHOLE U.S. POPULATION

Source	Average per capita Dose (mrem/year)		
Natural background			
Cosmic	31		
Terrestrial	68		
Tech. Inhanced	4		
Sub-total		103	
Man-made			
Medical			
X-ray	77		
Nuc. Med.	14		
Sub-total		91	
Nuclear weapons	4-5		
Nuclear power	<1		
Consumer products	0.5-1.5		
Sub-total		~8	
Total			~200

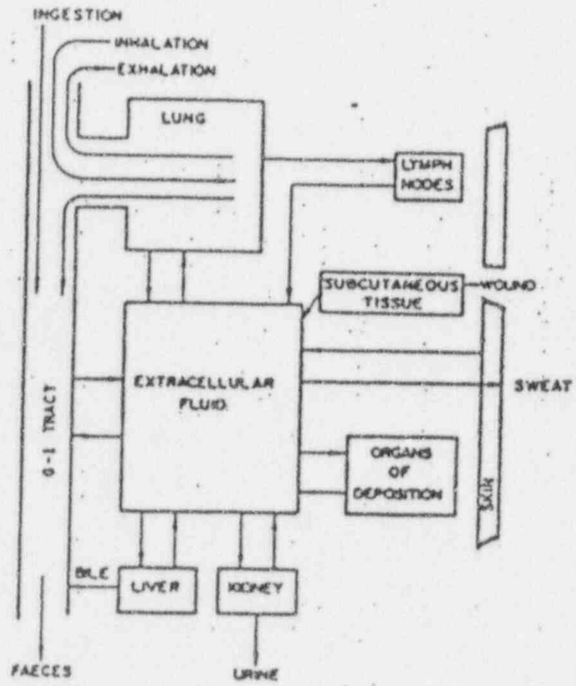
REF 3

U.S. AVERAGE ANNUAL DOSES

FROM RADIOACTIVE PRODUCTS

1. Radium wrist watch .... 3 mrem
2. Tritium wrist watch .... 0.6 mrem
3. Radium dial alarm clocks .... 7 to 9 mrem
4. Cigarettes, 1 1/2 pack per day, to lung ..... 8,000 mrem
5. Building materials, masonry .... 7 mrem
6. Road construction materials .... 4 mrem
7. Coal fired power plant, to lung .... 1 to 4 mrem
8. Cooking with natural gas stove .... 6 to 9 mrem
9. Residential ionization smoke detector .... 1 mrem
10. Dental porcelain in false teeth, to gum ..... 60,000 mrem
11. Thorium rose tinted eyeglasses, to eye ...... 4,000 mrem
12. Phonograph record static eliminator .... 0.001 mrem
13. Reading a book, 3 hrs/day .... 0.5 mrem
14. Aircraft luminous instrument dial .... 1,000 to 5,000 mrem
15. Radium pocket watch, GSD .... 6 mrem
16. Radioactive lightning rods .... 0.05 mrem
17. Uranium glaze in dinnerware, to skin .... 2,400 mrem
18. Farmer using phosphate fertilizer, GSD ...... 2 mrem
19. Worker in fertilizer plant, to lung .... 5,000 mrem
20. Gas lantern mantles for camping .... 0.1 to 0.4 mrem

REF 3



Principal Metabolic Pathways of Radionuclides in the body. (From ICRP 10)

BIOLOGICAL EFFECTS OF

EXPOSURE TO IONIZING RADIATION

Observed effects fall into two categories:

Stochastic Effects

1. occurs by chance
2. probability of effect is proportional to dose
3. no threshold, every increment of dose has a corresponding risk
4. Example: cancer or genetic effects

Non-Stochastic Effects

1. a minimum dose must be exceeded-threshold
2. magnitude of effect is proportional to dose
3. Example: LD 50/30 = 600-800 RADS

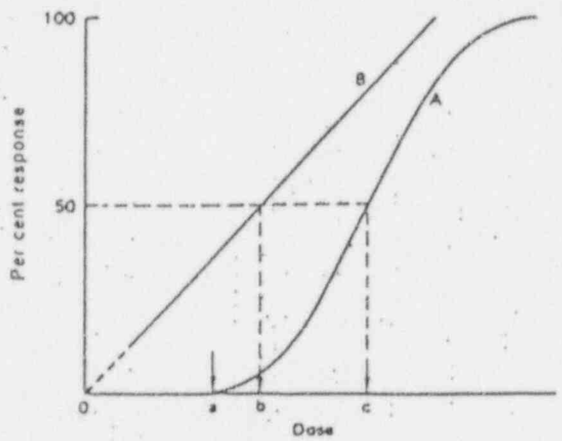


FIG. 7.1. Dose-response curves. Curve *A* is the characteristic shape for a biological effect that exhibits a threshold dose—point *a*. The spread of the curve, from the threshold at *a* until the 100% response is thought to be due to "biological variability" around the mean dose, point *c*, which is called the 50% dose. Curve *B* represents a zero-threshold, or linear response; point *b* represents the 50% dose for the zero-threshold biological effect.

CELL RADIOSENSITIVITY

Law of Bergonie and Tribondean (1906)

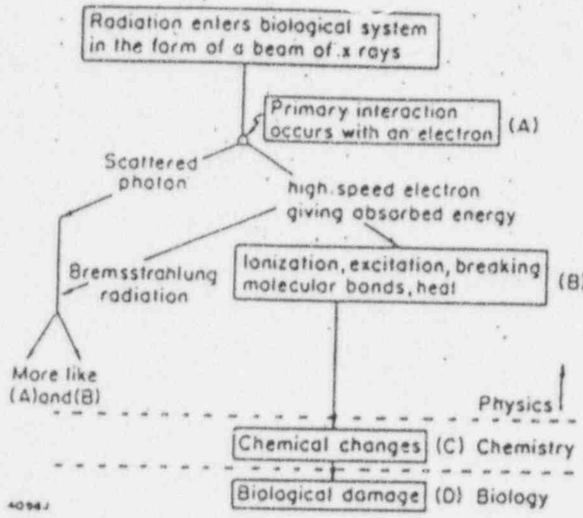
Cells that are most radiosensitive tend to have:

- a high division rate
- a long dividing future
- the capability to "specialize" at some future time into an "adult" cell type

"The generalization of the Law of Bergonie and Tribondeau is that tissues which are young and rapidly growing are most likely radiosensitive. A very practical application of the Law is given by NRC Regulatory Guide 8.13 which is titled "Instruction Concerning Prenatal Radiation Exposure". This Guide requires that women of reproductive age be informed of the increased risk of injury of the human fetus from radiation exposure because such a tissue meets all the criteria of the Law of Bergonie and Tribondeau. The human fetus is particularly sensitive in the first weeks of pregnancy when organs are forming. This is also a time period when the women may not be aware of her pregnancy. Most radiation protection standards recommend that the dose to a developing embryo and fetus be kept below 0.5 rem during the entire 9 months of gestation." (REF 3)

See also NCRP Report No. 54

Schematic Diagram Illustrating The Absorption Of Energy From Radiation Resulting In Biological Damage



Effects of overexposure

Direct action

- direct insult on a molecule by ionization or excitation and subsequent dissociation

Example: dissociation of an atom on a DNA molecule

Indirect action (by dissociation of atoms in water molecules)

$$H_2O \longrightarrow H^+ + OH^-$$

can recombine a number of ways

$$H + H \longrightarrow H_2 \quad \text{(gas)}$$

$$H + OH \longrightarrow H_2O \quad \text{(water)}$$

$$OH + OH \longrightarrow H_2O_2 \quad \text{(H peroxide)}$$

Peroxides are highly toxic (chemically) to cells.

Exposure Types

<u>Acute</u> - high dose in a short time

<u>Chronic</u> - lose doses over a long time (effects may take years to show up)

Clinical Effects

Acute Radiation Syndrome from acute whole body exposure.

1. Hemopoietic syndrome > 200 RADS
2. Gastrointestinal syndrome ≥ 1000 RADS
3. Central nervous system syndrome > 2000 RADS

Common to each are:

a. nausea and vomiting

b. malaise and fatigue

c. increased body temperature

* d. blood changes

*the most significant biological indicator of overexposure

Delayed Radiation Effects

- caused by acute large exposure <u>or</u> by a continuous low level exposure (internally or externally)
- effect occurs 5-20 years after exposure
- examples: Cancer (hemopoietic system, thyroid, bone and skin are the most common)

  Leukemia

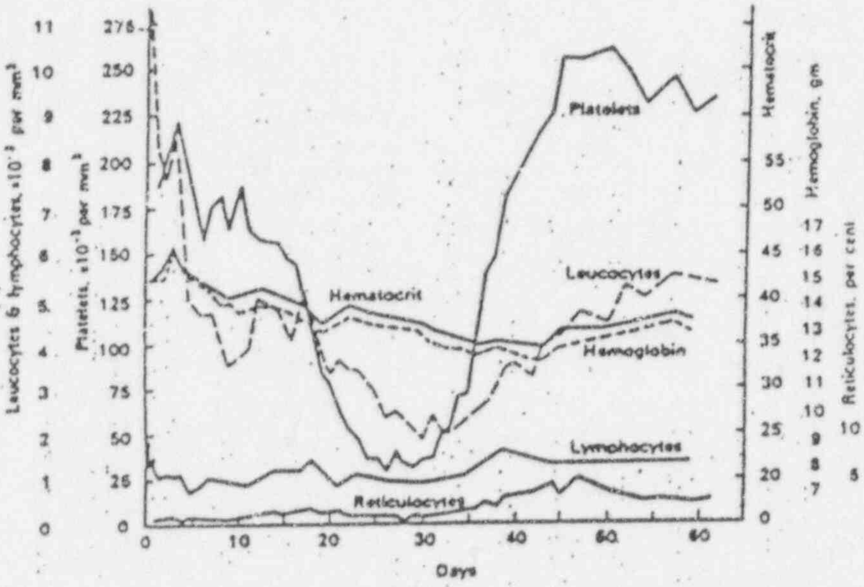
  Lung cancer

  Genetic effects

RADIOBIOLOGY

RANGE	Subclinical Range 0 to 100 rem	Therapeutic Range 100 to 1,000 rem			Lethal Range Over 1,000 rem	
		100 to 200 rem	200 to 600 rem	600 to 1,000 rem	1,000 to 5,000 rem	Over 5,000 r[cut off]
INCIDENCE OF VOMITING	None	100 rem: 5% 200 rem: 50%	300 rem: 100%	100%	100%	
DELAY TIME	- - -	3 hr	2 hr	1 hr	30 min	
LEADING ORGAN	None	Bone Marrow			Gastrointestinal Tract	Central Nerv[cut off] System
CHARACTERISTIC SIGNS	None	Moderate leukopenia	Severe leukopenia, hemorrhage, infection, purpura, epilation above 300 rem		Diarrhea, fever, electrolyte loss	Convulsions, tremor, atax[cut off]
THERAPY	Reassurance	Blood surveillance	Blood transfusion Antibiotics	Possible marrow transplant	Maintain electrolytes	Sedatives
PROGNOSIS	Excellent	Excellent	Good	Guarded	Hopeless	
INCIDENCE OF DEATH	None	None	0 to 80%	80 to 90%	90 to 100%	

REF 3



Hematologic effect of radiation overexposure. Average values for five patients who were exposed to 236–365 rad (estimated) during a criticality accident at the Y-12 plant in Oak Ridge on 16 June 1958. (G. H. Andrews, B. W. Sitterson, A. L. Kretchman and M. Brucer, Criticality accident at the Y-12 plant, *Diagnosis and Treatment of Acute Radiation Injury*, pp. 27–48, World Health Organization, Geneva, 1961.)

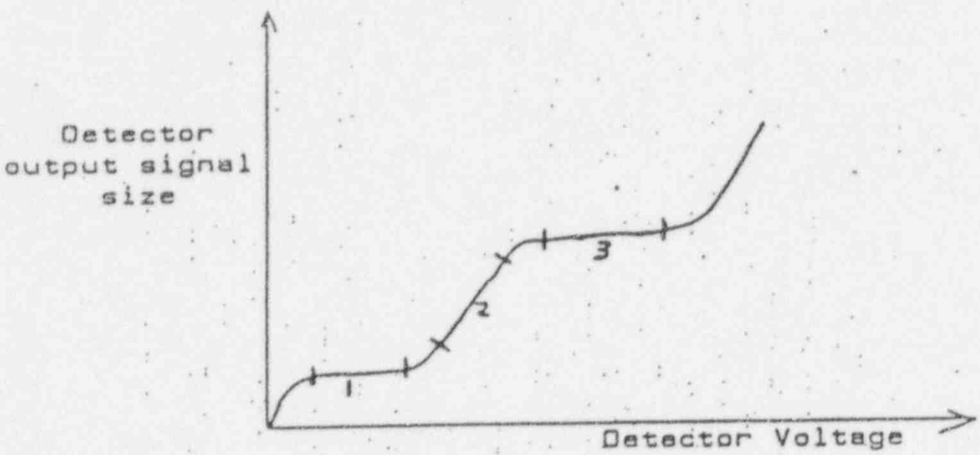
MECHANISMS FOR DETECTION

OF RADIATION

1.	IONIZATION	-	Release of ion pairs by the incoming radiation.
2.	BIOLOGICAL	-	Changes produced in a living system exposed to radiation.
3.	CHEMICAL	-	Changes caused in a chemical solution due to free radical release.
4.	HEAT	-	Energy deposited by the radiation causes a temperature rise in absorber.
5.	SCINTILLATION	-	Production of a flash of visible light in certain phosphors.
6.	THERMOLUMINESCENCE	-	The release of visible light after heating an irradiated sample.

GAS-FILLED DETECTOR

CHARACTERISTIC CURVE



Region 1

- Ion chamber region
- 100% collection of primary ionizations only
- no gas amplification
- can measure only cumulative effects

Region 2

- proportional counter region
- gas amplification produces secondary and tertiary ionizations
- output signal is proportional to incident radiation
- can measure individual events

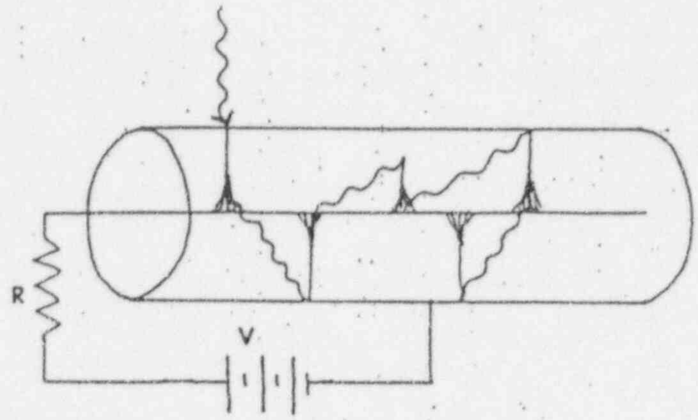
Region 3

- Geiger-Mueller region (G.M.)
- initial ion formation produces total avalanche of gas (complete discharge)
- output signal is the same for any energy of input radiation*

*may overrespond for low energy gamma rays

GM DETECTORS

SPECIAL CONSIDERATIONS



Tube saturation occurs when the tube is exposed to a very high exposure rate in a radiation field.

A conventional instrument will show a momentary upswing of the meter needle followed by a return of the needle to a point near zero, even though the instrument is still in the high field. In such a high field, the ionizing events are interacting with the counter tube with an average separation in time much closer together than the counter dead time. Most of these rays will be missed since the tube is "dead". The problem occurs near the end of the dead time while the last ions are being cleared. If a new event is detected then, the tube still has not fully recovered so the gas multiplication factor will still be depressed. This produces a must smaller pulse than normal. In fact, the pulses formed under these conditions are usually so small as to be at the same level as the background electronic noise. Since the noise pulses are discriminated against by the electronic circuit, this read count will be missed along with all the following counts that continue to trigger the tube before it can recover. Thus the instrument reads "background" while in fact the operator is in an extremely hazardous radiation field. This problem can be eliminated by using only the "non-saturating" type of geiger counters now commercially available. If in doubt, check the instrument specifications to make sure it will not saturate in fields which might be possible at your facility, even under worst case accident conditions.

REF 3

Health Physics Vol. 51, No. 5 (November), pp. 601–607, 1986
Printed in the U.S.A.

0017-9078/86 $3.00 + .00

LONG-TERM FOLLOW-UP AFTER ACCIDENTAL γ IRRADIATION FROM A ^{60}Co SOURCE

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(*Received* 1 *August* 1985; *accepted* 28 *April* 1986)

Abstract—In December 1973 a technician was accidentally irradiated when attempting to bring under control a sealed ^{60}Co source (110 TBq) which had been lodged in the head of a medical irradiation unit during a replacement operation. In the early period after the accident, severe skin changes on the left hand, epilation in a small area of the left temporal region and minor deviations in peripheral blood developed. In the following years, repeated surgery due to secondary skin defects of the left hand resulted in the loss of the fingers 2–5. Since 1975, changes in the lens of the left eye began to appear leading gradually to the deterioration of visual acuity. Later, opacities of the lens of the right eye were found. The patient's psychological and emotional attitude about the accident changed in the course of time. The factors influencing the psychic state of the patient are identified.

EVALUATION of the impact and consequences of an accident after some longer time complements the information obtained immediately after recovery from acute radiation injury and offers another useful lesson. The overall health status of a worker was followed for 11 y after quite severe non-uniform γ irradiation from a ^{60}Co source.

In the first years after the accident, the most significant health disorder was local necrosis of the skin and deeper layers of the left hand, which stabilized after a series of surgeries. Repeated monitoring of the eye lenses permitted reconstruction of the time course of development of a cataract and a description of its morphological characteristics.

CIRCUMSTANCES OF THE ACCIDENT AND IMMEDIATE CLINICAL MANIFESTATIONS

On 17 December 1973 a 26-y-old technician (A), responsible for servicing medical irradiation units, installed, together with his co-worker (B) a 110-TBq ^{60}Co source into the head of a tele-

therapy unit at a hospital outside Czechoslovakia. After sliding the source from the transport container into the head of the teletherapy unit, some doubts arose as to whether the operation had been conducted properly because the orange-yellow control light indicated that the source had not reached the resting position in the head. The workers were equipped with personal film dosimeters and a simple portable indicator on the principle of a GM-tube, which showed no deviation on routine assessment of the radiation field. The fault was concluded to be in the light signal system, namely in a broken wire; therefore, they repaired it by soldering it to the microswitch. In the course of repairing the wire, they determined that the actual failure was blockage of the source on its track into the head. During further manipulation of the head, the source dropped to the floor of the room. Both workers quickly left the room and after considering the situation, they decided to bring the source under control by their own efforts using improvised tools.

The source was sealed in a cylindrical capsule of 5.2-cm height and 2.6-cm radius and weighed about 1200 g. This capsule lay on the floor in the irradiation room about 3 m from the entrance and about 2 m from the source container which was near the shielded door. The objective of the operation was to transfer the source to the container with available remote manipulator tools and mirrors, taking advantage of the shielding capacity of the door. After some unsuccessful attempts, they finally managed to place the source back into the container.

Further action by the technicians was unfavorably influenced by the fact that the accident occurred far from their workplace and that the biological response began to appear during the Christmas and New Year holidays. Technician (A) felt ill on 18 December (12–24 h following the accident). He felt general malaise without vomiting, his left eye watered, and his nose bled twice though he previously never suffered from a bleeding nose. Both technicians had a blood count conducted which showed no marked deviation. After his return to Czechoslovakia, technician (A) did not report the accident and returned for routine evaluation the film dosimeter which at the time of the accident was worn on the left side of the chest.

On 25 December (the eighth day after the accident) technician (A) experienced a reddening on the left palm above the metacarpophalangeal joint of the fourth digit accompanied by painful swelling. The inflammatory changes, characterized by erythema and bullae, spread within a few days to the other fingers with the exception of the thumb. At that time he saw a doctor who diagnosed, in view of the elevated temperature (38.5°C), erysipelas and placed the patient on antibiotics. On 4 January 1974, the film dosimeter was evaluated and indicated an exposure corresponding to 1.59 Gy† which prompted the patient's hospitalization at the Clinic for Occupational Diseases, Faculty of General Medicine in Prague.

For assessing the severity of the accident and the prognosis of further clinical manifestations, physical as well as medico-biological methods were used. On the basis of information from both victims of the accident, the time course and geometric conditions of the particular phases of manipulation with the source after its drop to the floor were reconstructed. Attention was wrongly focused solely on this period of the accident, omitting a critical evaluation of the information about the absence of response of the portable dosimetric apparatus at the time of soldering the electric conductor. Thus the result of initial calculations showed doses to the left hand which could hardly induce severe lesions of the skin and deeper layers of the hand with a relatively short latency period. Only later was the possibility of GM-tube saturation considered. The geometry of changes on the left hand during the relapse indicated that the critical operation might have been soldering of the electric conductors on the head of the irradiation unit. In retrospect, it was not possible to determine exactly the phase of the operation in which technician (A) was irradiated.

On the twenty-seventh day after the accident, a cytogenetic examination of peripheral blood lymphocytes was performed in both workers, using a standard micromethod. In technician (A), 13 dicentrics were found in 100 metaphases which, when using a calibration curve for radio-

† In worker (B), the data on the film dosimeter corresponded to 0.1 Gy.

cobalt, led to the estimate of whole-body dose equivalent of 1.2–1.6 Gy (KI79). In worker (B), no chromosome aberrations of the dicentric or ring type were found in 100 cells. In view of these results and the absence of clinical symptoms in worker (B), the remainder of this report will deal solely with worker (A).

During hospitalization, care was given to the evaluation and treatment of general as well as local symptoms. Between Days 18 and 25 after the accident, the patient developed irregular subfebrile temperatures despite continued treatment with antibiotics. This was attributed to developing local changes on the left hand. Deviations in the peripheral blood count were not marked and were conspicuous only in comparison with individual mean values obtained from 14 examinations of peripheral blood prior to the accident (Fig. 1). The horizontal continuous line in Fig. 1 denotes individual means and broken lines ±2 standard deviations. The total leukocyte count and count of neutrophils the first day after the accident exceeded the band ±2 s. Between the second and seventeenth days after the accident, hematologic data are missing. On the thirty-first and forty-ninth postaccident days, the total leukocyte values were the lowest, and in this period a drop in the number of neutrophils below the lower limit was recorded. Lymphocyte count the first day after the accident was normal, but decreased below the level of the lower limit between Days 19 and 23 and later on the forty-ninth day. Morphological deviations in white blood elements were observable, including neutrophils with coarse granulations and hypersegmentation of nuclei. A number of mononuclears showed the pattern of lymphomonocyte cells. Thrombocytes were near the bottom limit of normal values (data not shown), but hemocoagulation examinations revealed no deviations. Sternal puncture was refused by the patient. Even at small quantitative changes, the time course of changes and concomitant qualitative deviations in white blood elements, being distinct responses of the hemopoietic system to irradiation, permitted assessment of the situation.

The most conspicuous and most serious medical problem was local damage on the left hand at the time of admission to the clinic. On the palm above the metacarpophalangeal joints of

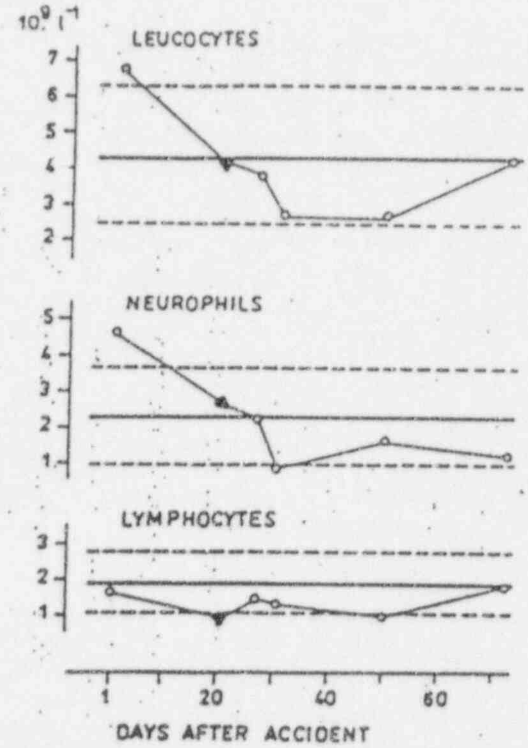

FIG. 1. The course in time of white blood cell count (total leucocytes, neutrophils, lymphocytes) in the exposed technician (A) 1–72 days after the accident. The mean (continuous line) and ±2 standard deviations (broken lines) calculated from 14 blood counts carried out during the last 6 y before the accident.

the third and fourth finger, an irregular oval defect 3 × 4 cm with whitish edges and bleeding bottom was observed. Palmar to the basal phalanges of the third and fourth finger were superficial skin lesions after removal of bullae. Localization of the changes is schematically illustrated in Fig. 2. Considerable spontaneous pain required administration of analgesics. The defects showed no tendency to heal, rather they spread to adjacent interdigital spaces. Therefore, between the thirty-fourth and fifty-third day after the accident, the patient was hospitalized in the Burn Unit of the Clinic of Plastic Surgery, Medical Faculty of Hygiene. No signs of necrosis developed during this period and the skin lesions healed.

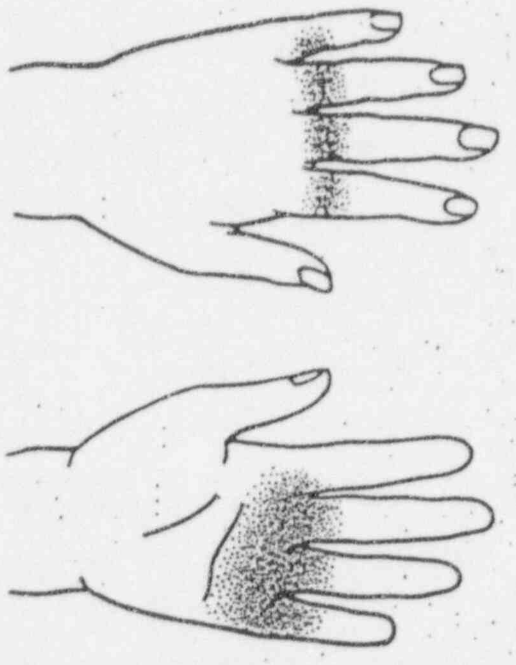

FIG. 2. Areas of the acute skin injury of the left hand in the exposed technician (A) 17 d after accident.

Local symptoms of lesser intensity appeared between Days 20 and 30 after the accident in the left temporal region with epilation of an area 4 × 6 cm; however, alopecia was incomplete. There was slight swelling of the left eyelid and slight reaction of the conjuctiva. Examination of the spermiogram on Days 31 and 42, and 6 mo after the accident showed no important deviations.

DEVELOPMENT OF LOCAL CHANGES ON THE LEFT HAND

Serious trophic changes persisted on the left hand, characterized by a smoothed discolored skin and disturbed local blood flow. The earlier defects were partly covered by a fine crust. Due to the hard swelling of deeper skin layers, motility of fingers 2–5 was greatly limited. Twelve months after the accident, a secondary defect developed on the palmar area of the basal phalange of the fifth finger. The patient was again admitted to the Burn Unit of the clinic for plastic surgery, when it was first attempted to cover the defect by tubular graft. Failure of this attempt necessitated within the next 4 mo successive amputations of fingers 5 through 2 and surgical interventions to improve function and cosmetic appearance of the remaining part of the left hand. The patient had been originally lefthanded and was trained to use the right hand. The state of the amputated hand in 1985 is shown in Fig. 3. The skin of the hand requires protection against cold, direct sunlight and chemical or mechanical irritation. Observing these principles, no relapse of skin defects has occurred since 1975, and the person in question continues to work as a testing technician at his original workplace; however, he does not work with radiation sources.

DEVELOPMENT OF CHANGES IN EYE LENSES

Early local manifestations in the left temporal region and in the anterior segment of the left eye

FIG. 3. Final outcome of the repeated surgery of the left hand (March 1985).

indicated a significant local dose in this region and prompted a systematic monitoring of the state of the eye lens.

The first changes in the form of fine radial opacities in the posterior cortex inferotemporally and of a flat posterior subcapsular cataract inferonasally were observed in May 1975 (17 mo after the accident). In 1977 (i.e. the fourth year after the accident and the patient's thirtieth year of age) vacuoles appeared under the anterior lens capsule, and the flat posterior subcapsular opacity became more strongly marked.

Vision in both eyes was 6/6 with −0.5 D sphere. In 1977 the patient started to read 6/6 to 6/8 with the left eye. Deterioration of visual acuity of the left eye progressed relatively rapidly. By October 1978 the patient's best corrected vision was 6/18. By April 1979 it was 6/60 uncorrected (6/24 with +1 D correction).

In 1980 changes appeared also in the right eye lens. At first, several vacuoles and powder-like opacities appeared under the anterior capsule. In the central area under the posterior capsule, there was a net-like opacity. Visual acuity of the right eye is normal; however, the refractive error changed as the opacities in the lens developed.

OPHTHALMOLOGIC FINDINGS IN MARCH 1985

External and intraocular findings up to the pupil were normal in both eyes.

Right eye. Under the central anterior capsule of the lens was a fine opacity with ray-like projections visible only with a slit lamp biomicroscope. Powder-like opacities were observed in both cortices. In the central posterior capsule, there was a nonhomogeneous, flat, ring-shaped, fairly dense opacity 2 mm in diameter with fine ray-like opacities. Vision was 6/6 uncorrected; 6/4 with +0.5 D sphere.

Left eye. Under the anterior capsule of the lens there was a similar spot as in the right eye, and powder-like opacities in both cortices were more frequent. Under the posterior capsule was a flat, nonhomogeneous, porous opacity 6 mm in diameter. The opacity had a wavy border and was denser at the periphery. From the opaque spot, fine ray-like opacities emerged to the equator. The opacity was granular and net-like. Around the posterior pole there was a dense, greyish, slightly oval opacity, denser at the periphery, about 1 mm in diameter, with no porous structure. Vision was 6/60 uncorrected; 6/24 with +1.5 D sphere.

Figure 4 shows the optical section of the cataract on the posterior pole of the lens of the right and the left eye. A substantially larger extent of the left eye opacity is apparent.

PSYCHOLOGICAL ASPECTS OF THE ACCIDENT

The patient's psychological and emotional attitude about the accident changed with the course of the illness. The day after the accident techni-

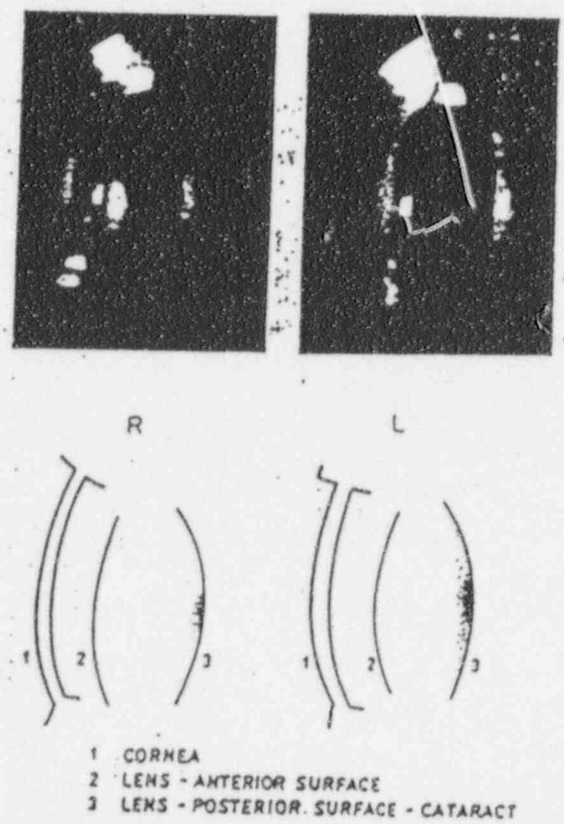

FIG. 4. Lateral optical sections of the lens of the right (R) and left (L) eye. The biconcave body of the lenses could be easily distinguished with the flat subcapsular opacity of the posterior pole clearly showing greater extent and density of the cataract of the left eye (March 1985).

cian (A) felt somehow uneasy and asked for his blood count to be made. The information that the values were within normal limits and the absence of skin response alleviated his anxiety. During his training, he had received basic information about the possible consequences of an accident. But at the moment the implications of the latency period escaped him, and he thought he was entirely out of danger. Five to six days after the accident, he painted and cleaned his apartment using no protection for his hands. During his first stay at hospital (Day 17 to Day 53 after the accident) he accepted the situation more or less rationally and felt reassured by the healing of the defects. After discharge from the hospital, painful swelling of the left-hand finger joints and their confined motility bothered him. Rehabilitation had, however, good results, and he expected further improvement.

The reappearance of the defect on the fifth finger of his left hand at the beginning of 1973 (13 mo after the accident) aroused considerable anxiety in worker (A). Repeated surgery during his long hospitalization and the successive amputation of fingers produced prolonged depression, accentuated by severe pain in the affected limb.

With the aim of gaining insight into the treatment of similar situations we have identified in retrospect the moments having a positive effect on the psychic state of the patient and those with an unfavorable effect. In the first days of hospitalization in January 1974 (at the time of determining the circumstances of the accident), the patient felt annoyed by the great number of questions pertaining to the accident. In this atmosphere the patient perceived that people had lost interest in his personal problems and his health, although objectively he received good medical care. He felt annoyed by the suspicion of some experts that during the handling of the accident he had touched the ^{60}Co source with his unprotected hand and that he concealed this fact. On the other hand, he recalls vividly the attitude of those doctors who showed a personal interest in his situation and who tried to influence actively his state of health. Throughout the whole period of treatment, he found great support among his family. The attitude of the employing organization and of his co-workers was one of understanding of his personal situation.

DISCUSSION

The retrospective evaluation of the consequences of the accident, which occurred 13 y ago, provides data on the development of some post-irradiation effects during a long period and a lesson about the management of persons affected in an accident.

Due to the long-term continual monitoring of the patient, it was possible to detect the development of a cataract from the very beginning. Initial changes in the lens of the more irradiated left eye appeared 18 mo after the accident and since then intensity of the opacity has been progressing. Forty-six months after the accident these changes have distinctly reduced visual acuity. Progressive changes in the right eye have been observed since 1980; however, visual acuity has thus far not been affected. The dose to the eye lens cannot be estimated from dosimetric data, but an estimate can be made from the presence of distinct incomplete epilation in the left temporal area early after the accident. A dose of 1–2 Gy will cause histological changes without clinical signs in hair follicles, 3–5 Gy will induce transient epilation, and doses greater than 7 Gy cause permanent epilation (Ru68; UNSCEAR82). Since hair follicles of the head may be more sensitive to irradiation than hair follicles of other parts of the body, the dose to the left temporal region was estimated to be 3–4 Gy. The dose to the left-eye lens may be comparable. The dose estimate to the right eye is more difficult. In view of the progressing changes on the right-eye lens and the presumed geometry at the time of irradiation, the dose to the right-eye lens may correspond to a significant fraction of the estimate for the left lens.

To prevent accidents during repair and maintenance of irradiation units, adequate technological and dosimetric equipment and clear-cut guidelines for their use are indispensable. Technical procedures for replacement of radiation sources must be devised to minimize the probability of technical problems during such operations. The procedures should provide for the use of high dose rate personal alarm monitors, as well as portable high dose rate radiation field monitors. Since a technical failure may occur and its correction may entail the possibility of higher dose rates, thorough plans should be prepared

for bringing the source under control and should include provision for the shielding of workers, use of remote manipulation, and monitoring of the operation.

Since the accident, there has been time to reconsider problems connected with the human factor and emotional reactions. In a radiation accident the victim is exposed to an extremely unusual situation. The great rush around him produces a sense of insecurity and even panic, which affects his cooperation with the medical team and can influence the outcome of medical care. The medical staff should endeavour to create conditions in which the patient will not feel like a mere subject of examinations but rather like a partner of the team providing medical help (Br83).

CONCLUSIONS

The analysis of the accident and the evaluation of the results of the long-term follow-up may be summarized as follows:

(1) Non-adherence to several safety precautions contributed to the cause of the accidental irradiation and inadequate response thereafter. All safety measures should be strictly observed in handling high-yield γ sources during mounting and maintenance work.

(2) The clinical signs in the injured worker were a guide for the medical approach, particularly when more detailed dosimetric data were lacking.

(3) The time course of the changes on the left hand confirmed the experience that the skin and subcutaneous injury after heavy local γ irradiation does not culminate in the early period but in the time of recurrence 1–2 y later. The overexposed skin should always be protected not only from ionizing radiation but from mechanical and chemical irritation as well.

(4) The time course of the changes in the lenses of both eyes contributed retrospectively to the assessment of the dose and its geometrical distribution on the head.

(5) Emotional problems preoccupied the mind of the overexposed individual a long time after the accident and deserved systematic support on the part of the physicians.

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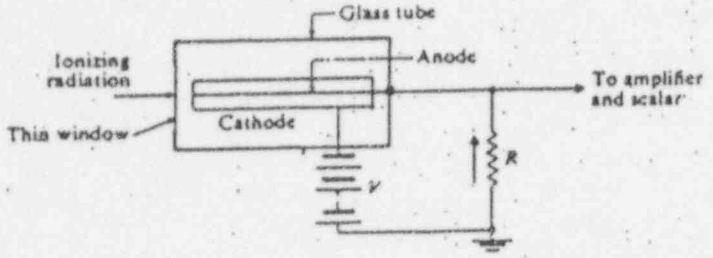
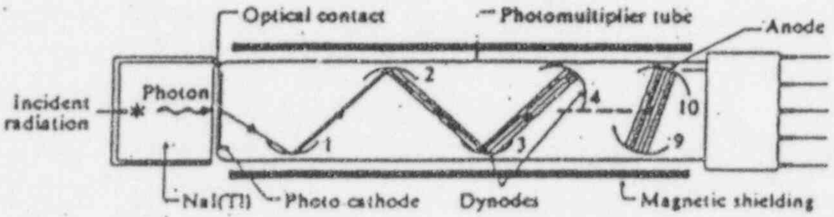
RADIATION DETECTION INSTRUMENTS

Gas Filled Detector



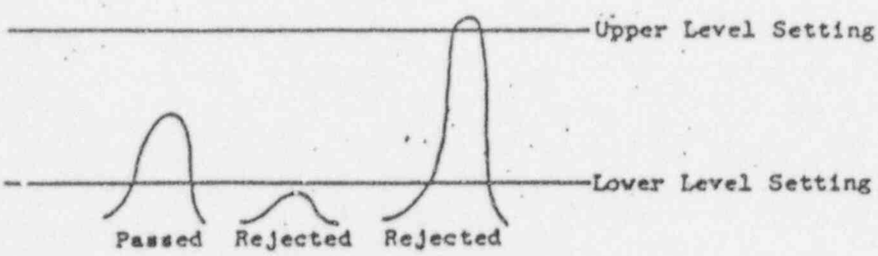
Typical gas-filled detector with a thin mica window so that or B particles may be counted. Depending on the gas pressure and the applied voltage, the detector may be operated as proportional counter or Geiger counter.

Scintillation Detector - not gas filled



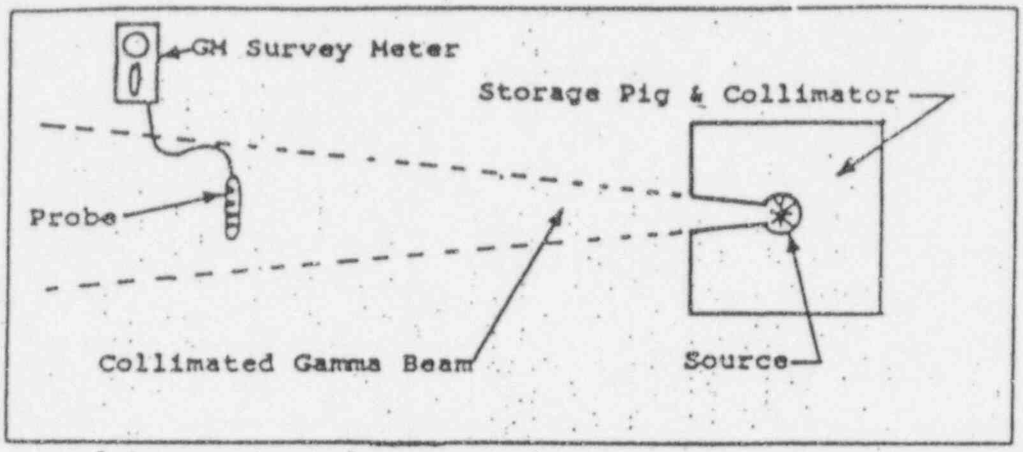
Typical NaI(Tl) scintillation detector. The number of photoelectrons emitted is multiplied by successive dynodes, resulting in an electrical pulse at the anode. Output at the anode is proportional to incident radiation.

A Single Channel Analyzer Voltage Window



REF 1 and 3

RADIATION SURVEY INSTRUMENT CALIBRATION



Each radiation survey instrument shall be calibrated:

(1) by a person licensed or registered by the Agency, another Agreement State, or the U.S. Nuclear Regulatory Commission to perform such service;

(2) at intervals not to exceed 12 months unless a more restrictive time interval is specified in another part of these rules;

(3) after each survey instrument repair;

(4) for the types of radiation used at energies appropriate for use; and

(5) at an accuracy within 20 percent of the true radiation level.

Records of survey instrument calibrations shall be maintained for inspection by the regulatory agency.

Bank One, Cleveland, NA
30 South Park Place
Post Office Box 268
Painesville Ohio 44077

BANK ONE.

January 24, 1995

Mr. John Grobe
U.S. Nuclear Regulatory Commission - Region 3
801 Warrenville Road
Lisle, IL 60532

Dear Mr. Grobe:

Please use this letter as confirmation that an irrevocable standby letter of credit for $1,800,000 has been approved for Advanced Medical Systems, Inc. by Bank One, Cleveland, NA. The letter of credit will have an expiration date of February 1, 1996, and will be automatically extended unless notice is provided by Bank One.

Bank One is completing the necessary documentation, and expects that the issuance of the letter of credit will be completed no later than February 1, 1995.

Please feel free to contact me at (216) 352-5698 if you have any questions.

Sincerely,

Jan E. Petrik
Vice President
Corporate Banking Division

JEP/pam

9702040071 1p.

SECTION 4 - WASTE HOLD-UP TANK ROOM INTEGRITY EVALUATION

As of the date of this submission, the WHUT Room Report has not yet been received. This report will be forwarded to the NRC upon receipt of finished document.