NRC Form 313 I (12-81) 10 CFR 30

U.S. NUCLEAR REGULATORY COMMISSION

# APPLICATION FOR BYPRODUCT MATERIAL LICENSE
## INDUSTRIAL

*See attached instructions for details.*

*Completed applications are filed in duplicate with the Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety, and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555 or applications may be filed in person at the Commission's office at 1717 H Street, NW, Washington, D. C. or 7915 Eastern Avenue, Silver Spring, Maryland.*

1. APPLICATION FOR: *(Check and/or complete as appropriate)*

| | |
|---|---|
| | a. NEW LICENSE |
| X | b. AMENDMENT TO: LICENSE NUMBER 19-17250-05 |
| | c. RENEWAL OF: LICENSE NUMBER |

2. APPLICANT'S NAME *(Institution, firm, person, etc.)*
Harry Diamond Laboratories
TELEPHONE NUMBER: AREA CODE – NUMBER EXTENSION

3. NAME AND TITLE OF PERSON TO BE CONTACTED REGARDING THIS APPLICATION
Michael Borisky, Radiation Protection Officer
TELEPHONE NUMBER: AREA CODE – NUMBER EXTENSION
202-394-2218

4. APPLICANT'S MAILING ADDRESS *(Include Zip Code)* *(Address to which NRC correspondence, notices, bulletins, etc., should be sent.)*
Harry Diamond Laboratories
ATTN: SLCIS-SO
2800 Powder Mill Road
Adelphi, MD 20783-1197

5. STREET ADDRESS WHERE LICENSED MATERIAL WILL BE USED *(Include Zip Code)*
Harry Diamond Laboratories
2800 Powder Mill Road
Adelphi, MD 20783-1197

(IF MORE SPACE IS NEEDED FOR ANY ITEM, USE ADDITIONAL PROPERLY KEYED PAGES.)

6. INDIVIDUAL(S) WHO WILL USE OR DIRECTLY SUPERVISE THE USE OF LICENSED MATERIAL
*(See Items 16 and 17 for required training and experience of each individual named below)*

| | FULL NAME | TITLE |
|---|---|---|
| a. | Klaus G. Kerris | Facility Supervisor |
| b. | Charles C. Casaer<br>Perry Sarigianis | Facility Operator<br>Facility Operator |
| c. | Michael Borisky<br>Harvey Eisen | Radiation Protection Officer<br>Alternate Radiation Protection Officer |

7. RADIATION PROTECTION OFFICER
Michael Borisky

*Attach a resume of person's training and experience as outlined in Items 16 and 17 and describe his responsibilities under Item 15.*

8. LICENSED MATERIAL

| LINE NO. | ELEMENT AND MASS NUMBER (A) | CHEMICAL AND/OR PHYSICAL FORM (B) | NAME OF MANUFACTURER AND MODEL NUMBER *(If Sealed Source)* (C) | MAXIMUM NUMBER OF MILLICURIES AND/OR SEALED SOURCES AND MAXIMUM ACTIVITY PER SOURCE WHICH WILL BE POSSESSED AT ANY ONE TIME (D) |
|---|---|---|---|---|
| (1) | Cobalt 60 | 8 ea sealed sources double encapsulated | Neutron Products Inc. Model 12CC5 | 8 sources, 78 Ci max, total = 522 Ci (7/1/86) |
| (2) | Cobalt 60 | 24 ea sealed sources double encapsulated | Neutron Products Inc. Model 12CC5 | 24 sources, 392 Ci max, total = 7,717 (7/1/86) |
| (3) | Cobalt 60 | 8 ea sealed sources double encapsulated | Neutron Products Inc. Model NPRP-330-14-K | 8 sources, 5,500 Ci max, total not to exceed |
| (4) | | See Supplement #1 | | 38,000 Ci grand total 46,239 Ci |

| | DESCRIBE USE OF LICENSED MATERIAL (E) |
|---|---|
| (1) | The Byproduct Material will be used for research and development as defined in Title 10, Code of Federal Regulations, Part 30, Section 30.4 (q). The Gamma |
| (2) | Radiation Facility is to be used for radiation effects testing on electronic components and for the performance of radiochemistry and dosimetry experiments. |
| (3) | Highly flammable or explosive materials will not be irradiated at the Gamma Radiation Facility. |
| (4) | See Supplement #1 |

FEE EXEMPT

NRC FORM 313 I (12-81)

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REG1 LIC30
19-17250-05 PDR

Encl 2

## 9. STORAGE OF SEALED SOURCES

| LINE NO. | CONTAINER AND/OR DEVICE IN WHICH EACH SEALED SOURCE WILL BE STORED OR USED. A. | NAME OF MANUFACTURER B. | MODEL NUMBER C. |
|---|---|---|---|
| (1) | See Supplement #5 | | |
| (2) | | | |
| (3) | | | |
| (4) | | | |

## 10. RADIATION DETECTION INSTRUMENTS

| LINE NO. | TYPE OF INSTRUMENT A | MANUFACTURER'S NAME B | MODEL NUMBER C | NUMBER AVAILABLE D | RADIATION DETECTED (alpha, beta, gamma, neutron) E | SENSITIVITY RANGE (milliroentgens/hour or counts/minute) F |
|---|---|---|---|---|---|---|
| (1) | See Supplement #4 | | | | | |
| (2) | | | | | | |
| (3) | | | | | | |
| (4) | | | | | | |

## 11. CALIBRATION OF INSTRUMENTS LISTED IN ITEM 10

☒ a. CALIBRATED BY SERVICE COMPANY NAME, ADDRESS, AND FREQUENCY portable instruments quarterly

Radiation Services Organization License # 
P. O. Box 419, Laurel, MD 20707 MD-33-021-01

☒ b. CALIBRATED BY APPLICANT RAM's and PC-4

*Attach a separate sheet describing method, frequency and standards used for calibrating instruments.*

See Supplement #4

## 12. PERSONNEL MONITORING DEVICES

| TYPE (Check and/or complete as appropriate.) A | SUPPLIER (Service Company) B | EXCHANGE FREQUENCY C |
|---|---|---|
| ☒ (1) FILM BADGE<br>☐ (2) THERMOLUMINESCENCE DOSIMETER *(TLD)*<br>☐ (3) OTHER *(Specify)*: ______ | U. S. Army Ionizing Radiation Dosimetry Center<br>ATTN: AMXTM-CE-DCR<br>Lexington, KY 40511-5102 | ☒ MONTHLY<br>☐ QUARTERLY<br>☐ OTHER *(Specify)*: ______ |

## 13. FACILITIES AND EQUIPMENT (Check were appropriate and attach annotated sketch(es) and description(s).

☐ a. LABORATORY FACILITIES, PLANT FACILITIES, FUME HOODS *(Include filtration, if any)*, ETC.
☒ b. STORAGE FACILITIES, CONTAINERS, SPECIAL SHIELDING *(fixed and/or temporary)*, ETC.
☒ c. REMOTE HANDLING TOOLS OR EQUIPMENT, ETC.
☐ d. RESPIRATORY PROTECTIVE EQUIPMENT, ETC.

See Supplement #5

## 14. WASTE DISPOSAL

a. NAME OF COMMERCIAL WASTE DISPOSAL SERVICE EMPLOYED

See Supplement #6

b. IF COMMERCIAL WASTE DISPOSAL SERVICE IS NOT EMPLOYED, SUBMIT A DETAILED DESCRIPTION OF METHODS WHICH WILL BE USED FOR DISPOSING OF RADIOACTIVE WASTES AND ESTIMATES OF THE TYPE AND AMOUNT OF ACTIVITY INVOLVED. IF THE APPLICATION IS FOR SEALED SOURCES AND DEVICES AND THEY WILL BE RETURNED TO THE MANUFACTURER, SO STATE.

## INFORMATION REQUIRED FOR ITEMS 15, 16 AND 17

Describe in detail the information required for Items 15, 16 and 17. Begin each item on a separate page and key to the application as follows:

15. RADIATION PROTECTION PROGRAM. Describe the radiation protection program as appropriate for the material to be used including the duties and responsibilities of the Radiation Protection Officer, control measures, bioassay procedures *(if needed)*, day-to-day general safety instruction to be followed, etc. If the application is for sealed source's also submit leak testing procedures, or if leak testing will be performed using a leak test kit, specify manufacturer and model number of the leak test kit.

    See Supplement #6

16. FORMAL TRAINING IN RADIATION SAFETY. Attach a resume for each individual named in Items 6 and 7. Describe individual's formal training in the following areas where applicable. Include the name of person or institution providing the training, duration of training, when training was received, etc.

    See Supplement #2

    a. Principles and practices of radiation protection.

    b. Radioactivity measurement standardization and monitoring techniques and instruments.

    c. Mathematics and calculations basic to the use and measurement of radioactivity.

    d. Biological effects of radiation.

17. EXPERIENCE. Attach a resume for each individual named in Items 6 and 7. Describe individual's work experience with radiation, including where experience was obtained. Work experience or on-the-job training should be commensurate with the proposed use. Include list of radioisotopes and maximum activity of each used.

    See Supplement #3

## 18. CERTIFICATE

*(This item must be completed by applicant)*

*The applicant and any official executing this certificate on behalf of the applicant named in Item 2, certify that this application is prepared in conformity with Title 10, Code of Federal Regulations, Part 30, and that all information contained herein, including any supplements attached hereto, is true and correct to the best of our knowledge and belief.*

**WARNING.**–18 U.S.C., Section 1001; Act of June 25, 1948; 62 Stat. 749; makes it a criminal offense to make a willfully false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

| | |
|---|---|
| a. LICENSE FEE REQUIRED *(See Section 170.31, 10 CFR 170)* | b. CERTIFYING OFFICIAL *(Signature)* Stuart M. Marcus |
| | c. NAME *(Type or print)* STUART M. MARCUS |
| (1) LICENSE FEE CATEGORY: | d. TITLE Director, Installation Support Activity |
| (2) LICENSE FEE ENCLOSED: $ | e. DATE 21 MAY 1980 |

See letter dtd 5-24-86

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TABLE OF CONTENTS (Continued)

SUPPLEMENT #1

Item 8B, Form NRC-313I, Description of Cobalt-60 Sources.

This amendment requests that Harry Diamond Laboratories be granted the authority to add 8 new source pencils to the currently licensed inventory of 32 source pencils. The 32 sources currently authorized and used by Harry Diamond Laboratories are Neutron Products Inc., Model 12CC5 sources. The 8 new sources Harry Diamond Laboratories is soliciting authority to possess, use, and store are Neutron Products Inc., Model NPRP-330-14-K sources. The Model NPRP-330-14-K sources will be fabricated to the same physical size so that the currently used source storage containers, manipulator, and leak test fixture can be used with the new sources. The following is a description of each model source.

1. Model 12CC5 Sources.

a. General Description: Each of the doubly encapsulated sources is comprised of a type 304L stainless steel tube containing a Model NPI 12CC5 clad wire coil of Cobalt-60. The outer capsule has stainless steel end caps and is sealed by TIG welding. The clad wire coil itself constitutes a singly encapsulated source. It consists of a cobalt wire approximately .060 inch in diameter which is contained within a stainless steel tube having an outer diameter of approximately .072 inch. The contained wire is sealed at both ends by TIG welding, and then wound into the shape of a coil prior to irradiation. It is subjected to an acid leak test prior to irradiation, and subsequent to irradiation it is subjected to a corrosion test and is also smeared to assure that cladding integrity has not been violated.

b. Specific Information: In addition to the information provided in Item 8 of the enclosed Form NRC 313I, the USNRC publication entitled "Guide-Information to be Submitted Concerning Sealed Sources Containing Radioactive Materials" solicits additional information concerning the radioisotope, construction, prototype tests, quality control and labeling data. Since all source specification drawings, construction specifications, prototype testing specifications, and quality control specifications are considered to be proprietary information by Neutron Products Inc., it is requested that the USNRC glean specific information concerning Neutron Products Inc., Model 12CC5 single encapsulated source, which has been double encapsulated in accordance with NPI's Procedure P2, from the USNRC Sealed Source/Device Catalog. This method of presenting required proprietary information was approved by the USNRC during the review of the initial license request application.

2. Model NPRP-330-14-K Sources.

The Model NPRP-330-14-K sources are registered with the State of Maryland, an NRC agreement state. The registration and safety evaluation of the sources are contained in the Source and Device Catalog. A copy of the registration - MD 474S108S, "Registry of Radioactive Sealed Source and Devices, Safety Evaluation of Sealed Source", is attached as Annex 1A to this supplement. Drawing No. 200320, attached as Annex 1B to this supplement, gives the details of actual construction of the Model NPRP-330-14-K source. It is requested that the USNRC glean information concerning the Neutron Products Model NPRP-330-14-K source from Annex 1A, Annex 1B, and the Source and Device Catalog, as needed. This method of presenting required proprietary information was approved by the USNRC during the review of the initial license request application.

3. Quantities.

a. Model 12CC5 Sources. As indicated in Item 8D of NRC Form 313I, the activity of the 32 Model 12CC5 sources will be 8,239 curies on 01 July 86. This activity is calculated using the original activity of each source assayed by Neutron Products on 01 July 75, and correcting for 11 years of radioactive decay.

b. Model NPRP-330-14-K Sources. Because the 8 NPRP-330-14-K sources will not be manufactured until after Harry Diamond Laboratories gains an appropriate NRC license amendment, actual activity values are not available at this time. Harry Diamond Laboratories has requested from Neutron Products 8 source pencils totaling 34-38 kCi, with no single source exceeding 5.5 kCi.

4. Labelling. Since the sources and source holders are stored under water, it would not be effective to attach labels which present the information required by the USNRC "Guide" to either the sources or the source holder. Consequently, a label which identifies the isotope, quantity of isotope, date of measurement, manufacturer's trademark, and contains the words "Caution - Radioactive Material," and the radiation symbol will be attached to the entrance door of the Cobalt-60 Facility Exposure Room. Attached as Annex 1C to this supplement is a facsimile of the label to be used.

5. Use. Sources will be used to conduct in-pool and in-air irradiations of electronic components, and for the performance of radiochemistry and dosimetry experiments. A maximum of eight sources will be used at any one time for in-air irradiations, with the remainder of the sources remaining in storage fixtures on the pool floor. Therefore, the maximum activity that will be used in-air will be less than or equal to 38 kCi. An elevator source fixture will be fabricated with only eight source holes to provide an engineering control to preclude more than eight pencils ever being placed on the elevator and raised out of the pool. For the sake of convenience the original shielding calculations in Supplements 5 & 6 that assumed 40 kCi in-air have been used to demonstrate adequacy for the less than or equal to 38 kCi that will actually be raised out of the pool. Generally speaking, the 8 new sources will be used exclusively for in-air irradiations, and the 32 old sources for in-pool irradiation. This will alleviate the need for

Supplement #1 continued.

operators to transfer sources back and forth between the in-pool irradiation fixture, and the elevator source fixture used for in-air irradiations. This will result in a reduction in operator exposure, and reduce the probability or source damage and/or leakage due to handling.



105607

FEB 27 1986

REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
SAFETY EVALUATION OF SEALED SOURCE



SEALED SOURCE TYPE: Radiation Processing

MODEL: NPRP-XXXX-XX-X where XXXX signifies the source length in millimeters and is less than 1370 and greater than 100, XX signifies the nominal diameter in millimeters and is less than 40 and greater than 6 and the last digit represents one or more letters designating the end cap configuration.

MANUFACTURER/DISTRIBUTOR: Neutron Products, Inc.
22301 Mt. Ephraim Road, Box 68
Dickerson, Maryland 20842
Marvin M. Turkanis
301/349-5001

ISOTOPE: Cobalt-60 MAXIMUM ACTIVITY: Not to exceed 100 curies per millimeter

LEAK TEST FREQUENCY:

For Category I and II Irradiators 1/: Wipe test likely leakage paths every six months

For Category III and IV Irradiators: Continual monitoring of water in wet storage pool

PRINCIPAL USE: Gamma irradiators: Categories I, II, III, and IV

CUSTOM SOURCE: ___ YES _X_ NO

1/ Gamma Irradiators have been divided into four distinct categories per ANS N542:

Category I - Self Contained - Dry Source Storage
Category II - Panoramic - Dry Source Storage
Category III - Self Contained - Wet Source Storage
Category IV - Panoramic - Wet Source Storage

ANNEX 1A

SEALED SOURCE TYPE: Radiation Processing

DESCRIPTION:

Solid cobalt-59 metal which has had between 1% and 20% of its atoms converted to cobalt-60 may be in the form of wire, rods, disks, coils, tubes, etc. These pieces may be singly encapsulated in austenitic stainless steel or hastelloy, either individually or in groups. The single encapsulated arrangement may then either by itself, or in connection with other singly encapsulated components be again seal welded within a 304L or 316L stainless steel capsule. All capsules are sealed by tungsten inert gas welding to the same type endcaps. All second encapsulations are specifically designed to fit the source holders of the users' irradiator.

Because of the various types of irradiators in use today, the source length can vary from about four inches (100 mm) to fifty four inches (1370 mm); and the diameter can vary from 1/4 inch (6 mm) to around 1-1/2 inch (40 mm).

Each of these sealed sources is designed and fabricated to meet or exceed the requirements of the American National Standards Institute (ANSI) classification 77E43424. The specific requirements of this classification are attached to this document.

LABELING:

A unique serial number, incorporating the letters "NP", is engraved on the endcaps of most sources. For small sources, special labeling methods are used to maintain sealed source integrity.

In addition, documentation is provided for the total contained source activity in curies, distribution of the activity along the length of the source, assay date, and results of wipe testing of both the single encapsulated source components and the completed double encapsulated sealed source.

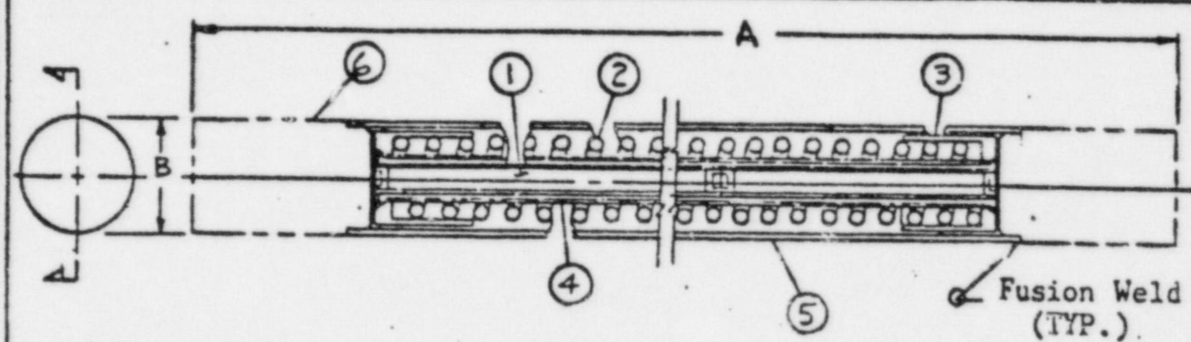
Placing a caution and radiation symbol or other standard radioactive device warning label on each source is neither practical nor useful due to the physical size and nature of the sources and their inherent high activity. These sources are intended for use in licensed facilities and equipment and only for use by licensed users in equipment properly designed for such use. In such facilities, personnel access to these sources is appropriately prevented by design and, therefore, labels are unnecessary.

105607

**NO.:** MD474S108S **DATE:** FEB 29 1984 

**SEALED SOURCE TYPE:** Radiation Processing

**DIAGRAM:**




1. Solid source Components *
2. Coil Source Component* or Spacer Coil
3. Retainers (when required)
4. Stabilizing Tube (when required)
5. Outer Tube **
6. End Caps: Same Material as Outer Tube

A. 100 mm $<$ A $\leq$ 1370 mm
B. 6 mm $\leq$ B $\leq$ 40 mm

* Encapsulated in austenitic stainless steel or Hastelloy.
** 304L or 316L stainless steel only.

NPRP-XXXX-XX-X
DWG. MGH. DATE 2-13-84
neutron products inc

**CONDITIONS FOR NORMAL USE:**

These sources are designed for use in licensed facilities by licensed users. Under normal conditions, the useful life of the source will be determined by economics not failure. Generally speaking, sources of this type will be in use for ten to twenty years. Examples of irradiators for which these sources are designed are the Neutron Products, Inc. irradiators, designated Dickerson I and Dickerson II and the industrial and research irradiators produced by the Atomic Energy of Canada, Limited.

Irradiators of these types are specifically designed for personnel and public safety, as well as irradiation efficiency. There are ANSI standards and regulatory requirements specific to these machines. The intent of these standards and requirements is to assure the safe and effective utilization of radiation processing sources. Accidents and fires occurring when the sources are in the irradiators are considered in the design of the irradiator. Accidents and fires occurring during transportation are considered in the design of the licensed shipping containers.

SEALED SOURCE TYPE: Radiation Processing

PROTOTYPE TESTING:

Each radiation processing source produced by Neutron Products, Inc. will be certified to meet the ANSI 77E43424 requirements either by prototype testing of the specific source or by derivation from previous tests which demonstrate that the source will pass the test if the test were performed.

EXTERNAL RADIATION LEVELS:

Since the dose rate associated with one curie of cobalt-60 is approximately 1.3 R/hr. at one meter, the dose rate associated with a 10,000 curie radiation processing source will be on the order of 13,000 R/hr. at one meter.

QUALITY ASSURANCE AND CONTROL:

The quality control procedure applicable to the production of these sources is NPI (Proprietary) Specification Q-1, "Quality Control and Procedures for Welded Closures of Stainless Steel Encapsulated Cobalt-60 Sources and Reactor Targets".

Both the inner and outer capsules are wipe (smear) tested per Paragraph A2.1.1. of ANSI N542-1977. The outer capsule is helium pressure tested to A2.2.2.3. of ANSI N542-1977.

The activity content of each source is determined comparatively in accordance with NPI (Proprietary) Procedure R2007 which ratios the dose rate of a source integrated along its entire length to the dose rate of a "standard" source integrated along its length. At this time, there is no applicable national calibration standard for the sources of this type.

Each source design is reviewed and approved by the Vice President responsible for source fabrication and by the customer.

# REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
## SAFETY EVALUATION OF SEALED SOURCE



SEALED SOURCE TYPE: Radiation Processing

LIMITATION AND/OR OTHER CONSIDERATIONS OF USE:

These sources should only be stored in halogen free environments which allow sufficient heat transfer and provide adequate radiation shielding. For Category I and II irradiators, either the surfaces of the sources or the surfaces of likely leakage paths should be smeared at least once every six months to monitor for radioactive contamination. For Category III and IV irradiators, continual monitoring of the water systems is indicated. Water resistivity should be 50,000 ohm-centimeter or better. No user servicing of these sources is recommended.

Periodic visual examination in a hot cell or under water is desirable but not required. Discoloration, surface and weld condition should be noted. If there is any doubt as to the integrity of the source, the manufacturer should be notified.

NPI shall obtain knowledge of the application for which these sources are intended to ascertain the compatibility of the intended use with the source design. Sources will not be sold to unlicensed users or for any use for which there is reasonable doubt of the safety of application.

NPI verifies in advance that its radiation processing source customers are licensed recipients or users. These sources are intended for use in licensed facilities which provide adequate shielding, heat transfer and noncorrosive environments.

Installation and removal of these sources is normally provided by Neutron Products, Inc. utilizing NPI's equipment and personnel. Emergency assistance and disposal services are available from NPI.

Installation, dismantling, relocation, repair, initial testing, replacement and/or disposal of the source shall be performed in accordance with the terms and conditions of a specific license issued by the Nuclear Regulatory Commission or an Agreement State.

SAFETY ANALYSIS SUMMARY:

Based upon our review of the information and data contained in the references cited below, we conclude that the sealed sources designated as NPRP-XXXX-XX-X are acceptable for general use in gamma irradiations categories I, II, III, and IV.

SEALED SOURCE TYPE: Radiation Processing

REFERENCES:

Reference 1: Letter from D. Nussbaumer, NRC to R. Brisson, MD DHMH, February 21, 1984. This letter transmitted an internal NRC letter from B. Singer to D. Nussbaumer, February 14, 1984. The February 14, 1984, NRC letter concluded that the NPI source design as described in the references below would be acceptable for licensing purposes when fabricated to NPI specifications.

Reference 2: Application for the Registration of Radiation Processing Source NPRP-XXXX-XX-X, February 17, 1984. Transmitted by cover letter February 21, 1984, from C. Smedira, NPI to R. Corcoran, MD DHMH.

Reference 3: Letter from R. Corcoran, MD DHMH to D. Nussbaumer, NRC, November 22, 1983. This letter forwarded Reference 4 below to the NRC.

Reference 4: Letter from C. Smedira, NPI to R. Corcoran, MD DHMH, November 14, 1983. This letter provided answers to the NRC questions transmitted by the MD DHMH in their letter of August 25, 1983.

Reference 5: Letter from R. Corcoran, MD DHMH to C. Smedira, NPI, August 25, 1983. This letter transmitted NRC questions on NPI's request for licensing radiation processing sources with activities up to 30,000 curies per foot.

Reference 6: Letter from D. Nussbaumer, NRC to R. Corcoran, MD DHMH, July 29, 1983. This letter provided NRC questions on NPI's request for licensing radiation processing sources with activities up to 30,000 curies per foot.

Reference 7: Letter from R. Corcoran, MD DHMH to D. Nussbaumer, NRC, June 20, 1983. This letter requested NRC technical assistance in evaluating NPI requests of June 3, 1983.

Reference 8: Letter from J. Ransohoff, NPI to R. Corcoran, MD DHMH, June 3, 1983. This letter clarified the request made in Reference 9 below.

Reference 9: Letter from J. Ransohoff, NPI to R. Corcoran, MD DHMH, June 3, 1983. This letter requested MD DHMH approval of the use at Dickerson, MD. of radiation processing sources with activities up to 30,000 curies per foot.

REGISTRY OF RADIOACTIVE SEALED SOURCES AND DEVICES
SAFETY EVALUATION OF SEALED SOURCE



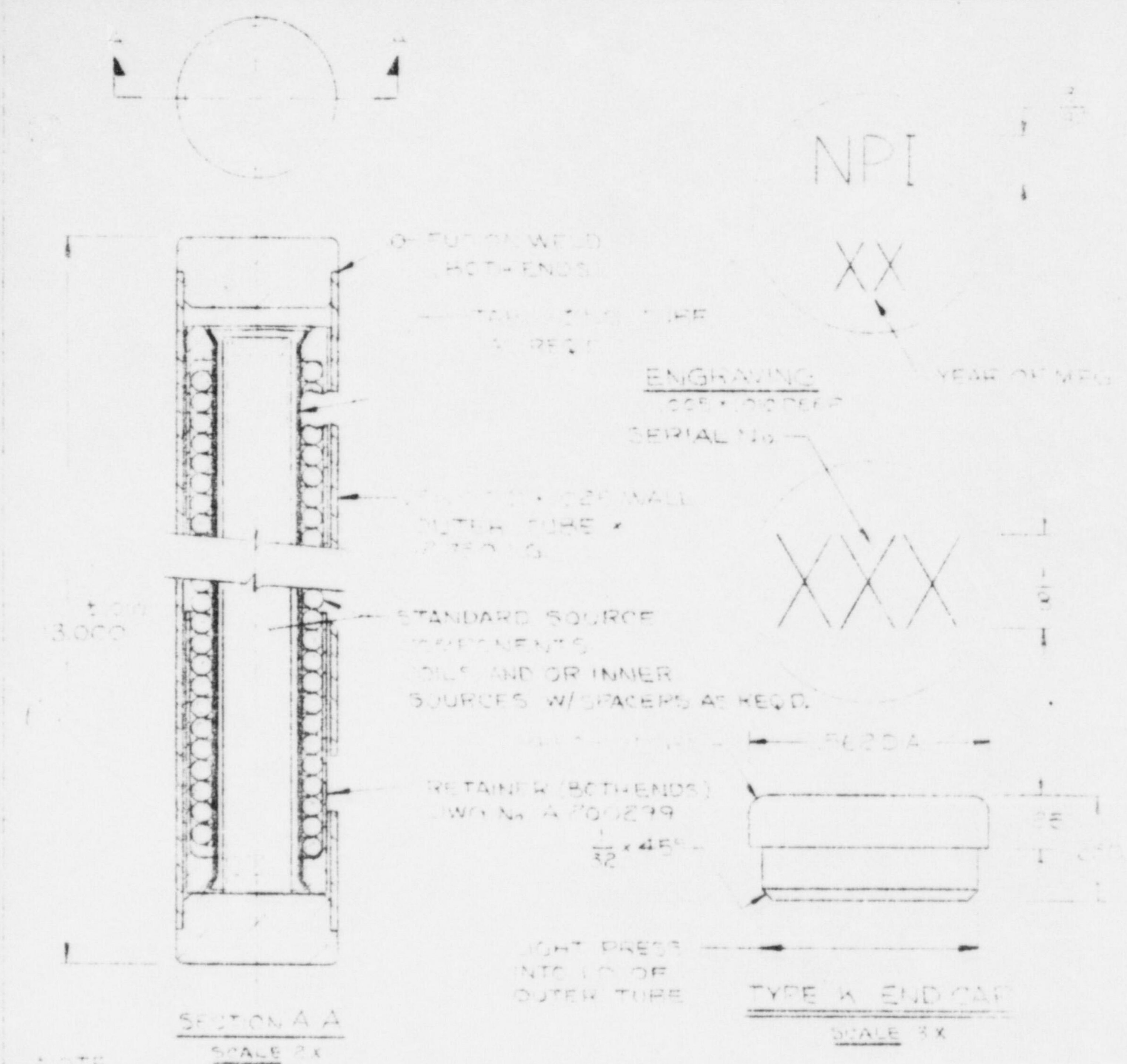
SEALED SOURCE TYPE: Radiation Processing

ISSUING AGENCY

Maryland Department of Health and Mental Hygiene

Date: 2/29/84 Reviewer: Richard J. Susson

Date: 2/29/84 Concurrence: Robert E. Corcoran

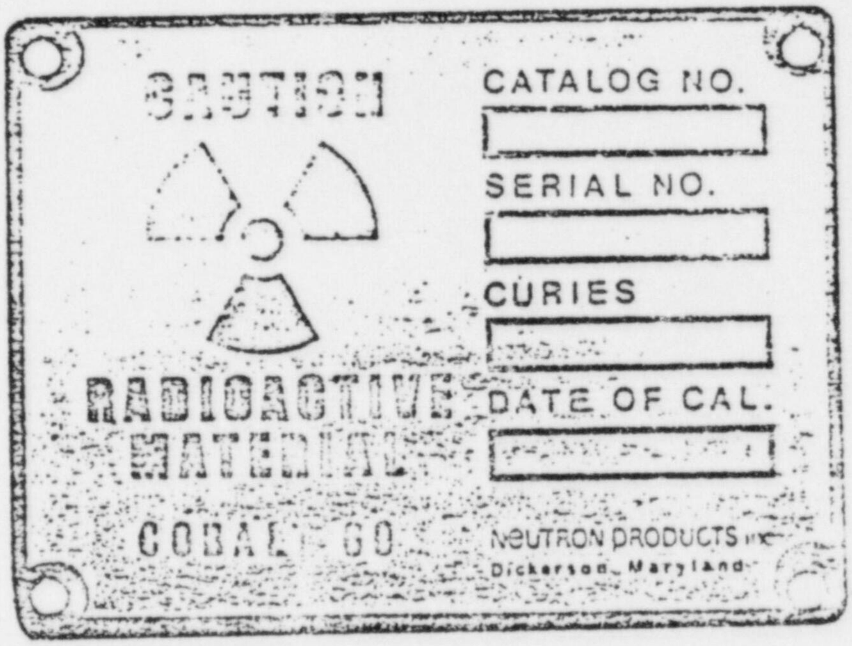



NOTE: MAT'L TUBING & END CAPS - STN. STL. TYPE 316L

FEB 20 1986

| | | | |
|---|---|---|---|
| TOLERANCES | **neutron products inc** Dickerson, Maryland | | |
| DRAWN MLH 2-11-86 | TITLE | APPROVED | ISSUED DATE |
| DESIGN | DIA - 13 SOURCE | SIZE A | DWG NO. 200320 |
| CHECKED | CAT. No. NPRP - 330 - 14 - K | SCALE NOTED | SHEET |

ANNEX 1B


CATALOG NO.
SERIAL NO.
CURIES
RADIOACTIVE
DATE OF CAL.
NEUTRON PRODUCTS
Dickerson, Maryland

ANNEX No. 1-C

SUPPLEMENT #2

Item 16, Form NRC 313I, Formal Training in Radiation Safety

MICHAEL BORISKY (Radiation Protection Officer)

M.H.S., Radiation Health, Johns Hopkins School of Public Health and Hygiene, 1985
B.A., Biological Sciences, University of Md at Baltimore County, 1977

| TYPE OF TRAINING | WHERE TRAINED | DATE | DURATION | ON THE JOB | FORMAL COURSE |
|---|---|---|---|---|---|
| a. Principles | Johns Hopkins (graduate) | | | | |
| | Intro to Rad Health 18A67(70%)* | Sep 82 | 28 hrs | No | Yes |
| | Radiation Safety 18A70(70%) | Nov 83 | 11 hrs | No | Yes |
| | Occupational Saf. and Health 18A23(50%) | Jan 84 | 12 hrs | No | Yes |
| | Environ. Health Admin & Policy 18A19(50%) | Mar 84 | 8 hrs | No | Yes |
| | University of Maryland (undergraduate) Baltimore, MD | | | | |
| | Physics 100 (10%)* | Feb 74 | 4 hrs | No | Yes |
| | Physics 111 (10%) | Sep 75 | 6 hrs | No | Yes |
| | Physics 112 (10%) | Feb 76 | 6 hrs | No | Yes |
| | USA Chemical School Ft McClellan, Alabama | | | | |
| | Rad Safety Course 7K-F3 | Jan 81 | 34 hrs | No | Yes |
| b. Mathematics | Johns Hopkins (graduate) | | | | |
| | Intro to Rad Health 18A67(10%) | Sep 82 | 4 hrs | No | Yes |
| | Biostatistics 14M01(20%) | Sep 83 | 8 hrs | No | Yes |
| | Radiochemistry 18A65(10%) | Nov 83 | 5 hrs | No | Yes |
| | Radiation Safety 18A70(10%) | Nov 83 | 2 hrs | No | Yes |
| | Radiation Dosimetry 18A73(40%) | Nov 83 | 6 hrs | No | Yes |
| | University of Maryland (undergraduate) Baltimore, MD | | | | |
| | Precalculus 150 | Feb 74 | 42 hrs | No | Yes |
| | Calculus and Anal Geom 151 | Sep 74 | 56 hrs | No | Yes |
| | Statistics 160 | Sep 75 | 42 hrs | No | Yes |
| | USA Chemical School Ft McClellan, Alabama | | | | |
| | Rad Safety Course 7K-F3 | Jan 81 | 36 hrs | No | Yes |

*percentage of course applicable to category of training

Supplement #2 continued.

| TYPE OF TRAINING | WHERE TRAINED | DATE | DURATION | ON THE JOB | FORMAL COURSE |
|---|---|---|---|---|---|
| c. Measurement | Johns Hopkins (graduate) | | | | |
| | Intro to Rad Health 18A67(10%) | Sep 82 | 4 hrs | No | Yes |
| | Radiotracer Techniques 18A61(50%) | Sep 82 | 8 hrs | No | Yes |
| | Nuclear Instrumentation 18A64(100%) | Nov 82 | 48 hrs | No | Yes |
| | Radiotracer Techniques 18B61(50%) | Nov 82 | 4 hrs | No | Yes |
| | Advanced Nuc Inst (100%) | Jan 83 | 48 hrs | No | Yes |
| | Radiochemistry 18A65 (50%) | Nov 83 | 25 hrs | No | Yes |
| | Radiation Safety 18A70 (10%) | Nov 83 | 2 hrs | No | Yes |
| | Radiation Dosimetry 18A73(40%) | Nov 83 | 6 hrs | No | Yes |
| | USA Chemical School Ft McClellan, Alabama | | | | |
| | Rad Safety Course 7K-F3 | Jan 81 | 34 hrs | No | Yes |
| d. Biological | Johns Hopkins (graduate) | | | | |
| | Intro to Rad Health 18A67(10%) | Sep 82 | 4 hrs | No | Yes |
| | Radiobiology 18A71 (100%) | Jan 83 | 24 hrs | No | Yes |
| | Radiochemistry 18A65 (20%) | Nov 83 | 10 hrs | No | Yes |
| | Radiation Safety 18A70(10%) | Nov 83 | 2 hrs | No | Yes |
| | Radiation Dosimetry 18A73(10%) | Nov 83 | 1.5 hrs | No | Yes |
| | University of Maryland Baltimore, MD | | | | |
| | Concepts of Biology 100 (10%) | Sep 74 | 4 hrs | No | Yes |
| | Genetics 310(20%) | Sep 75 | 12 hrs | No | Yes |
| | Cell Biology 320 (10%) | Feb 76 | 6 hrs | No | Yes |
| | Developmental Biology 340(10%) | Sep 76 | 6 hrs | No | Yes |

Supplement #2 continued.

| | | | | |
|---|---|---|---|---|
| Organismic Biology 350 (10%) | Feb 77 | 6 hrs | No | Yes |
| USA Chemical School<br>Ft McClellan, Alabama<br>Rad Safety Course 7K-F3 | Jan 81 | 8 hrs | No | Yes |
| Johns Hopkins University<br>Baltimore, MD<br>Biochemistry (10%) | Feb 78 | 3 hrs | No | Yes |

| TYPE OF TRAINING | WHERE TRAINED | DURATION OF TRAINING | ON THE JOB | FORMAL COURSE |
|---|---|---|---|---|
| KLAUS G. KERRIS (Physicist) | | | | |
| a. Principles | UCLA | 3 years | Yes | Yes |
| | Hughes Aircraft Co | 11 years | Yes | No |
| | Harry Diamond Labs | 14 years | Yes | No |
| b. Measurements | UCLA | 3 years | Yes | Yes |
| | Hughes Aircraft Co | 11 years | Yes | No |
| | Harry Diamond Labs | 14 years | Yes | No |
| c. Mathematics | Ohio State University | 2 years | No | Yes |
| | UCLA | 4 years | Yes | Yes |
| | Hughes Aircraft Co | 11 years | Yes | No |
| | Harry Diamond Labs | 14 years | Yes | No |
| d. Biological | Harry Diamond Labs | 14 years | Yes | No |
| CHARLES C. CASAER (Chief Operator, Cobalt-60 Irradiator) | | | | |
| a. Principles | Harry Diamond Labs | 17 years | Yes | No |
| b. Measurements | Harry Diamond Labe | 17 years | Yes | No |
| c. Mathematics | Harry Diamond Labs | 17 years | Yes | No |
| d. Biological | Harry Diamond Labs | 14 years | Yes | No |
| PERRY SARIGIANIS (Alternate Operator, Cobalt-60 Irradiator) | | | | |
| a. Principles | Harry Diamond Labs | 5 years | Yes | No |
| | The Martin Co | 3 months | Yes | No |
| | Allis Chalmers Co | 2 months | Yes | No |
| b. Measurements | Harry Diamond Labs | 5 years | Yes | No |
| | The Martin Co | 3 months | Yes | No |
| | Allis Chalmers Co | 2 months | Yes | No |
| c. Mathematics | The Martin Co | 3 months | Yes | No |
| | Allis Chalmers Co | 2 months | Yes | No |
| | Harry Diamond Labs | 5 years | Yes | No |
| d. Biological | Harry Diamond Labs | 5 years | Yes | No |
| | The Martin Co | 3 months | Yes | No |
| | Allis Chalmers Co | 2 months | Yes | No |

Supplement #2 continued

DR. HARVEY EISEN (Alternate Radiation Protection Officer)

| TYPE OF TRAINING | WHERE TRAINED | DATE | HOURS** | ON THE JOB | FORMAL COURSE |
|---|---|---|---|---|---|
| a. Principles | Univ of Md (undergraduate) | | | | |
| | General Physics (10%)* | Sep 57 | 7 | no | yes |
| | General Physics (10%) | Feb 58 | 7 | no | yes |
| | Intro to Nuc Tech (20%) | Sep 58 | 8 | no | yes |
| | Heat Power-Nuc and Chem (10%) | Feb 60 | 6 | no | yes |
| | Univ of Md. (graduate) | | | | |
| | Modern Physics (10%) | Sep 60 | 4 | no | yes |
| | Nuc Tech Lab (50%) | Sep 60 | 21 | no | yes |
| | Nuc Eng Sem (20%) | Feb 61 | 3 | no | yes |
| | Spec Prob Nuc Eng (20%) | Feb 61 | 6 | no | yes |
| | Nuc Pow Use Nuc Rad (50%) | Feb 61 | 15 | no | yes |
| | Nuc Reactor Eng (50%) | Sep 61 | 21 | no | yes |
| | Nuc Reactor Eng (50%) | Feb 62 | 21 | no | yes |
| | Nuc Pow Use Nuc Rad (50%) | Sep 62 | 21 | no | yes |
| | Nuc Eng Res (20%) | Sep 62 | 3 | no | yes |
| | Sem in Nuc Energy (20%) | Feb 63 | 3 | no | yes |
| | Nuc Eng Research (20%) | Feb 63 | 3 | no | yes |
| | Nuc Eng Research (20%) | Sep 63 | 3 | no | yes |
| | Nuc Eng Research (20%) | Sep 64 | 3 | no | yes |
| | Sem in Nuc Eng (20%) | Sep 64 | 3 | no | yes |
| | Nuc Eng Research (20%) | Feb 65 | 3 | no | yes |
| | Sem in Nuc Eng (20%) | Feb 65 | 3 | no | yes |
| | Radiation Shielding (50%) | Sep 66 | 21 | no | yes |
| | Nuc Reactor Dynamics (10%) | Feb 67 | 4 | no | yes |
| | Nuc Eng Research (20%) | Feb 67 | 3 | no | yes |
| | National Bureau of Standards(NBS)/Harry Diamond Labs(HDL) | | | | |
| | Radiation Safety Course | 1960 | 6 | yes | yes |
| | Medical Self Help Course | 1965 | 4 | yes | yes |
| | Safety Aspects of Ionizing Radiation Source Use | 1977 | 4 | yes | yes |
| b. Mathematics | Univ of Md. (undergraduate) | | | | |
| | General Physics (20%) | Sep 57 | 14 | no | yes |
| | Diff Equations | Sep 57 | 42 | no | yes |
| | Basic Elect Eng (20%) | Feb 58 | 8 | no | yes |
| | Intro to Nuc Tech (20%) | Sep 58 | 8 | no | yes |
| | Univ of Md. (graduate) | | | | |
| | Heat Power-Nuc and Chem (20%) | Apr 60 | 12 | no | yes |
| | Rad Shield Energy Dep (50%) | Sep 66 | 21 | no | yes |
| | Nuc Reactor Dynamics (50%) | Feb 67 | 21 | no | yes |
| | George Washington University | | | | |
| | Math for Sci and Eng | 1959 | 42 | no | yes |
| | NBS/HDL | | | | |
| | Radiation Safety Course | 1960 | 6 | yes | yes |
| | Saf Asp of Ion Rad Use | 1977 | 1 | yes | yes |

* percentage of course applicable to category of training
** hours of the course applicable to category of training

Supplement #2 continued

DR. HARVEY EISEN (Alternate Radiation Protection Officer)

| TYPE OF TRAINING | WHERE TRAINED | DATE | HOURS** | ON THE JOB | FORMAL COURSE |
|---|---|---|---|---|---|
| c. Measurement | Univ of Md. (undergraduate) | | | | |
| | General Physics (5%)* | Sep 57 | 4 | no | yes |
| | General Physics (5%) | Feb 58 | 4 | no | yes |
| | Basic Elect Eng (20%) | Feb 58 | 14 | no | yes |
| | Alt Current Circuits (10%) | Sep 58 | 6 | no | yes |
| | Elect and Magn (20%) | Sep 58 | 8 | no | yes |
| | Intro to Nuc Tech (20%) | Sep 58 | 8 | no | yes |
| | Eng Elect (20%) | Feb 59 | 11 | no | yse |
| | Applied Elect (20%) | Feb 60 | 3 | no | yes |
| | Heat Power-Nuc and Chem (10%) | Feb 60 | 6 | no | yes |
| | Univ of Md. (graduate) | | | | |
| | Nuc Tech Lab (50%) | Sep 60 | 28 | no | yes |
| | Nuc Pow Use of Nuc Rad (20%) | Sep 60 | 6 | no | yes |
| | Nuc Pow Use of Nuc Rad (20%) | Sep 62 | 6 | no | yes |
| | Rad Shield Energy Dep (10%) | Sep 66 | 4 | no | yes |
| | Nuc Reactor Dynamics (20%) | Feb 67 | 8 | no | yes |
| | NBS/HDL | | | | |
| | Radiation Safety Course | 1960 | 6 | yes | yes |
| | Saf Asp Ion Rad Use | 1977 | 1 | yes | yes |
| d. Biology | Univ of Md. (graduate) | | | | |
| | Nuc Tech Lab (10%) | Sep 66 | 6 | no | yes |
| | Rad Shield Energy Dep (10%) | Sep 66 | 4 | no | yes |
| | NBS/HDL | | | | |
| | Radiation Saf Course | 1960 | 6 | yes | yes |
| | Medical Self Help Course | 1965 | 12 | yes | yes |
| | Saf Asp of Ion Rad Use | 1977 | 1 | yes | yes |

* percentage of course applicable to category of training
** hours of the course applicable to category of training

SUPPLEMENT #3

Item 17, Form NRC 313 I, Experience/Resumes

MICHAEL J. BORISKY

| ISOTOPE | MAXIMUM AMOUNT | WHERE EXPERIENCE GAINED | DURATION OF EXPERIENCE | TYPE OF USE |
|---|---|---|---|---|
| Co-60 | 15,020 Ci | Harry Diamond Labs | 4 years | Routine Health Physics |
| Cs-137 | 721 mCi | Harry Diamond Labs | 4 years | Routine Health Physics and Instrument Checks |
| Atomic Nos 3 thru 83 | 250 mCi | Harry Diamond Labs | 4 years | Routine Health Physics |
| $Pu^{239}$ | 67 gms | Harry Diamond Labs | 4 years | " " " |
| $U^{235}$ | 22 gms | Harry Diamond Labs | 4 years | " " " |
| $Np^{237}$ | 12 gms | Harry Diamond Labs | 4 years | " " " |
| $Sr\text{-}Yt^{90}$ | 400 mCi | Ft Meade, MD | 1 year | Routine Health Physics |
| $Pu^{239}$ | 40 uCi | Ft Meade, MD | 1 year | Calibration, Routine Health Physics |
| $Cs^{137}$ | 10 mCi | Ft Meade, MD | 1 year | Routine Health Physics |
| $Am^{241}$ | 60 mCi | Ft Meade, MD | 1 year | " " " |
| $H\text{-}^{3}$ | 10 Ci | Ft Meade, MD | 1 year | " " " |
| $Ra^{226}$ | microcuries | Ft Meade, MD | 1 year | " " " |

In addition, while at Harry Diamond Labs. Mr. Borisky has been performing routine health physics functions for the 11 MeV Aurora Facility, 3 MeV HIFX Facility, and three industrial X-ray units, ranging from 110 kVp to 300 kVp. Health Physics duties have included the evaluation and monitoring of facility modifications.

See attached resume.

Supplement #3 continued

MICHAEL BORISKY (Radiation Protection Officer)

EDUCATION

1985 Master of Health Science, Radiation Health Science, Johns Hopkins School of Hygiene and Public Health, Baltimore, MD. GPA 3.87

1977 Bachelor of Science, Biological Sciences, University of Maryland at Baltimore County, Baltimore, MD. Cum Laude

PROFESSIONAL EXPERIENCE

December 1981 to present — Health Physicist, U.S. Army Harry Diamond Laboratories, Adelphi, MD. Responsible for the management of the Radiation Protection Program. Sources at Harry Diamond include an NRC licensed 40,000 Curie Co-60 facility, a 14 MV flash X-ray facility, a 5 MV flash X-ray facility, MW to GW pulse microwave facilities, over 100 lasers, and various unique electronic sources of both ionizing and nonionizing radiation. Duties and responsibilities include: chairing the Radiation Control Committee; planning and design of new sources and facilities and modifications to existing sources and facilities, usually requiring detailed hazard analysis and shielding calculations; formulating procedures for the safe use of new or modified radiation sources; evaluating and revising local standards, procedures, and controls to assure compliance with Federal law, Army regulations, and accepted practices; performing periodic surveys of sources and procedures; conducting training for personnel using radiation sources; maintaining NRC licenses and DA authorizations for the use of radioactive materials; directing and reviewing personnel monitoring; and periodically reviewing radiation protection literature. As the only Health Physicist at Harry Diamond, works independently without any technical supervision.

December 1980 to December 1981 — Health Physicist, U.S. Army Fort George G. Meade, Ft. Meade, MD. Developed and managed Fort Meade's first Radiation Protection Program. Radiation sources were Army commodities containing radioactive materials. Developed program to ensure the proper handling, leak testing, storage, use, inventory, disposal, and transport of radioactive commodities. As the only Health Physicist at Fort Meade, worked independently without any technical supervision.

December 1978 to December 1980 — Research Technician, Johns Hopkins School of Hygiene and Public Health, Baltimore, MD. Participated in research to investigate how to better treat public water and sewage systems to protect the public from microbiological contamination of water supplies. Duties included participation in study design, conducting experiments, fabrication and design of special apparatus, and interpretation of results.

| | | |
|---|---|---|
| PROFESSIONAL ORGANIZATIONS | Health Physics Society | |
| ADDITIONAL EDUCATION | Biochemistry | Johns Hopkins University |
| | Aquatic Chemistry (grad) | Johns Hopkins University |
| | Information Management Systems (grad) | Johns Hopkins University |

AWARDS

Harry Diamond Laboratories Fellowship, 1982-1984, Johns Hopkins School of Hygiene and Public Health.

Harry Diamond Laboratories, Special Service Award, 1985.

University of Maryland, 1977, Cum Laude.

COURSE WORK

Academic coursework included:

University of Maryland
- Physics
- Biological Sciences
- Chemistry
- Calculus
- Statistics

Johns Hopkins School of Hygiene and Public Health
- Nuclear Instrumentation
- Radiobiology
- Radiation Dosimetry
- Radiochemistry
- Radiation Physics
- Radiation Safety
- Biostatistics
- Epidemiology

DR. HARVEY EISEN (Alternate Radiation Protection Officer)

PhD Nuclear Engineering
BS Electrical Engineering

| ISOTOPE | MAXIMUM AMOUNT | WHERE EXPERIENCE GAINED | DURATION | USE |
|---|---|---|---|---|
| Co-60 | 40,000 Curies | Harry Diamond Labs | 20 years | Radiation Effects Stud. |
| Triga Reactor | 250 kW | General Atomic | 3 years | Radiation Effects Stud. |
| Triga Reactor | 250 kW | Harry Diamond Labs DORF Facility | 7 years | Radiation Effects Stud. |

In addition to the above experience, Dr. Eisen also served for 5 years as an active member of the Diamond Ordnance Reactor Facility (DORF) Triga Reactor Safeguards Committee. Dr. Eisen is currently serving as a member of the HDL Radiation Control Committee.

Dr. Eisen has also gained radiation worker experience from his occasional use of particle accelerators over the years. Dr. Eisen's occassional use of particle accelerators includes the following: 12 years with HDL's 10 MV AURORA flash X-ray facility; 17 years with HDL's 5 MV HIFX flash X-ray facility; 12 years with NRL's 10-40 MV LINAC linear accelerator; and 2 years with the NBS/AFRRI 2 MV Van de Graff facility.

PROFESSIONAL EXPERIENCE

May 1973 to present
Harry Diamond Laboratories, Adelphi, MD

Supervises a section studying nuclear radiation effects on electronics. Studies include both experimental and analytical work, ranging from component studies to systems analyses, including radiation effects field testing. These studies require a knowledge of radiation transport, use of reactors and other ionizing radiation sources, radiation dosimetry, modern electronic components and circuitry, and radiation effects mechanisms. Responsibilities include both technical and administrative supervision of the research group, including new program development, funding, and research. Currently manages a DOD-wide radiation effects information center, and acts as a consultant to other Army project offices and agencies.

Nov 1971 to May 1973
Harry Diamond Laboratories, Adelphi, MD

Senior member of research groups studying radiation effects on semiconductor devices. Co-author of a major survey on the status of knowledge of radiation effects on MOS technology devices. Served as a member of several advisory panels and working groups and committees to other Government agencies. Contributed to thermonuclear shock studies and was a Project Officer on a Nevada Test Site underground test.



105607

DR HARVEY EISEN (Alternate Radiation Protection Officer)

Sept 1970 to Nov 1971
National Bureau of Standards, Wash., DC

Developed a technique for using radiochromic dye films for making absolute, high precision measurements of energy deposited by radiation. Measured electron energy deposition profiles in a variety of targets and made comparisons to theoretical calculations. These measurements were the first of their kind, and qualified for Dr. Eisen's PhD thesis. Results were presented at an IAEA Symposium in Vienna.

June 1965 to Sept 1970
Harry Diamond Laboratories, Adelphi, MD

Responsible for the laboratory and field testing in an investigation of transient radiation susceptibility and hardening of transistors. Obtained and used several complex computer radiation energy deposition codes. Served as technical monitor for large development contracts. Developed the first method of measuring the free surface motion of pulse-radiation excited materials.

June 1960 to June 1965
Harry Diamond Laboratories, Adelphi, MD

Served as an istrumentation engineer for radiation effects experiments. Responsible for planning, executing, and reporting on original experiments, consulting on new instrumentation requirements for others, and planning and choosing new instrumentation equipment.

KLAUS G. KERRIS (Physicist)

| ISOTOPE | MAXIMUM AMOUNT | WHERE EXPERIENCE WAS GAINED | DURATION OF EXPERIENCE | TYPE OF USE |
|---|---|---|---|---|
| Cobalt-60 | 39,448 Ci | Harry Diamond Labs | 11 years | Facility Supervisor of a $Co^{60}$ Water-Well Irradiator |
| Sodium-22 | Microcuries | UCLA | 3 years | Spectrometry |
| Cobalt-60 | 7,000 Ci | Hughes Aircraft Co | 11 years | Radiation Effects Study |
| Zinc-63 | Microcuries | UCLA | 3 years | Spectrometry |
| Strontium-90 | Microcuries | Hughes Aircraft Co | 11 years | Instrument Calibration |
| Cesium-137 | Microcuries | UCLA | 3 years | Spectrometry |

Mr. Kerris was employed by UCLA as a Research Assistant for 3 years. During that time, he assisted in the development and construction of a 50 MeV proton cyclotron. He was also involved in the operation of the 18 MeV proton cyclotron and used various small sources for beta and gamma spectrometry and instrument calibration.

At Hughes Aircraft Company, he participated in the design of several linear electron accelerators. He was extensively involved in experiments using a 10 MeV linear electron accelerator, a 1 MeV Electron Beam Generator, and a 7 kCi Cobalt-60 source.

At Harry Diamond Laboratories, he has been in charge of dosimetry measurements at Aurora, a 10 MeV pulsed bremsstrahlung generator. In addition, he has functioned as Facility Supervisor of the HDL Cobalt-60 Water-Well Irradiator for the past 11 years.

CHARLES C. CASAER (Chief Operator, Cobalt-60 Irradiator)

| | | | | |
|---|---|---|---|---|
| Cobalt-60 | 1 Ci | Harry Diamond Labs | 14 years | In-Air Instrument Calibration |
| Cobalt-60 | 25,000 Ci | Harry Diamond Labs | 7 years | In-Air Radiation Effects Testing |

In addition, Mr. Casaer has been Chief Operator of the Pulsed X-ray Generator (HIFX) at HDL for the past 17 years. His duties in this position involved the use of GM, Scintillation, and T.L.D. instrumentation for general radiation surveys, remote area monitors, and radiation effects dosimetry. He has also completed a 48-hour course of instruction and training in operation of the HDL Cobalt-60 Facility for in-air irradiations. Instruction and supervision was provided by Mr. Klaus Kerris, Supervisor of the Cobalt-60 Facility.

PERRY SARIGIANIS (Alternate Operator, Cobalt-60 Irradiator)

| | | | | |
|---|---|---|---|---|
| Cobalt-60 | 20,000 Ci | Harry Diamond Labs | 5 years | Irradiator |
| Cf252 | 90 ug | USGS | 10 months | Activation Analysis |
| PuBe | | Allis Chalmers Co | 3 years | Detector Calibration |
| Cs137 | | Allis Chalmers Co | 3 years | Detector Calibration |
| Cs137 | | USGA | 1 year | Detector Calibration |
| Cobalt-60 | 10 Ci | Allis Chalmers Co | 4 years | Detector Calibration |

Perry Sarigianis (Alternate Operator, Cobalt-60 Irradiator continued)

Furthermore, Mr. Sarigianis has been Senior Technician for the 10 MeV, pulsed bremsstrahlung generator (Aurora) at Harry Diamond Labs for 14 years. His duties included instrumentation control and electromechanics. He has also completed a two day course of instruction and training at the HDL Cobalt-60 Facility for in-air irradiation. Instruction and supervision was provided by Mr. Klaus Kerris, Supervisor of the Cobalt-60 Facility and approved by the Ionizing Radiation Committee at Harry Diamond Laboratories.

SUPPLEMENT #4

Item 10, Form NRC 313 I, Radiation Detection Instruments.

Portable Instruments

| TYPE | MANUFACTURER | MODEL # | NO. AVAIL | RADIATION DETECTED | SENSITIVITY RANGE |
|---|---|---|---|---|---|
| Proportional | Nuclear Measurements Corp. | PC-4 | 1 | Alpha, beta | 0-3.5 x $10^6$ cpm |
| G-M | Ludlum Measurements Inc. | Model 2 | 2 | Beta, gamma | 0.1-50 mR/hr |
| G-M | Victoreen | Thyac II, Model 489 | 1 | Alpha, beta, gamma | 0.05 - 20 mR/hr<br>50 - 800 cpm |
| G-M | Victoreen | Thyac III, Model 490 | 1 | Beta, gamma | 0.05 - 200 mR/hr |
| Ion Chamber | Victoreen | Model 440-RF | 1 | Gamma | 1 - 300 mR/hr |
| Scintillation | Eberline Instrument | Gadora-1B | 1 | Gamma | 1 - 1000 R/hr |
| Ion Chamber | Keithley Instrument Co. | Model 3615 | 1 | Gamma, beta | 0-20 R/hr<br>0-20 mR |
| G-M | Eberline Instrument | Teletector 6112B | 2 | Gamma, beta | 0.01 - $10^6$ mR/hr |

Area/Resin Bed Monitors

| TYPE | MANUFACTURER | MODEL # | NO. AVAIL | RADIATION DETECTED | SENSITIVITY RANGE |
|---|---|---|---|---|---|
| Scintillation | Nuclear Measurements Corp | Model GA-2T | 1 | Gamma | 0.1 - 1000 mR/hr |
| Scintillation | Nuclear Measurements Corp | Model GA-2T | 2 | Gamma | 10 mR/hr - 100 R/hr |
| Scintillation | Nuclear Measurements Corp | Model GA-2TO | 1 | Gamma | 0.1 - 1000 mR/hr |
| Scintillation | Ludlum Measurements Inc. | Model 44 | 1 | Gamma | 0.02 - 20 mR/hr |

Supplement #4 continued

Item 11, Form NRC 313I, Calibration of Instruments

Portable instruments are calibrated quarterly by Radiation Services Organization (RSO), as indicated on Form NRC 313I. A certificate of calibration by a NBS traceable source is issued by RSO and kept on file in the HDL Safety Office. Sources listed below are available for constancy checks.

Remote Area and Resin Bed Monitors permanently installed in the Gamma Radiation Facility are calibrated at periods not to exceed three months. Instruments are placed a known distance from a known source. Calculated values at various distances from the known sources are compared with the observed meter response. The following sources are available for calibration and constance checks:

a. 1 Co-60 source, 12.3 mR/h at one meter, 26 Jan 1961 (NBS calibrated)

b. 1 Co-60 source, 1.07 mR/h at one meter, 26 Jan 1961 (NBS calibrated)

c. 1 Co-60 source, 2.58 mR/h at one meter, 30 Nov 1972 (US Army calibrated)

d. 1 Cs-137 " , 32.6 R/h at one meter, 2 Mar 1970 (AFRRI calibrated, traceable to NBS)

e. Radium (D&E) check source obtained from the National Bureau of Standards approximately 28,000 counts/min alpha, plus beta, 23 Mar 1962.

The Nuclear Measurement Corp., Model PC-4, internal proportional counter is used for wipe test analysis, and is calibrated quarterly by the Radiation Protection Officer, using NBS traceable Co-60, Cs-137, and Am-241 calibration sources.

See Supplement #6, Annex 6-F for calibration procedures for the facility monitors and the proportional counter.

SUPPLEMENT #5

Item 13, Form NRC 313 I, Facilities and Equipment.

1. Area Description and General Features of Facility Construction.

a. Facility Location and Structural Characteristics. The Cobalt-60 Gamma Radiation Facility is comprised of four rooms which are located in the Building 504 Radiation Facility at Harry Diamond Laboratories (HDL), 2800 Powder Mill Road, Adelphi, Maryland. Plan/elevation drawings which characterize the construction of the Radiation Facility and the surrounding area were presented in the initial application as Figures 5-1 through 5-33. Figure 5-1 was included in order to indicate the geographical location of the HDL Radiation Facility and its relationship to the surrounding Washington, DC suburban area. Figures 5-2 through 5-4 were included in order to present a more detailed overview of the HDL complex and provide topographical information about the area immediately surrounding the Radiation Facility. Figures 5-5 through 5-33 are the architect's drawings/specifications from which the Radiation Facility was constructed. The entire building is classified as a "noncombustible construction" type structure as defined in the National Fire Codes, Volume 9, Part 220, published by the National Fire Protection Association in 1975.

b. Location of Cobalt-60. Within the Building 504 Radiation Facility are the four rooms which comprise the Cobalt-60 Gamma Radiation Facility. These rooms are numerically designated on Figures 5-5 through 5-33 as follows: Room 2 is the Exposure Room in which all of the Cobalt-60 source elements will be used and stored. Room 4 is the Control Room from which the source elevator is remotely controlled. Room 1 is an entrance maze which connects the Exposure Room to the Control Room. Room 9 is a Mechanical Equipment room which houses the Cobalt-60 elevator drive mechanism and Exposure Room air handling equipment. The Cobalt-60 source elements will always be stored at the bottom of the water-filled cylindrical pool which is located in the Exposure Room, except when they are raised above the surface of the pool water via a remotely controlled source elevator. The dimensions of Rooms 1, 2, 4, and 9 are presented in Figures 5-5 and 5-7.

c. Radiation Shielding. The Exposure Room (Rm 2) and the source storage pool located therein are designed to provide protection to personnel from the ionizing radiation emanating from a 40,000 curie Cobalt-60 source when the source is raised above the pool, and when the source is on the elevator at the bottom of the pool. The pool is designed to provide 10½ feet of deionized water shielding over the sources when they are located at the bottom of the pool in a source storage fixture, and 9 feet of deionized water shielding over the sources when located on the source elevator at the bottom of the pool. As illustrated in Table 5-2 of this supplement, if 40,000 curies of Co-60 is located on the elevator at pool bottom, this shielding will reduce the exposure rate at pool surface to about 1.6 mR/hr. As further illustrated in Table 5-2 of this supplement, if an additional 8,240 curies of Co-60 is located on the pool bottom in a source storage fixture, this shielding will reduce the additional exposure rate at pool surface to 0.02 mR/hr. Details concerning the construction of the pool are presented in Paragraph 2.a of this supplement. For in-air irradiation, the Exposure Room walls are designed for a maximum transmitted exposure rate of 0.5 mR/h to the unrestricted areas external to the Exposure Room; the roof is designed for a maximum transmitted exposure rate of 10 mR/h at the roof surface external to the Exposure Room and the entrance maze is designed for a maximum transmitted exposure rate to the maze door of less than 0.25 mR/h. The Exposure Room floor, regolith upon which it rests, and the extension of the Exposure Room walls well into the earth serve to shield the building and grounds areas external to the Exposure Room from exposure rates in excess of 0.25 mR/h. Since all shielding calculations involving the use of concrete were based on the assumption that the concrete would have a density of 147 pounds per cubic foot, random pour-samples were analyzed. All samples were found to meet or exceed the assumed density. Figures 5-5 and 5-7 present information concerning the thickness and composition of the radiation shielding.

d. Radiation Levels. The Co-60 Gamma Radiation Facility shielding is designed to limit the exposure rate to "unrestricted areas" in and around the building to 0.5 mrem/hr. This level of exposure satisfies the requirement for "unrestricted areas" as defined in Title 10, Chapter 1, Code of Federal Regulations, Part 20. Areas where the radiation level exceeds 0.5 mrem/hr when the sources are in the raised position are the exposure room, the entrance maze, the mechanical room, and the exposure room roof. The 0.5 mrem/hr level is also exceeded directly over the pool area when 40,000 curies of Co-60 is on the source elevator at the bottom of the pool, and an addition 8,240 curies is located on the pool floor in a source storage fixture.

(1) Pool Area. The following parameters are used to calculate the exposure rates in the pool area associated with the use of 40,000 curies Co-60 on the elevator, 8240 curies Co-60 on the pool floor, and the manipulation of sources for source elevator loading and leak testing. The following calculations assume the source array to be a point source located at a position corresponding to the vertical center of the source pencils. "Point isotropic" buildup factors are used for reasons stated in paragraph 1d(2)(a) of this supplement.

- d= distance from source array to point of interest (m)
- t= water shield thickness (cm)
- u= linear attenuation coefficient for 1.25 MeV photons in water of density 1.00 $gm/cm^3$ = 0.064 $cm^{-1}$ (reference 8).
- B= "point isotropic" buildup factor, infinite medium (see para 2 (a))
- $I_o$= exposure rate at point of interest without shielding
- I= exposure rate at point of interest with shielding

Sample Calculation 1: Exposure rate 2 ft above pool grating from 8,240 curies on pool floor.

$I = BI_{o}e^{-ut}$

$I_o$ = gamma constant $X \frac{1}{d^2}$ X source activity

$= 1.32 \frac{R\text{-}m^2}{hr\text{-}Ci} X \frac{1}{(4.115m)^2} X\ 8{,}240\ Ci$

= 642.3 R/hr (without shielding)

$I = B\ (642.3\ R/hr)e^{(-0.064\ cm^{-1})(332.7cm)}$

$I = B\ (3.63 \times 10^{-7})R/hr$

for ut = (0.064)(332.7) = 21.29, Reference 8, Table A 4.3 estimates B=68

Supplement No. 5 continued.

$\therefore I = 68(3.63 X 10^{-7})$ R/hr = $2.5 X 10^{-5}$ R/hr = 0.025 mR/hr

Sample Calculation 2: Exposure rate 2 ft above pool grating from 40,000 curies on elevator at pool bottom.

$I_o$ = gamma constant X $\frac{1}{d^2}$ X source activity

$= 1.32 \frac{R\text{-}m^2}{hr\text{-}Ci} X \frac{1}{(3.67m)^2} X 40{,}000$ Ci

$= 3.92 X 10^3$ R/hr (without shielding)

$I = B(3.92 X 10^3) e^{(-.064 \text{ cm-1})(288 \text{ cm})}$

$I = B (3.876 X 10^{-5}$ R/hr)

for ut= (.064)(288) = 18.4, Reference 8, Table A4.3 estimates B=55

$\therefore I = 55(3.876 X 10^{-5}$R/hr) = $2.13 X 10^{-3}$ R/hr = 2.13 mR/hr

Sample Calculation 3: Exposure rate at pool surface from 40,000 curies on elevator at pool bottom.

$I_o = 1.32 \frac{R\text{-}m^2}{hr\text{-}Ci} X \frac{1}{(2.87m)^2} X 40{,}000$ Ci

$= 6.41 X 10^3$ (without shielding)

$I = B (6.41 X 10^3$ R/hr) $e^{(-.064 \text{ cm-1})(288 \text{ cm})}$

$I = B (6.338 X 10^{-5}$ R/hr)

for ut= (.064)(288) = 18.43, Reference 8, Table A4.3 estimates B= 55

$\therefore I = 55(6.338 X 10^{-5})$ R/hr = $3.486 X 10^{-3}$ R/hr = 3.49 mR/hr

Sample Calculation 4: Exposure rate 2 ft above pool grating from raising a 5,500 curie source with the source manipulator for lowering/raising in/out the leak test container or source elevator. If the source manipulator is raised until the warning mark is at the water surface, the center of the source will be 8 ft 2 in below the water surface. Also, the reference point 2 ft above the pool grating will then be 10 ft 9 in from the center of the source.

$I_o = 1.32 \frac{R\text{-}m^2}{hr\text{-}Ci} X \frac{1}{(3.28 m)^2} X 5{,}500$ Ci

= 675 R/hr (without shielding)

$I = B(675$ R/hr) $e^{(-.064 \text{ cm}^{-1})(248.9 \text{ cm}^{-1})}$

$I = B(8.14 X 10^{-5}$ R/hr)

for ut = (.064)(248.9) = 15.9, Reference 8, Table A4.3 estimates B = 44

therefore, I= 44 ($8.14 X 10^{-5}$ R/hr) = $3.62 X 10^{-3}$ R/hr = 3.6 mR/hr

Sample Calculation 5: Empirical derivation of buildup factor using currently licensed sources in the pool is possible by actually measuring the exposure rate at the water surface and at a point 2 ft above the pool grating directly over the sources. These measurements were conducted 12 Mar 86 by Michael Borisky, Radiation Protection Officer. The instruments used were: Keithley Model 36150 Ion Chamber Survey Meter, SN 19442, last calibrated 24 Jan 86; and Ludlum Model 2 G-M Survey Instrument, SN 11519, last calibrated 04 Feb 86. The ion chamber instrument was used to make the measurements, and the G-M instrument only to confirm the measurements were in the correct range.

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Measurements were made with a known activity in the three configurations of interest, i.e., on pool floor, on elevator at pool bottom, and on the source manipulator raised to the warning mark. The following radiation levels (excluding background) were observed:

| Source | Position | Instrument | Pool Surface | 2 Ft above Grating |
|---|---|---|---|---|
| 8,060 Ci | pool floor | Keithley IC | 0.02 mR/hr | bkg (0.015 mR/hr) |
| | | Ludlum GM | 0.02 mR/hr | bkg (0.015 mR/hr) |
| 8,060 Ci | elevator | Keithley IC | 0.33 mR/hr | 0.15 mR/hr |
| | | Ludlum GM | 0.32 mR/hr | 0.13 mR/hr |
| 320 Ci | raised manipulator | Keithley IC | 0.11 mR/hr | 0.08 mR/hr |
| | raised manipulator | Ludlum GM | 0.16 mR/hr | 0.06 mR/hr |

Keithley Ion Chamber measurements were made using the integrate mode to better define the exposure rates present, as the smallest exposure rate unit the Keithley offers is 0.1 mR/hr. On the other hand, in the integrated mode, the Keithley offers exposure units as small as 0.0001 mR. The exposure was integrated for 3 minutes and the exposure rate then calculated in mR/hr. An empirically derived buildup factor can now be calculated for the exact geometrical and shielding configuration of the Co-60 pool. For example, in Sample Calculation 2, the 40,000 curie term is replaced with 8,060 curies since this amount of activity was actually present on the elevator when the measurements were made. In this way, the intensity at the point of interest without shielding can be calculated for the 8,060 curies, and placed into the shielding equation as $I_o$. The exposure rate measured at the point of interest is then put into the shielding equation as I, and the equation solved for B.

$$I_o = 1.32 \frac{R\text{-}m2}{hr\text{-}Ci} \times \frac{1}{(3.67m)^2} \times 8{,}060 \text{ Ci}$$

$$I_o = 7.90 \times 10^2 \text{ R/hr}$$

$$1.5 \times 10^{-4} \text{ R/hr} = B(7.90 \times 10^2 \text{ R/hr})\, e^{(-.064cm^{-1})(288 \text{ cm})}$$

$$19.2 = B \text{ (derived)}$$

Likewise for Sample Calculation 3, a buildup factor can be empirically derived for the actual shielding and geometric configuration when the Co-60 sources are on the elevator, and the exposure rate at pool water surface is of interest.

$$I_o = 1.32 \frac{R\text{-}m^2}{hr\text{-}Ci} \times \frac{1}{(2.87m)^2} \times 8{,}060 \text{ Ci}$$

$$I_o = 1.29 \times 10^3 \text{ R/hr}$$

$$3.3 \times 10^{-4} \text{ R/hr} = B\, (1.29 \times 10^3 \text{ R/hr})\, e^{(-.064cm^{-1})(288cm)}$$

$$25.8 = B \text{ (derived)}$$

It is obvious from actual measurements that the buildup factor tabulated in Reference 8 overestimates the buildup actually present under the shielding/geometrical configuration of the Co-60 facility pool. The following tables summarize the exposure rates that can be expected in the pool area using (1) tabulated buildup factors, and (2) measured (actual) buildup factors:

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TABLE 5-1
Pool Area Exposure Rates
Tabulated Buildup

| Source | Position | 2 ft above pool grating | B | Pool Surface | B |
|---|---|---|---|---|---|
| 40 kCi | elevator down | 2.13 mR/hr | 55 | 3.49 mR/hr | 55 |
| 5.5 kCi | raised manipulator | 3.6 mR/hr | 44 | 6.2 mR/hr | 44 |
| 8.2 kCi | pool floor | 0.025 mR/hr | 68 | 0.035 mR/hr | 68 |

TABLE 5-2
Pool Area Exposure Rates
Actual Buildup

| Source | Position | 2 ft above pool grating | B | Pool Surface | B |
|---|---|---|---|---|---|
| 40 kCi | elevator down | 0.74 mR/hr | 19.2 | 1.64 mR/hr | 25.8 |
| 5.5 kCi | raised manipulator | 1.37 mR/hr | 16.9 | 1.88 mR/hr | 13.4 |
| 8.2 kCi | pool floor | $<$0.02 mR/hr | $<$56 | 0.02 mR/hr | 36.9 |

(2) Exposure Room. Since in-air exposures require that the cobalt-60 source elements be raised from the pool via the source elevator, the source elements will be located 6 feet from the east and west walls, 28.33 feet from the north wall, 14.5 feet from the south wall and 8.5 feet from the ceiling. For purposes of in-air exposure calculations presented below, it is assumed that 8 source elements, containing a total of 40,000 curies of Co-60, are arranged in a circle with a radius of 14.49 centimeters, and raised via the elevator to a height of 5.5 feet from the Exposure Room floor. The list of references used to perform the following analysis is found in paragraph 1d(3) of this supplement.

(a) East and West Walls. According to Reference 1, page 7-71, the source-shield geometry for the east and west walls requires the use of "point isotropic" build-up factors in order to calculate the attenuation provided by the concrete walls. This determination is made as follows:

If $\frac{a}{d-t} < \frac{\sqrt{2ut + 1}}{ut}$ and $d > t$, use "plane collimated" build-up factor. If both conditions are not true, use "point source" build-up factor.

- d = distance from source array to shield = 182.88 cm
- a = maximum radius of source array, measured perpendicular to d = 14.49 cm
- t = shield thickness = 152.4 cm
- u = linear attenuation coefficient for 1.25 meV photons in concrete of density 2.35 gm/cm$^3$ = 0.1332 cm$^{-1}$ (Reference 1, page 7-62)
- $d > t$ = 182.88 cm $>$ 152.4 cm (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut + 1}}{ut} = \frac{14.49 \text{ cm}}{(182.88 \text{ cm}) - (152.4 \text{ cm})} < \frac{\sqrt{2(.1332)(152.4 \text{ cm}) + 1}}{(0.1332 \text{ cm}^{-1})(152.4 \text{ cm})} =$$

0.4754 $<$ 0.3177. Since the second condition is not satisfied, one should use point isotropic source build-up factors for east and west shield wall attenuation calculations.[5]

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Use of Capo's formula for a "point source" in an infinite medium, presented in Reference 2, page 213-217, yields a conservative build-up factor of 62.4 for 1.25 MeV photons passing through 152.4 cm of ordinary concrete with a density of 2.35 $gm/cm^3$. ($uX$ = 20.30 mean free path lengths)

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The attenuation factor "$A_R$" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is A = I/Io = b exp(-uX).

Io = original exposure rate to unshielded external wall surface
I = attenuated radiation exposure rate due to shield
u = linear absorption coefficient (0.1332 $cm^{-1}$)
X = shield thickness (152.4 cm concrete)
b = build-up factor = 62.4

$$Io = \left(\frac{3.28'}{11'}\right)^2 \times (40{,}000\ Ci)(1.32\ R/h\ at\ 1\ meter/Ci) = 4.695 \times 10^3\ R/h$$

Required attenuation factor for "unrestricted areas": $A_R$

$$A_R = \frac{I}{Io} = 0.5\ mR/h \big/ 4.695 \times 10^6\ mR/h = 10.65 \times 10^{-8}$$

Attenuation factor provided by 152.4 cm of concrete =

$$A_p = b\ e^{-uX}$$

$$A_p = (62.4)\ (e^{-(0.1332\ cm^{-1})(152.4\ cm)}) = 62.4(1.527 \times 10^{-9}) = 9.53 \times 10^{-8}$$

Since $A_p < A_R$ (ie, $9.53 \times 10^{-8} < 10.65 \times 10^{-8}$) the shielding for both the east and west walls in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the walls to < 0.5 mR/h.

(b) North Wall. According to Reference 1, the source-shield geometry for the north wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the north wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

d > t = 863.6 cm > 137.16 cm, (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut + 1}}{ut} = \frac{14.49\ cm}{(863.6\ cm)-(137.16\ cm)} < \frac{\sqrt{2(0.1332\ cm^{-1})(137.16\ cm) + 1}}{(0.1332\ cm^{-1})(137.16\ cm)} =$$

0.020 < 0.335. Since this condition is also satisfied, one should use "plane collimated" build-up factors for north wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 17 for a broad parallel beam of 1.25 MeV photons passing through 137.16 cm (uX = 18.28 mean free paths) of ordinary concrete.

The attenuation factor "$A_R$" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

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$$Io = \left(\frac{3.28'}{32.83'}\right)^2 (40{,}000\ Ci)(1.32 R/h \text{ at } 1 \text{ meter/Ci}) = 5.270 \times 10^2 \ R/h$$

Required attenuation factor for "unrestricted area" = $A_R$

$$A_R = \frac{I}{Io} = 0.5 \ mR/h / 5.269 \times 10^5 \ mR/h = 9.489 \times 10^{-7}$$

Attenuation factor provided by 137.2 cm of concrete:

$$A_p = b\, e^{-uX}$$

$$A_p = 17\, e^{-(0.1332\ cm^{-1})(137.2\ cm)} = 17(1.157 \times 10^{-8}) = 1.967 \times 10^{-7}$$

Since $A_p < A_R$ (ie, $1.967 \times 10^{-7} < 9.489 \times 10^{-7}$) the shielding for the north wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to <0.5 mR/h.

(c) South Wall. According to Reference 1, the source-shield geometry for the south wall requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the south wall. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$d > t$ = 441.96 cm > 152.4 cm, (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49\ cm}{(441.96\ cm)-(152.4\ cm)} < \frac{\sqrt{2(0.1332\ cm^{-1})(152.4\ cm)+1}}{(0.1332\ cm^{-1})(152.4\ cm)} =$$

0.05 < 0.3177. Since this condition is also satisfied, one should use "plane collimated" build-up factors for south wall shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 20 for a broad parallel beam of 1.25 MeV photons passing through 152.4 cm ($uX$ = 20.30 mean free paths) of ordinary concrete.

The attenuation factor "$A_R$" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$Io = \left(\frac{3.28'}{19.5'}\right)^2 (40{,}000 \text{ curies})(1.32 \ R/h \text{ at } 1 \text{ meter/Ci}) = 1.494 \times 10^3 \ R/h$$

Required attenuation factor for unrestricted area = $A_R$

$$A_R = \frac{I}{Io} = 0.5 \ mR/h / 1.494 \times 10^6 \ mR/h = 3.347 \times 10^{-7}$$

Attenuation factor provided by 152.4 cm of concrete:

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$A_p = b\ e^{-uX}$

$A_p = 20\ e^{-(0.1332\ cm^{-1})(152.4\ cm)} = 20(1.527 \times 10^{-9})$
$= 3.055 \times 10^{-8}$

Since $A_p < A_R$ (ie, $3.055 \times 10^{-8} < 3.347 \times 10^{-7}$) the shielding for the south wall in the worst case is adequate to reduce the exposure rate at the "unrestricted area" side of the wall to <0.5 mR/h.

(d) Roof. The roof over the Cobalt-60 Gamma Radiation Facility Exposure Room is a "restricted area". Personnel access to this area is not permitted during periods when in-air irradiation are in progress. Consequently, an exposure rate of 5 mR/h at a distance of 6 inches from the outer surface of the Exposure Room roof shield slab is considered adequate.

According to Reference 1, the source-shield geometry for the roof requires the use of "plane collimated" build-up factors in order to calculate the attenuation provided by the roof. This determination is made by employing the same procedure illustrated in paragraph 1d(1)(a) of this supplement.

$d > t = (213.36\ cm) > (121.92\ cm)$, (condition satisfied)

$$\frac{a}{d-t} < \frac{\sqrt{2ut+1}}{ut} = \frac{14.49\ cm}{(213.36\ cm)-(121.92\ cm)} < \frac{\sqrt{2(0.1332\ cm^{-1})(121.92\ cm)+1}}{(0.1332\ cm^{-1})(121.92\ cm)} =$$

0.158 < 0.356. Since this condition is also satisfied, one should use "plane collimated" build-up factors for roof shield attenuation calculations.

Conservative interpolation of Figure 4.3-24 in Reference 2, page 222, yields a build-up factor of 15 for a broad parallel beam of 1.25 MeV photons passing through 121.92 cm (uX = 16.24 mean free paths) of ordinary concrete.

The attenuation factor "$A_R$" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$Io = \left(\frac{3.28'}{13'}\right)^2 (40{,}000\ \text{curies})(1.32\ \text{R/h at 1 meter/curie}) = 3.361 \times 10^3\ R/h$$

Required attenuation factor for 5 mR/h "restricted area" roof = $A_R$

$$A_R = \frac{I}{Io} = 5\ mR/h / 3.361 \times 10^{6} mR/h = 1.488 \times 10^{-6}$$

Attenuation factor provided by 121.92 cm of concrete:

$A_p = b\ e^{-uX}$

$A_p = 15\ e^{-(0.1332\ cm^{-1})(121.92\ cm)} = 15(8.878 \times 10^{-8})$
$= 1.332 \times 10^{-6}$

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Since $A_p < A_R$ (ie, $1.332 \times 10^{-6} < 1.488 \times 10^{-6}$) the shielding for the roof in the worst case is adequate to reduce the exposure rate at 6 inches past the external surface of the roof shield slab to <5 mR/h.

(e) Floor. As illustrated on Figure 5-7, all Exposure Room walls extend well past the floor into the soil. This structural characteristic serves to shield personnel located outside of the Exposure Room from scattered photons which have passed through the floor during in-air irradiations. Since the north wall of the Exposure Room extends the shortest distance into the soil, less shielding is provided by the soil in this area than in any other. Consequently, the following analysis presents the "worst case" situation.

The shortest distance between the exposed source and a point beneath the north wall where a scatter angle of 30° exists is (18' air + 14' soil) = 32 feet.

Since the density of the sandy soil on which the facility is built is approximately equal to concrete, a conservative estimate of the soil build-up factor is obtained by extrapolation of Figure 4.3-24 in Reference 2, page 222. For 1.25 MeV photons passing through 426 cm of soil (uX = 60 mean free paths) a build-up factor 300 is chosen.

The mass attenuation coefficient (u/p) for sandy soil is determined by using the weighted average method presented in Reference 2, page 172. The chemical composition of the soil necessary for the determination of u/p was obtained from Reference 3. The value of u/p obtained via this method = 0.05695 $cm^2/gm$. The density of the sandy soil used for the determination of u/p is 2.471 $gm/cm^3$.

The attenuation factor "$A_R$" required to reduce the exposure rate from 40,000 curies of cobalt-60 to 0.5 mR/h is found via the method described in paragraph 1d(1)(a) of this supplement.

$$Io = \left(\frac{3.28'}{32'}\right)^2 \text{(40,000 curies)(1.32 R/h at 1 meter/Ci)} = 5.55 \times 10^2 \text{ R/h}$$

$$A_R = \frac{I}{Io} = \frac{0.5 \text{ mR/h}}{5.55 \times 10^5 \text{ mR/h}} = 9.01 \times 10^{-7}$$

Attenuation factor provided by 426 cm of soil:

$$A_p = b\, e^{-uX}$$

$$A_p = 300 \quad e^{-(0.1407\ cm^{-1})(426\ cm)} = 2.79 \times 10^{-24}$$

Since $A_p < A_R$ (ie, $2.79 \times 10^{-24} < 9.01 \times 10^{-7}$) the shielding provided by the soil in the worst case is adequate to reduce the exposure rate to well below 0.5 mR/h before the photons can pass from the scatter point beneath the wall to any point exterior to the building.

(f) Exposure Room Entrance Maze. As illustrated on Sketch 5-1, the maze leading from the Exposure Room to the Control Room present a path for gamma

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radiation, originating at the source elevator, which contains 3 right-angle bends. In order to conservatively calculate the exposure rate to the maze-side of the maze entrance door, the data presented in Reference 4, page 73, will be used.

The concrete walls, ceilings, and floor of the Exposure Room and Maze are in excess of 2 mean free path lengths thick (5.9 in.), and therefore are treated as being infinitely thick reflectors of 1.25 MeV cobalt-60 gamma photons. This assumption is supported by Reference 5.

Since the maze contains three right-angle bends and both the calculated and measured dose rates (D/Do) ($10^4$) given in Reference 4, Table II, are for two-legged concrete ducts, the maze will be treated as a combination of 2, two-legged duct arrangements, connected in series. The dose rate at point $P_2$, resulting from the cobalt-60 source located at point $P_1$, is calculated. Then the dose rate at point $P_3$ is calculated using the dose rate at the point $P_2$ as the source of gamma radiation. Since the gamma photons at point $P_2$ will be primarily the result of Compton interaction and the data given in Reference 4, Table II is based on cobalt-60 source emitting photons with a mean energy of 1.25 MeV, the dose rate calculated for point $P_3$ will be conservative. In addition, the dose rate values extracted from Table II for this analysis will be greater than encountered in the actual maze due to the fact that the duct dimensions corresponding to the exposure rate values in Table II are chosen for smaller values of W, smaller values of $L_1/W$ and smaller values of $L_2/W$ than are encountered in the actual maze.

In addition to the symbols presented on Sketch 5-1, the following notation will be used in the calculations: $D_o$ = dose rate at 1 foot from the source
D = dose rate at a point located in the second leg of a two-legged duct (ie, $P_2$ and $P_3$)

$$\underline{\text{Do (point } P_1)} = \left(\frac{3.28}{1}\right)^2 (4.0 \times 10^4 \text{Ci})(1.32 \text{ R/h at 1 meter per Ci})$$
$$= 5.68 \times 10^5 \text{ R/h}$$

<u>D at point $P_2$</u>: Value of (D/Do x $10^4$) selected using Table II data for Terrell's work which involved the use of a 3.67 Ci Co-60 source in a duct with specifications W = 6', $L_1/W = 2.0$, and $L_2/W = 3.17$.

$$D/(Do \times 10^{-4}) = 0.203 \therefore D = (0.203)(Do)(10^{-4})$$
$$= (0.203)(5.68 \times 10^5 \text{ R/h})(10^{-4})$$
$$= 11.53 \text{ R/h at point } P_2$$

<u>D at point $P_3$</u>: Using the dose rate calculated above at point $P_2$ as the origin of the gamma radiation one may conservatively calculate the dose rate at point $P_3$. The value of (D/Do x $10^4$) is selected using Table II data for Chapman's work which involved the use of a 2.4 Ci Co-60 source in a duct with specifications W = 3', $L_1/W = 2$, and $L_2/W = 1.67$.

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$$D/(Do \times 10^{-4}) = 5.95 \therefore D = (5.95)(Do)(10^{-4})$$
$$= (5.95)(11.53\ R/h)(10^{-4})$$
$$= 6.9 \times 10^{-3}\ R/h \text{ at point } P_3$$

Consequently, assuming air attenuation to be negligible, the dose rate at the center of the maze-side surface of the maze doors will be approximately:

$$I_1 = \frac{Iodo^2}{d_1^2} = \frac{(6.9 \times 10^{-3}\ R/h)(2.5')^2}{(10')^2\ \ (10^3)} = 0.43\ mR/h$$

(g) West Wall of Maze. Since the dose rate at the point $P_2$ (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value is used to evaluate the adequacy of shielding provided by the west wall of the maze. The most probable energy of the cobalt-60 gamma photons scattered through an angle of $90^o$ as a result of a single collision is 0.362 MeV according to Reference 6, page 59. The mass attenuation coefficient from Reference 1 for 0.5 MeV gamma photons in concrete will be used in the following calculations. The dose rate at the outside surface of the west maze wall without shielding = Io.

$$Io = \frac{(11.53\ R/h)(1')^2}{(14.49')^2} = 5.49 \times 10^{-2}\ R/h$$

The shielding factor required to reduce the exposure rate at the outside surface of the west maze wall = $A_R$.

$$A_R = I/Io = 0.5\ mR/h / 54.9\ mR/h = 9.11 \times 10^{-3}$$

The shielding factor provided by the west maze wall (61 cm of concrete) = $A_p = b\ e^{-uX}$

"b" for 12.5 mean free path lengths in concrete ≈15 [note uX = (0.2045)(61 cm) = 12.47] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 15\ e^{-(.2045\ cm^{-1})(61\ cm)} = 5.73 \times 10^{-5}$$

Since $A_p < A_R$ (ie, $5.73 \times 10^{-5} < 9.11 \times 10^{-3}$) the shielding for the west wall of the maze is sufficient to reduce the dose rate at the "unrestricted area" side of the wall to $<0.5$ mR/h.

(h) Maze Scatter Shield. Since the dose rate at the point $P_2$ (shown on Sketch 5-1) is calculated to be 11.53 R/h, this value will be used to evaluate the adequacy of shielding provided to the Control Room by the maze scatter shield. As in the analysis presented in paragraph 1d(1)(g), it will be assumed that the gamma photons have an initial energy of 0.5 MeV.

Shield factor required to reduce the dose rate at the maze-side of the maze entrance door to 0.5 mR/h is $A_R$.

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$$Io = \frac{(11.53\ R/h)(1)^2}{(8.5')^2} = 1.6 \times 10^{-1}\ R/h$$

$$A_R = I/Io = 0.5\ mR/h / 160\ mR/h = 3.125 \times 10^{-3}$$

The shielding factor provided by the maze scatter shield is $A_p = b\ e^{-uX}$.

"b" for 9.4 mean free paths in concrete ≈ 10 [note $uX = (0.2045\ cm^{-1})(45.7\ cm) = 9.35$] from interpolation of Figure 4.3-24 in Reference 2, page 222.

$$A_p = 10\ e^{-(.2045\ cm^{-1})(45.7\ cm)} = 8.73 \times 10^{-4}$$

Since $A_p < A_R$ (ie, $8.73 \times 10^{-4} < 3.125 \times 10^{-3}$) the shielding provided by the maze scatter shield is sufficient to reduce the dose rate at the maze-side of the maze entrance door to less than 0.5 mR/h. Consequently, the dose rate at the Control Room side of the maze entrance doors will also be less than 0.5 mR/h.

(3) Exposure Room Shielding Penetrations

(a) Exhaust Ventilation Duct. The exhaust ventilation duct penetrates the Exposure Room roof slab at a location near the south wall. As illustrated on Figures 5-7, 5-12, and Sketch 5-2, the exhaust duct is designed to provide shielding for both direct and scattered gamma radiation emanating from the cobalt-60 sources when they are utilized for in-air irradiations. All primary cobalt-60 gamma photons entering the "radiation trap" will be attenuated by a minimum of 46 inches of concrete. This amount of shielding is sufficient to reduce the exposure rate at a distance of one foot from the external surface of the "radiation trap" to less than 5 mR/h. The following "worst case" analysis assumes that the path of primary gamma photons is through 4 inches of the corner lip of the first right-angle bend in the duct prior to impinging on the south shield wall of the "radiation trap".

$$Io = \left(\frac{3.28'}{26'}\right)^2 (40{,}000\ Ci)(1.32\ R/h\ at\ 1\ meter\ per\ Ci) = 8.403 \times 10^2\ R/h$$

Attenuation required to reduce the exposure rate to 5.0 mR/h at a distance of 1 foot from the external surface of the shield = $A_R$.

$$A_R = I/Io = 5\ mR/h / 8.403 \times 10^5\ mR/h = 5.95 \times 10^{-6}$$

Attenuation provided by the concrete shield for 1.25 MeV gamma photons = $A_p$.

$$A_p = b\ e^{-uX}$$

"b" for 15.5 mean free paths = 30 (conservative estimate from Table 43.3-7, Reference 1, page 224 for cos θ = 0.75)

$$A_p = (30)\ e^{-(0.1332\ cm^{-1})(116.84\ cm)} = 5.226 \times 10^{-6}$$

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Since $A_p < A_B$ (ie, $5.226 \times 10^{-6} < 5.95 \times 10^{-6}$) the "radiation trap" shielding for primary gamma radiation from a 40,000 curie cobalt-60 source is sufficient to reduce the exposure rate to less than 5 mR/h at a distance of one foot from the external surface of the "radiation trap".

A conservative estimate of the exposure rate at the exhaust point of the ventilation duct which passes through the "radiation trap" is obtained by using the data presented by Green in Reference 4, Table II and assuming that the exposure rate at the Exposure Room side of the duct is due to primary cobalt-60 gamma photons from a point source. In order to use the data in Reference 4, it will be assumed that the width (W) of the "radiation trap" duct is 9.47 inches instead of the actual dimension of 34 inches. The exposure rate value calculated assuming a 9.47 inch duct width will be increased by a factor of 3.59 in order to estimate the total exposure rate from the 34 inch wide duct. Use of this method effectively increases the primary and multiple surface scatter areas by 76%. Since, according to Reference 4, the primary scatter areas contribute 42% and the multiple surface scatter contributes 32% of the total dose in the second leg of a two-legged duct, the final exposure rate estimate will be approximately 56% high. In addition, the dose rate values selected from Table II are values which represent a worst case estimate. The "radiation trap" will be treated as a combination of 2, two-legged ducts connected in series. With references to Sketch 5-2, the dose rate at the point $P_2$ resulting from a cobalt-60 source located at point $P_0$ is calculated. Then, the dose rate at point $P_4$ is calculated using the dose rate at the point $P_2$ as the source of gamma radiation. Although the energy of the cobalt-60 gamma photons traveling from point $P_2$ to point $P_3$ will be degraded from previous Compton interactions, it will be assumed that they have an energy of 1.25 MeV. This assumption will also result in a higher calculated dose rate at the exhaust point than will actually be encountered.

| Data for First 2 Legged Duct Section | Data for Second 2 Legged Duct Section |
|---|---|
| $L_1$ = 18" | $L_3$ = 54" |
| $L_2$ = 28" | $L_4$ = 52" |
| W = 9.47" | W = 9.47" |
| $L_1/W$ = 1.90 | $L_3/W$ = 5.70 |
| $L_2/W$ = 2.96 | $L_4/W$ = 5.49 |
| $(D/Do) \times (10^4)$ value selected: 66.0 | $(D/Do) \times (10^4)$ value selected: 2.34 |

Exposure rate at point $P_0$ = Do

$$Do = \left(\frac{3.28'}{17'}\right)^2 (4.0 \times 10^4 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 1.966 \times 10^3 \text{ R/h}$$

$$\text{Dose at Point } P_2 = D/(Do \times 10^{-4}) = 66 \therefore D = (66)(Do)(10^{-4})$$
$$= (66)(1.966 \times 10^6 \text{mR/h})(10^{-4})$$
$$= 1.297 \times 10^4 \text{mR/h}$$

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Dose at Point $P_4 = D/(Do \times 10^{-4}) = 2.34 \therefore D = (2.34)(Do)(10^{-4})$
$= (2.34)(1.297 \times 10^4 mR/h)(10^{-4})$
$= 3.035$ mR/h

Conservative estimate of the exposure rate at the exhaust point of the ventilation duct (point $P_4$): (3.035 mR/h/section)(3.59 sections) = 10.9 mR/h

(b) Elevator-Drive Cable-Ducts. Figures 5-18, 5-19 and Sketch 5-3 illustrate the wall penetrations between the Exposure Room (Rm. 2) and the Mechanical Equipment Room (Rm. 9) which serve to provide a path for the source-elevator drive-cables. Both cable-ducts are also pathways for scattered gamma radiation-streaming during in-air irradiation procedures. The following determination of exposure rate in the Mechanical Equipment Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to an in-air irradiation position 5.5 feet above the Exposure Room floor. Due to the location of the two cable-ducts, it is also assumed that all gamma photons passing through them have a reflected flight-path which is approximately parallel to the axis of the cable-duct. In order to estimate the exposure rate in the Mechanical Equipment Room from scattered gamma radiation streaming through the cable-ducts, the differential dose albedo formulas and constants presented in Reference 7 will be used. Sketch 5-3 is annotated to define the reference points used in the calculations. Since this represents a "worst case" analysis, only the lower cable-duct is considered.

Formulas Used

$$dD = \frac{Do\, \alpha d \cos \theta_o dA}{r_2^2} \quad \text{(Ref 7)}$$

Where: $dD$ = differential dose at point of interest due to scatter
$Do$ = dose in incident beam at area $dA$
$r_2$ = distance from scatter area to point of interest
$\theta_o$ = polar angle of incident radiation
$dA$ = differential area of reflecting surface
$\alpha d$ = differential albedo

$$\alpha d = \frac{C\, K(\theta_s)\, 10^{26} + C'}{1 + \cos \theta_o \sec \theta} \quad \text{(Ref 7)}$$

Where: $C$ & $C'$ = Parameters for semiempirical formula given in Ref 7, Table 1, for 1 MeV photons.
$K(\theta_s)$ = Klein-Nashina value of the energy scattering cross section per electron depending on the scatter angle $\theta_s$ [ie, (Photon scattering cross section) x (ratio of scattered to incident energy)]
$\theta_o$ = polar angle of incident radiation
$\theta$ = polar angle of reflected radiation

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$$E = \frac{E_o}{1 + (E_o/0.511)(1 - \cos\theta_s)} \quad \text{(Ref 2)}$$

Where: E = energy in MeV of photon after one Compton scatter
$E_o$ = energy in MeV of photon before Compton scatter
$\theta_s$ = angle through which the photon is scattered

Differential dose at point $P_5$ resulting from gamma photons reflected parallel to the cable duct axis at point $P_2$.

$$E = \frac{1.25\ \text{MeV}}{1 + (1.25\ \text{MeV}/0.511)(1 - \cos 131^o)} = 0.219\ \text{MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24}\ \frac{cm^2}{e^-})(\frac{0.219\ \text{MeV}}{1.25\ \text{MeV}}) = 3.5 \times 10^{-26}\ \frac{cm^2}{e'}$$

$$\alpha d = \frac{(0.0547)(3.5 \times 10^{-26})(10^{26}) + (0.0111)}{1 + (\cos 49^o)(\sec 0^o)} = 0.122\ sr^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3\ R/h)(0.122\ sr^{-1})(0.660)(5\ cm^2)}{(518\ cm)^2} = 1.03 \times 10^{-2}\ R/h$$

Differential dose at point $P_5$ resulting from gamma photons undergoing one Compton scatter in the west wall of the exposure room which redirects their flight path along the axis of the cable-duct.

$$E = \frac{1.25\ \text{MeV}}{1 + (1.25\ \text{MeV}/0.511)(1 - \cos 49^o)} = 0.679\ \text{MeV}$$

$$K(\theta_s) \approx (0.2 \times 10^{-24}\ \frac{cm^2}{e^-})(\frac{0.679\ \text{MeV}}{1.25\ \text{MeV}}) = 10.9 \times 10^{-26}$$

$$\alpha d = \frac{(0.0547)(10.9 \times 10^{-26})(10^{26}) + (0.0111)}{1 + (\cos 41^o \sec 89^o)} = 0.014\ sr^{-1}$$

$$dD \text{ at } P_5 = \frac{(6.87 \times 10^3\ R/h)(0.014\ sr^{-1})(0.755)(5\ cm^2)}{(152\ cm)^2} = 15.6\ mR/h$$

Since the exposure rate on the Mechanical Equipment Room side of the cable-duct is estimated to be in excess of 0.5 mR/h, the room will be treated as a "restricted area" during in-air irradiation procedures. Unless the initial radiation survey of the facility indicates the restriction may be removed, access to the Mechanical Equipment Room will be controlled by the Cobalt-60 Facility Supervisor via control of the door key for this room.

(c) Conduit Maze in West Wall. Figure 5-16 illustrates a conduit maze consisting of four aluminum conduits, each of which contain two right-angle bends. These 4-inch diameter conduits serve as raceways between the Exposure

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Room and Control Room. The following estimate of the exposure rate to be expected in the Control Room is based on the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height above the floor equal to that of the conduit. Since the two conduits closest to the source represent the "worst case" for gamma radiation streaming, only these conduits are examined in the following analysis. Also, since the total mass attenuation coefficients for concrete and aluminum are nearly equal, the walls of the conduit are considered to be concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

Exposure rate to conduit opening = $D_o$

$$D_o = \left(\frac{3.28}{8.7'}\right)^2 (4.0 \times 10^4 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 7.5 \times 10^3 \text{ R/h}$$

E = energy in MeV after one Compton scatter

$$E = \frac{1.25 \text{ MeV}}{1 + (1.25/0.511)(1\text{-Cos } 46^o)} = 0.71 \text{ MeV}$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{cm^2}{e^-})(\frac{0.71}{1.25}) = 1.14 \times 10^{-25} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(1.14 \times 10^{-25} \frac{cm^2}{e})(10^{26}) + (0.0111)}{1 + (0.728)(57.3)} = 0.015 \text{ sr}^{-1}$$

Assume that the first leg of the conduit perpendicular to the plane of the wall extends a distance of 2.5 feet into the wall. Then the exposure rate at the beginning of the first right-angle bend = dD.

$$dD = \frac{(7.5 \times 10^6 \text{ mR/h})(0.015 \text{ sr}^{-1})(0.728)(81 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.14 \times 10^3 \text{ mR/h}$$

The exposure rate at the surface of the shield wall in the Control Room due to a collimated source of 0.8 MeV photons, which yields an exposure rate of $1.14 \times 10^3$ mR/h, and is located midway in the west wall = I.

$$I = Io\ b\ e^{-uX} = (1.14 \times 10^3 \text{ mR/h})(5) \exp^{-(0.1659)(76.2 \text{ cm})}$$

$I = 1.8410^{-2}$ mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of the conduit is 3 feet long and is directed away from the first leg of conduit at an angle of 89°. The exposure rate at the end of the second leg of conduit is:

$$E = \frac{0.71 \text{ MeV}}{1 + (\frac{0.71}{0.511})(1-0.707)} = 0.505$$

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$$K(\theta_s) = (0.25 \times 10^{-24} \frac{cm^2}{e^-})(\frac{0.505}{0.71}) = 17.8 \times 10^{-26} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(17.8 \times 10^{-26} \frac{cm^2}{e^-})(10^{26}) + (0.0111)}{1 + (1)(57.3)} = 0.017\ sr^{-1}$$

$$dD = \frac{(1.14 \times 10^3\ mR/h)(0.017\ sr^{-1})(1)(81\ cm^2)}{8.36 \times 10^3\ cm^2} = 0.188\ mR/h$$

Since the exposure rate at the beginning of the second right-angle bend will be less than 0.5 mR/h, the exposure rate at the point the conduit exits in the Control Room will also be less than 0.5 mR/h.

(d) Water Pipe for Emergency Pool Water Makeup. Figures 5-13, 5-14 and 5-21 illustrate the emergency pool water makeup which is located in the wall which separates the Exposure Room from the Mechanical Equipment Room. This 2-inch diameter pipe contains two right-angle bends and is positioned such that the point of entry in the Mechanical Equipment Room is 2 feet above the floor and the point of exit in the Exposure Room is 6 inches above the floor. The following estimate of the expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. Presentation of the formula and associated symbol definitions used therein is found in paragraph 1d(2)(b) of this supplement.

Do = Exposure rate to wall at point of pipe penetration

$$Do = \left(\frac{3.28'}{8.06'}\right)^2 (40{,}000\ Ci)(1.32\ R/h\ \text{at 1 meter per Ci}) = 8.74 \times 10^3\ R/h$$

E = Energy in MeV after 1 Compton scatter through 18°

$$E = \frac{1.25}{1 + (\frac{1.25}{0.511})(1 - \cos 18^\circ)} = 1.12\ MeV$$

$$K(\theta_s) = (0.2 \times 10^{-24} \frac{cm^2}{e^-})(\frac{1.12}{1.25}) = 1.79 \times 10^{-25} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(1.79 \times 10^{-25} \frac{cm^2}{e^-})(10^{26}) + (0.0111)}{1 + (\cos 72^\circ)(\sec 89^\circ)} = 0.053\ sr^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD

$$dD = \frac{(8.74 \times 10^6\ mR/h)(0.053\ sr^{-1})(0.309)(20\ cm^2)}{(5.81 \times 10^3\ cm^2)} = 4.93 \times 10^2\ mR/h$$

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The exposure rate at the Control Room surface of the shield wall resulting from a 493 mR/h source of 1.12 MeV gamma photons located behind 2.5 feet of concrete = I.

$$I = Io\ b\ e^{-uX} = (493\ mR/h)(10)\ e^{-(0.1492)(76.2\ cm)}$$

I = 0.06 mR/h, which is less than 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of the pipe is 5 feet long and is directed away from the first leg at an angle of 89°. The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:

$$E = \frac{1.12\ MeV}{1 + (\frac{1.12}{0.511})(1-\cos 89^o)} = 0.355\ MeV$$

$$K(\theta_s) = (0.2023 \times 10^{-24}\ \frac{cm^2}{e^-})(\frac{0.355}{1.12}) = 0.64 \times 10^{-25}\ \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(6.4 \times 10^{-26}\ \frac{cm^2}{e})(10^{26}) + (0.0111)}{1 + (\cos 0^o)(\sec 89^o)} = 6.2 \times 10^{-3}\ sr^{-1}$$

$$dD = \frac{(493\ mR/h)(6.2 \times 10^{-3}\ sr^{-1})(1)(20\ cm^2)}{(2.32 \times 10^4\ cm^2)} = 2.64 \times 10^{-3}\ mR/h$$

Since the exposure rate at the beginning of the second right-angle bend is less than 0.5 mR/h, the exposure rate at the point the pipe exits into the Mechanical Equipment Room will also be less than 0.5 mR/h.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.7 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the final right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

Io = Exposure rate at second right-angle bend without shield.

$$Io = (\frac{3.28}{9'})^2 (40{,}000\ Ci)(1.32\ R/h\ \text{at 1 meter per Ci}) = 7.01 \times 10^3\ R/h$$

Exposure rate at second right-angle bend with 2.7 feet of concrete shielding = I

$$I = Io\ b\ e^{-uX} = (7.01 \times 10^6\ mR/h)(20)\ e^{-(.1332\ cm^{-1})(82\ cm)} = 2.53 \times 10^3\ mR/h$$

$$K(\theta_s) = (0.20 \times 10^{-24}\ \frac{cm^2}{e})(\frac{0.8}{1.25}) = 12.2 \times 10^{-26}\ \frac{cm^2}{e}$$

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$$\alpha d = \frac{(0.0547)(12.2 \times 10^{-26} \frac{cm^2}{e^-})(10^{26}) + (0.0111)}{1 + (\text{Cos } 69^o)(\text{sec } 89^o)} = 3.15 \times 10^{-2}\ sr^{-1}$$

$$dD = \frac{(2.53 \times 10^3\ mR/h)(3.15 \times 10^{-2}\ sr^{-1})(0.358)(5\ cm^2)}{5.81 \times 10^3\ cm^2} = 0.026\ mR/h$$

which is also less than the 0.5 mR/h limit for "unrestricted areas".

(e) Water Pipe for Normal Pool Water Makeup. Figures 5-13 and 5-14 illustrate a ½-inch diameter water pipe, which passes from the Mechanical Equipment Room through the west shield wall to the southwest corner of the Exposure Room. The pipe passes horizontally through the shield wall at a distance of 2.5' beneath the floor and contains a right-angle bend on each side of the shield wall which allows vertical floor penetration in both rooms. Since this pipe is part of the automatic pool water makeup system, it is normally filled with water. Consequently, all gamma radiation entering the pipe during in-air irradiation procedures will be attenuated to some degree. The following estimate of the exposure rate to be expected in the Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a position 5.5 feet above the Exposure Room floor. Conservatively assuming that all gamma photons reaching the Mechanical Equipment Room through the pipe have scattered through an angle of 90° as a result of a single collision, their most probable energy will be approximately 0.4 MeV (Reference 6). Also assuming that the gamma photons travel a straight line distance equivalent to the total length of the water-filled pipe, allows a conservative estimate of the exposure rate at the Mechanical Equipment Room side of the pipe.

Io = exposure rate at the pipe location in the Exposure Room.

$$Io = \left(\frac{3.28'}{15.98'}\right)^2 (40{,}000\ Ci)(1.32\ R/h \text{ at 1 meter per Ci}) = 2.22 \times 10^3\ R/h$$

$I = Io\ b\ \exp(-uX)$ = exposure rate at pipe location in Mechanical Equipment Room.

Where: u = linear attenuation coefficient for 0.4 MeV photons in water = $0.106\ cm^{-1}$
X = total length of photon path in pipe = 304.8 cm
b = buildup factor for 0.4 MeV photons in water, with uX = 32.3 is $\approx 10^3$ (Reference 6).

$$I = (2.22 \times 10^6\ mR/h)(10^3)\ \exp^{-(0.106\ cm^{-1})(304.8\ cm)} = 2.1 \times 10^{-5}\ mR/h$$

NOTE: Assuming a gamma photon energy of 1.25 MeV and a straight line distance of 304.8 cm, the exposure rate at the pipe location in the Mechanical Equipment Room is 0.2 mR/h.

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(f) Emergency Air Pressure Release Line for Elevator Drive. Figures 5-14 and 5-20 illustrate the 3/8-inch diameter air line which passes through the shield wall between the Exposure Room and Mechanical Equipment Room. This line connects the emergency-air pressure release valve in the Exposure Room to the air supply for the pneumatically driven elevator drive piston located in the Mechanical Equipment Room. This pipe contains two right-angle bends, and is located 4 feet above floor level. The following estimate of expected exposure rate in the Control Room and Mechanical Equipment Room due to gamma radiation streaming through the pipe assumes that (1) the pipe is filled with air; (2) that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor; and (3) that the total mass attenuation coefficient for the pipe material is equal to that of concrete. The semiempirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

Do = exposure rate to wall at point of pipe penetration.

$$Do = \left(\frac{3.28}{8'}\right)^2 (40{,}000\ Ci)(1.32\ R/h\ \text{at 1 meter per}\ Ci) = 8.88 \times 10^3\ R/h$$

E = Energy in MeV after one Compton Scatter through $41^o$

$$E = \frac{1.25}{1 + (\frac{1.25}{0.511})(1 - \cos 41^o)} = 0.782\ MeV$$

$$K\theta_s = (0.2 \times 10^{-24}\ \frac{cm^2}{e})(\frac{0.782}{1.25}) = 12.5 \times 10^{-26}\ \frac{cm^2}{e}$$

$$\alpha d = \frac{(0.0547)(12.5 \times 10^{-26}\ \frac{cm^2}{e})(10^{26}) + (0.0111)}{1 + (\cos 49^o)(\sec 89^o)} = 0.018\ sr^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD.

$$dD = \frac{(8.88 \times 10^6\ mR/h)(0.018\ sr^{-1})(0.656)(1\ cm^2)}{(580.6\ cm^2)} = 180.6\ mR/h$$

The exposure rate at the Control Room surface of the shield wall resulting from a 181 mR/h source of 0.8 MeV photons located behind 2.5 feet of concrete = I.

$$I = Io\ b\ e^{-uX} = (181\ mR/h)(20)\ e^{-(0.1659\ cm^{-1})(76.2)} = 0.012\ mR/h$$

I = 0.012 mR/h, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume that the second leg of pipe is 5 feet long and is directed away from the first leg at an angle of $89^o$. The exposure rate at the end of the second leg of pipe, located at the beginning of the second right-angle bend, is:



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$$E = \frac{0.782 \text{ MeV}}{1 + (0.782/0.511)(1-\text{Cos } 89^{o})} = 0.312 \text{ MeV}$$

$$K(\theta_s) = (0.24 \times 10^{-24} \frac{cm^2}{e^-})(\frac{0.312}{0.782}) = 9.6 \times 10^{-26} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(9.6 \times 10^{-26})(10^{26}) + (0.0111)}{1 + (\text{Cos } 0^{o})(\text{sec } 89^{o})} = 0.01 \text{ sr}^{-1}$$

$$dD = \frac{(181 \text{ mR/h})(0.01 \text{ sr}^{-1})(1)(1 \text{ cm}^2)}{(2.32 \times 10^4 \text{ cm}^2)} = 7.8 \times 10^{-5} \text{ mR/h}$$

Since the exposure rate at the beginning of the second right angle bend is less than 0.5 mR/h, it will also be less than 0.5 mR/h at the point the pipe exits in the Mechanical Equipment Room.

Gamma photons reaching the straight section of pipe, which extends from midway in the shield wall to the exit point in the Mechanical Equipment Room, must pass through 2.54 feet of concrete and will be degraded in energy to at least 0.8 MeV. Assuming that the gamma photons arriving at the second right-angle bend are redirected to a path along the axis of the pipe, the exposure rate at the point where the pipe exits in the Mechanical Equipment Room is estimated as follows:

Io = Exposure rate at right-angle bend without shield.

$$Io = \left(\frac{3.28}{8.63'}\right)^2 (40{,}000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 7.63 \times 10^3 \text{ R/h}$$

The exposure rate at the second right-angle bend with 2.54 feet of concrete shielding = I.

$$I = Io\ b\ e^{-uX} = (7.63 \times 10^6 \text{ mR/h})(20)\ e^{-(0.1332 \text{ cm}^{-1})(77.4 \text{ cm})}$$

$$I = 5.08 \times 10^3 \text{ mR/h}$$

$$K(\theta_s) = (0.20 \times 10^{-24})(\frac{0.8}{1.25}) = 12.8 \times 10^{-26} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(12.8 \times 10^{-26} \frac{cm^2}{e})(10^{26}) + (0.0111)}{1 + (\text{Cos } 10^{o})(\text{sec } 89^{o})} = 0.0002 \text{ sr}^{-1}$$

$$dD = \frac{(5.08 \times 10^3 \text{ mR/h})(0.0002 \text{ sr}^{-1})(0.985)(1 \text{ cm}^2)}{(5.81 \times 10^3 \text{ cm}^2)} = 1.7 \times 10^{-4} \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for "unrestricted areas".

(g) Electrical Conduits. Figure 5-18 illustrates three electrical conduits which are 2 inches in diameter and pass through the west shield wall of the

Exposure Room at a height of 8 feet above the floor. The physical dimensions of all three conduits are identical and each contains 2 right-angle bends. Since "conduit B" is located closest to the cobalt-60 sources during in-air irradiations, it provides a more direct path for gamma radiation streaming than either of the other two conduits. Consequently, the following estimate of the exposure rate in "unrestricted areas" due to any of the three conduits is based on "conduit B". It is further assumed that the conduit is filled with air, that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the floor and that the total mass attenuation coefficient of the conduit material is equal to that of concrete. The semi-empirical formula for differential dose albedo presented in Reference 7 is used in the following calculations. The formulas and associated symbol definitions are found in paragraph 1d(2)(b) of this supplement.

Do = exposure rate to wall at point of conduit penetration.

$$Do = \left(\frac{3.28'}{7.4'}\right)^2 (40{,}000 \text{ Ci})(1.32 \text{ R/h at 1 meter per Ci}) = 1.04 \times 10^4 \text{ R/h}$$

E = energy in MeV after one Compton scatter through 36°

$$E = \frac{1.25}{1 + \left(\frac{1.25}{0.511}\right)(1 - \text{Cos } 36^\circ)} = 0.85 \text{ MeV}$$

$$K(\theta_s) = \left(0.2 \times 10^{-24} \frac{cm^2}{e^-}\right)\left(\frac{0.85}{1.25}\right) = 13.6 \times 10^{-26} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(13.6 \times 10^{-26} \frac{cm^2}{e})(10^{26}) + (0.0111)}{1 + (\text{Cos } 54^\circ)(\text{sec } 89^\circ)} = 0.022 \text{ sr}^{-1}$$

Dose rate at point of first right-angle bend (ie, 2.5 feet into the shield wall) = dD.

$$dD = \frac{(1.04 \times 10^7 \text{ mR/h})(0.022 \text{ sr}^{-1})(0.588)(20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 4.64 \times 10^3 \text{ mR/h}$$

The exposure rate at the Control Room surface of the shield wall resulting from a $4.64 \times 10^3$ mR/h source of 0.85 MeV photons located behind 2.5 feet of concrete = I.

$$I = Io\ b\ e^{-uX} = (4.64 \times 10^3 \text{ mR/h})(20)\ e^{-(0.1659 \text{ cm}^{-1})(76.2 \text{ cm})} = 0.3 \text{ mR/h}$$

I = 0.3 mR/h, which is less than the 0.5 mR/h limit for "unrestricted areas".

Assume the second leg of conduit is 2.5 feet long and is directed away from the first leg at an angle of 89°. The exposure rate at the end of the second leg of conduit, located at the beginning of the second right-angle bend, is:

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$$E = \frac{0.85 \text{ MeV}}{1 + (\frac{0.85}{0.511})(1 - \cos 89^{o})} = 0.32 \text{ MeV}$$

$$K(\theta_s) = (0.23 \times 10^{-24} \frac{cm^2}{e})(\frac{0.32}{0.85}) = 8.66 \times 10^{-26} \frac{cm^2}{e^-}$$

$$\alpha d = \frac{(0.0547)(8.66 \times 10^{-26} \frac{cm^2}{e^-})(10^{26}) + (0.0111)}{1 + (\cos 0^{o})(\sec 89^{o})} = 0.008 \text{ sr}^{-1}$$

$$dD = \frac{(4.64 \times 10^3 \text{ mR/h})(0.008 \text{ sr}^{-1})(1)(20 \text{ cm}^2)}{(580.6 \text{ cm}^2)} = 1.28 \text{ mR/h}$$

The exposure rate at the point the conduit enters the Control Room resulting from a 1.76 mR/h source of 0.3 MeV photons which pass from the location of the second right-angle bend to the Control Room via 2.5 feet of air-filled conduit is estimated below. For a straight cylindrical duct with radius R and length L, the line-of-sight exposure contribution at the end of the duct due to a point isotropic source at the entrance of the duct is proportional to $1/L^2$ (Reference 2, paragraph 8.1.2).

$$I = Io/L^2 = 1.76 \text{ mR/h} / (2.5)^2 = 0.28 \text{ mR/h}$$

which is less than the 0.5 mR/h exposure rate limit for unrestricted areas.

(4) References.


(a) Reference 1: Etherington, Nuclear Engineering Handbook, McGraw-Hill Book Company Inc., New York, (1958).

(b) Reference 2: Engineering Compendium on Radiation Shielding, Volume I, "Shielding Fundamentals and Methods", Springer-Verlag New York Inc., (1968).

(c) Reference 3: F. E. Bear, Chemistry of the Soil, 2nd Ed., (1964), 118.

(d) Reference 4: J. M. Chapman and C. M. Huddleston, "Dose Attenuation in Two-Legged Concrete Ducts for Various Gamma Ray Energies", Nuclear Science and Engineering, Volume 25, American Nuclear Society Inc., Hinsdale, IL, (1966), 66-74.

(e) Reference 5: Martin-Leimdörfer, "The Backscattering of Gamma Radiation from Plane Concrete Walls", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 345-351.

(f) Reference 6: Price, Horton and Spinney, Radiation Shielding, Pergamon Press, (1957).

(g) Reference 7: A. B. Chilton, "A Semiempirical Formula for Differential Dose Albedo for Gamma Rays on Concrete", Nuclear Science and Engineering, Volume 17, American Nuclear Society Inc., Hinsdale, IL, (1963), 419-424.

(h) Reference 8: A. B. Chilton, Principles of Radiation Shielding, Prentice-Hall, Englewood Cliffs, N. J., 1984

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(5) Occupancy of Shielded Areas: Immediately surrounding the Exposure Room are building and grounds areas which are shielded against the ionizing radiation emanating from the cobalt-60 sources during in-air irradiations. An estimate of the degree and type of occupancy for these areas during in-air irradiation procedures is given below. This estimate assumes normal operating conditions during a 40 hour work week. The calculated exposure rate values given in the table are "worst case" values which result from the assumption that 40,000 curies of cobalt-60 is raised by the source elevator to a height of 5.5 feet above the Exposure Room floor.

| AREA | TYPE OCCUPANCY | DEGREE OF OCCUPANCY | CALCULATED EXPOSURE RATE |
|---|---|---|---|
| Entrance Maze (Rm. 1) | None | 0% | >0.5 mR/h |
| Control Room (Rm. 4) | Radiation Worker | 100% | <0.5 mR/h |
| Mechanical Equip. Rm. (Rm. 9) | None | 0% | <16.0 mR/h |
| Restroom (Rm. 8) | Non-Radiation Worker | 25% | <0.5 mR/h |
| Plasma Lab (Rm. 18) | Non-Radiation Worker | 100% | <0.5 mR/h |
| Rad. Material Storage (Rm. 19) | Radiation Worker | 25% | <0.5 mR/h |
| Decon Area (Rms. 20, 21, 22) | Radiation Worker | 0% | <0.5 mR/h |
| Preparation Room (Rm. 10) | Non-Radiation Worker | 100% | <0.5 mR/h |
| Instrumentation Room (Rm. 5) | Non-Radiation Worker | 100% | <0.5 mR/h |
| Van de Graaf Room (Rm. 3) | Radiation Worker | 100% | <0.5 mR/h |
| Exposure Room Roof | None | 0% | <10.0 mR/h |
| Grounds Areas | Non-Radiation Worker | 25% | <0.5 mR/h |

e. Personnel Exclusion Barriers. (1) The sole entrance to the Cobalt-60 Exposure Room is provided by the double doors between the Control Room and the entrance maze which leads to the Cobalt-60 Exposure Room. These doors are interlocked to preclude the possibility that an individual could inadvertently enter the Exposure Room during in-air-irradiation procedures. Before the source elevator drive system is functional, the operator must (1) enter the Exposure Room, (2) actuate the in-cell reset switch with the same key that operates the elevator system, (3) exit from the Exposure Room, and (4) close the maze entrance doors within approximately 15 seconds from the time the in-cell reset switch is actuated. If this sequence of operator actions is accomplished in the prescribed time, the elevator controls become operational, and the maze doors automatically locked upon raising the sources. Should the operator fail to accomplish this sequence of procedures in the prescribed time, no power is available to the elevator drive system and the procedure must be repeated before elevator operation may commence. In order to ensure that no individual is prevented from leaving the Exposure Room, a manually operated "crash bar" is installed on the maze-side of the doors which provides a means of emergency exit at all times. If either of the maze entrance doors are opened after the operator completes the preoperational sequences described above the electrical power necessary to raise and sustain the elevator car in an uplifted position is lost until the preoperational sequence is performed again.

(2) The mechanical equipment room (Rm. 9) contains the only roof scuttle in the Building 504 Radiation Facility. Access to the roof via this scuttle

will be denied during in-air-irradiation procedures, which cause the exposure rate at the surface of the roof to exceed 0.5 mR/h, by locking the door to the mechanical equipment room. During these periods, access to the mechanical equipment room will be controlled by the Cobalt-60 Facility Supervisor, Chief Operator, or Alternate Operator.

f. Contamination Control. (1) Although each of the cobalt-60 source elements is doubly encapsulated, as described in Supplement No. 1 of this application, the Exposure Room, Entrance Maze, and Control Room are designed to ensure containment/entrapment of soluble and insoluble particulates. All three areas are equipped with seamless, acid-resistant floors, and epoxy-coated walls and ceilings. The floor drain in the Exposure Room and sink drain in the Control Room vent to a 4000 gallon acid-resistant holding tank. Due to the remote possibility that the liquid effluents might contain trace amounts of radioactive material, no fluid from the holding tank will be discharged to the sanitary sewage system unless an analysis has been performed to assure that it does not exceed the maximum permissible concentration (MPC) guides set forth in Title 10, Code of Federal Regulations, Part 20. The plumbing plan and holding tank for liquid effluents are illustrated on Figures 5-13 and 5-14 respectively.

(2) Heating and cooling of the Exposure Room is accomplished via a "closed-loop" air conditioning system which isolates the supply and exhaust air for this area from the rest of the Building 504 Radiation Facility. As illustrated on Figures 5-11 and 5-12, the exhaust plenum in the Exposure Room is equipped with high-efficiency-particulate-air (HEPA) filters through which all effluent room air must pass. The air handling system continuously delivers air to the Exposure Room at a rate of 2885 cubic feet per minute (CFM) and exhausts it at a rate of 3000 CFM. Consequently, a negative pressure is maintained in the Exposure Room which assures filtration of all room air. After passing through the exhaust filters in the Exposure Room, 290 CFM is discharged to the outside environment and 2710 CFM is recirculated to the air handling unit (AH-1). Finally, fresh air is added to the recirculated air at a rate of 175 CFM in order to sustain the 2885 CFM delivery of conditioned air to the Exposure Room.

g. Ozone Production, Detection, and Control. (1) During in-air irradiation procedures ozone will be produced in the Exposure Room as a result of air ionization processes. The following analysis of radiation-induced ozone formation in the Exposure Room assumes that 40,000 curies of cobalt-60 is raised via the source elevator to a height of 5.5 feet above the floor. It is further assumed that each gamma photon emanating from the cobalt-60 source travels the entire length of the Exposure Room. The investigation of G. R. A. Johnson and J. M. Warman presented in "Formation of Ozone from Oxygen by the Action of Ionizing Radiations", Discussions of the Faraday Society, Volume 37, (1964), 87-95, indicates that the yield of $O_3$ from $O_2$ may be as high as $G(O_3)$ = 13 molecules of $O_3$ per 100 eV. Although this value of $G(O_3)$ may be somewhat high, due to the presence of other rare gasses in breathing air, it will be used to ensure that the following analysis yields conservative results.

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Exposure room volume: $2.04 \times 10^8$ cm$^3$
Air path for each photon: $r = 1.31 \times 10^3$ cm
Linear energy absorption coefficient for air $= u_a = 0.32 \times 10^{-4}$ cm$^{-1}$

$u_a r = (1.31 \times 10^3 \text{ cm})(0.32 \times 10^{-4} \text{ cm}^{-1}) = 0.04192$

Since 21% of air is $O_2$, multiply $u_a r$ by 0.21

$u_a r = (0.04192)(0.21) = 8.8 \times 10^{-3}$

$\therefore$ the energy absorbed by $O_2$ in 1310 cm of air $= 1 - e^{-u_a r}$
$= 1 - e^{-0.0088}$
$= 0.009$

Since cobalt-60 emits an average of 2.5 MeV/dis. the energy absorbed by room air per second = $(4 \times 10^4 \text{ ci})(3.7 \times 10^{10} \text{ dis/sec-ci})(2.5 \text{ MeV/dis})(0.009) =$ $3.33 \times 10^{13}$ MeV/sec.

$(3.33 \times 10^{19} \text{ eV/sec})(13 \text{ molecules}/100 \text{ eV}) = 4.33 \times 10^{18}$ molecules $O_3$/sec

$$\left(\frac{4.33 \times 10^{18} \text{ molecules } O_3/\text{sec}}{6.02 \times 10^{23} \text{ molecules/gm mole}}\right)\left(\frac{48 \text{ gm}O_3}{\text{gm mole}}\right) = 3.45 \times 10^{-4} \text{ gm}O_3/\text{sec}$$

$\therefore 3.45 \times 10^{-4}$ gm$O_3$/sec is produced in the Exposure Room.

$$\frac{3.45 \times 10^{-4} \text{ gm}O_3/\text{sec}}{2.04 \times 10^8 \text{ cm}^3 \text{ air}} = 1.69 \times 10^{-12} \text{ gm}O_3/\text{sec cm}^3 \text{ air}$$

$$\& \ \frac{1.69 \times 10^{-12} \text{ gm}O_3/\text{sec cm}^3 \text{ air}}{1.293 \times 10^{-3} \text{ gm air/cm}^3 \text{ air}} = 1.31 \times 10^{-9} \text{ gm}O_3/\text{sec-gm air}$$

& $(1.31 \times 10^{-9} \text{ gm}O_3/\text{sec-gm air})(3.6 \times 10^3 \text{ sec/hr}) = 4.72 \times 10^{-6}$ gm$O_3$/hr-gm air

= 4.72 PPM $O_3$ produced in the Exposure Room air in a period of one hour as a result of the photons emanating from a 40,000 curie cobalt-60 source.

(2) Since the approximate half-life of ozone at 20°C is 3 days, and also since 90% of the air removed from the Exposure Room is returned during the normal operating mode of the "closed-loop" ventilation system, the Cobalt-60 Gamma Radiation Facility is equipped with ozone detection and control equipment. In order to continuously measure the ozone concentration in the Exposure Room during in-air-irradiation procedures, a Bendix Ozone Detector, Model 8002, is installed in the Control Room. A sampling tube, extending from the unit to a location adjacent to the source elevator, provides the unit with a representative sample of Exposure Room air. The detector analyzes the air sample by the chemiluminescence principle, and displays results which lie within a 0.01 to 1.0 PPM $O_3$ range. As illustrated on Figure 5-23, the Cobalt-60 Facility control-console houses a meter which reproduces the reading displayed at the detector unit. In addition, the VISI-CON Annunciator Monitor, located adjacent to the control console, produces an

audio-visual signal if the ozone monitor is not operating or if high ozone concentrations are present in the Exposure Room.

(3) The normal operating mode of the "closed-loop" ventilation system keeps the Exposure Room at negative pressure with respect to the rest of the building. Consequently, unless exhausted to the roof of Building 504, any ozone produced by in-air irradiation procedures will remain in the Exposure Room and in the ducts of the "closed-loop" ventilation system. When it is desirable to reduce the ozone concentration in the Exposure Room, the control-console operator manually actuates a "purge cycle" control switch. During a purge cycle, the air handling system continuously delivers fresh air to the Exposure Room at a rate of 3000 CFM and exhausts air from the Exposure Room to the roof of Building 504 at the same rate. No room air is recirculated during a purge cycle. Thus, the control console operator is always able to reduce the ozone concentration in the Exposure Room to the 0.1 PPM threshold limit value recommended by the Occupational Health and Safety Administration (OSHA).

h. Fire Protection. As pointed out in paragraph 1a of this supplement, the Cobalt-60 Gamma Radiation Facility is located within a building which is classed as a "noncombustible construction" type structure. All areas within Building 504 are equipped with fire detection/alarm units which provide local warning to building occupants and also transmit the alarm signal to a panel which is monitored in the HDL Central Guard Office. The Cobalt-60 Facility is equipped with combination fixed temperature/rate of rise Thermal Fire Detectors in order to ensure reliability both during and after exposures to high levels of ionizing radiation. Emergency response to fire alarms is provided by HDL fire protection personnel, four nearby county fire departments and the Naval Surface Weapons Center Fire Department which is located adjacent to HDL.

i. Seismic Analysis. (1) The Building 504 Radiation Facility was designed in accordance with the criteria, guidance, and standards furnished in US Army Technical Manual 5-809-10, "Seismic Design for Buildings", published March 1966. This manual assigns each geographical location in the United States to one of five "seismic zones" which are designated by the numbers 0 through 4. Assignment of a high seismic zone number to a region, indicates that a high probability of severe, frequent and damaging earthquakes exists in that region. The fact that the entire State of Maryland is designated as being in Seismic Probability Zone 1 indicates only minor damage is to be expected from any earthquake which might occur in this region. Although the evidence is not conclusive, and any prediction is uncertain at best, Freeman states (Freeman, John R., 1932, Earthquake Damage and Earthquake Insurance, New York: McGraw-Hill Book Co.) that only one destructive earthquake may be expected per century in the Atlantic region, comprising 600,000 square miles and extending from Quebec to Florida. The likelihood that the epicenter of a destructive earthquake would be in or near the Washington, DC area seems remote.

(2) Since the Cobalt-60 Gamma Radiation Facility is located in a building which was designed in accordance with US Army seismic design criteria for this geographical region, it seems highly unlikely that the shielding, pool, or

complementary structures would be subject to rupture, shifting, or tilting as a result of any probable seismic phenomena.

2. Irradiator System and Operational Characteristics.

a. Pool and Associated Equipment. (1) The cobalt-60 source elements will be stored in the exposure room at the bottom of the 12 feet deep, water filled pool illustrated in Figures 5-5, 5-7, and 5-18. The concrete used to construct the one foot thick walls and floor of the pool were poured monolithically in one continuous pour and thoroughly vibrated by mechanical vibrators. The entire internal surface area of the pool is lined with a 3/16 inch thick, A-304 stainless steel liner in order to ensure water-tight integrity. Immediately surrounding the edge of the pool is a concrete toeboard which is 4 inches in height. Removable pipe railings, which meet the specifications presented in 29 CFR Part 1910-23, Occupational Safety and Health Act, are inserted into the toeboard on all sides of the pool in order to provide a personnel protective barrier for the floor opening. In addition to the toeboard and railing, the surface area of the pool is protected by a "metal grating" type floor-hole cover which is designed to support a live load of 200 pounds per square foot. As illustrated in Figure 5-6, the floor hole cover consists of 10 sections of removable grating and two removable supports which accommodate the rails for a movable cart. By removing a section of grating, an individual may work safely over the pool while supported by the remaining sections of the floor hole cover. Two underwater lighting fixtures, similar to those illustrated on Figure 5-15, are attached to removable sections of grating and suspended beneath the surface of the pool water in order to provide sufficient light for source element manipulation and accurate positioning of experiment containers. Both fixtures meet the specification and installation requirement set forth in the National Electrical Code (NFPA No. 70-1975) for "underwater lighting fixtures".

(2) The pool water circulation/treatment system consists of a 50 gallon per minute circulating pump, a replaceable sediment filter, and two mixed-bed resin demineralizers. As illustrated on Figures 5-17, 5-18, and 5-21, pool water is continuously extracted at a point two feet below the pool curb and is filtered and deionized before being returned to the bottom of the pool. Since the circulation system inlet is located one foot below the water, it is impossible to remove more than one foot of water shielding should one of the system water lines accidentally burst. This system will recirculate the entire volume of pool water approximately 28 times a day and maintain pool water conductivity at less than 10 micromhos per centimeter without difficulty. A pool water conductivity monitor, installed at the inlet of the circulation pump, continuously analyzes the pool water and transmits an alarm to the Control Room annunciator panel if the ion concentration in the pool water is detrimental to source encapsulation life expectancy. Two in-line pressure gauges, one on each side of the sediment filter, provides a visual indication of water circulation system performance.

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(3) Pool water is maintained at a depth of 11 feet by an automatic water level sensing/replacement system. As illustrated in Figures 5-17, 5-18, and 5-23, the pool water level indicator, located in the Control Room, indicates the water level in the pool by responding to a change in the water pressure applied to an evacuated tube. Four adjustable, pressure-actuated switches are attached to the water level indicator for the purpose of providing electrical contact openings for alarm and water level control equipment circuits. Switch #1 initiates a "high level" alarm on the control room annunciator panel when the pool water level exceeds 139 inches. Switch #2 interrupts power to the pool water circulation pump when the pool water level falls below 134 inches. Switch #3 energizes the solenoid valves illustrated on Figure 5-21 to maintain the pool water level between 134 and 137 inches. Switch #4 initiates a "low level" alarm on the control room annunciator panel if the pool water level drops to 133 inches. The solenoid valves actuated by switch #3 may also be operated manually from the control console. Although water will normally be added to the pool via the above mentioned solenoid valves, one may always add water manually by utilizing the emergency-fill water system illustrated on Figures 5-14, 5-18, and 5-21. The manually operated gate valve for this system is located in the Mechanical Equipment Room in order to assure that water may always be added to the pool without entering the Exposure Room.

(4) If an unexpected event causes overflowing of the pool, the excess water will be contained by the seamless, acid-resistant floor of the Exposure Room and vented to a 4000 gallon acid-resistant holding tank via the Exposure Room floor drain. As explained in paragraph 1f(1) of this supplement, no fluid is discharged from this holding tank to the sanitary sewage system unless an analysis confirms that radioactive material concentrations are below the maximum permissible concentration guides set forth in Title 10, Code of Federal Regulations, Part 20.

b. Cobalt-60 Source Elevator and Associated Equipment. (1) The Cobalt-60 Source Elevator system is designed for two principle modes of operation. The Console Operational Mode (COM) permits one to operate the system from the Control Room during free-air-irradiation procedures. The In-cell Operational Mode (ICOM) permits operation of the system using controls located adjacent to the pool. Use of the ICOM is restricted to operations involving maintenance of the elevator system, attachment of source holding fixtures to the elevator car platform, and lowering experimental products to the bottom of the pool, where the source material is stored.

(2) Mechanical design of the elevator system incorporates both safety and utilitarian considerations. As illustrated on Figure 5-18, the elevator assembly used to raise cobalt-60 source elements for free air irradiation, or to lower product to the source elements for in pool irradiation, is permanently positioned against the wall of the exposure room pool and contains a multiplicity of 1½ inch diameter holes in order to ensure that the water level in the shaft equals that of the pool. The cable-driven elevator car,

illustrated on Figures 5-18 and 5-19, is mechanically restricted to vertical movement along an elevator shaft which extends from the bottom of the pool to a distance of 7 feet above the exposure room floor. A platform, containing tapped holes to permit rigid attachment of a variety of source holding fixtures, is bolted to the base of the elevator car. The design of each source holding fixture will be reviewed by the HDL Radiation Control Committee prior to fabrication or use in order to assure that the fixture will restrain source element movement under all conceivable conditions. Structural design of the elevator limits the maximum distance the platform may rise above the exposure room floor to 5 feet 8 inches. The speed and distance traveled by the cable-driven elevator car is controlled by adjusting the speed and distance traveled by an aircraft cable attached to a pneumatic piston and counter weight assembly located in the mechanical equipment room and control room respectively. As illustrated on Figures 5-18 and 5-20, an Air Control Box located in the mechanical equipment room contains (1) an air supply valve for the elevator drive cylinder; (2) an air pressure regulator assembly for limiting, regulating and conditioning the air supply for the elevator drive; (3) a descent control valve for limiting elevator car descent speed; (4) an ascent control valve for limiting elevator car ascent speed; and (5) a four way solenoid valve used to change the routing of the air supply on command of the control console causing either ascent or descent of the elevator car. A 150 PSI reserve surge tank is incorporated into the air supply system for the purpose of supplying sufficient reserve air capacity to return the elevator car to the pool bottom in the event the power and/or primary air supply system fails. An additional positive down-drive for the elevator car is provided by the aforementioned 50 pound counter weight assembly located in the control room. Although it is not well illustrated by Figures 5-18, 5-19, and 5-20, the counter weight assembly is designed to continuously exert a downward force on the elevator car by routing the counter weight support cable to the base of the elevator car via a sheave assembly welded to the bottom of the pool. Consequently, the elevator drive system must exert sufficient pneumatic force to raise both the elevator car and the counter weight when sources are raised from the pool bottom. If the pneumatic elevator drive system loses the air pressure necessary to maintain the elevator car and counter weight in an elevated position, the counter weight assembly will pull the elevator car back to the bottom of the pool. Should mechanical binding between the elevator car and shaft occur, the counter weight/elevator drive assembly cables are accessible from a location external to the Exposure Room and provide an effective means of freeing the elevator car.

(3) A functional description of the operational characteristics associated with the elevator control system is provided in Annex 5-A to this supplement. Additionally, the following figures illustrate electrical circuitry and equipment incorporated into the elevator control system design: Figure 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS); Figure 5-30 (IRRADIATOR CONSOLE LAYOUT); Figure 5-31 (CONTROL CONSOLE WIRING); and Figures 5-32 and 5-33 (IRRADIATOR WIRING DIAGRAM).

c. Radiation Safety Interlock System. Operation of the elevator control system is limited by a radiation safety interlock system designed and installed for the purpose of assuring that no individual will be exposed to an area where it is possible to receive a dose in excess of 100 mrem in one hour as a result of free-air-irradiation procedures initiated at the Cobalt-60 Facility. The following information catalogs the radiation safety control functions provided by the interlock system.

(1) The sole entrance door to the Exposure Room is automatically locked immediately prior to, and during, free-air-irradiation procedures in order to prevent an individual from entering when it is possible to receive a dose in excess of 100 mrem in one hour. This Exposure Room access control device permits deliberate entry to the Exposure Room only when radiation levels therein are less than 20 mR/h.

(2) The Visi-Con Annunciator Monitor, located in the Control Room, automatically provides both audible and visual signals to the operator of the elevator system if the Exposure Room access control device (electric lock) fails to function properly. Nonilluminated legends on the Visi-Con Annunciator Monitor indicate that the access control device is functioning properly.

(3) Crash bars are installed on the maze side of the entrance door to the Exposure Room in order to assure that no individual will be prevented from leaving the Exposure Room.

(4) Should the Exposure Room access control device (electric lock) fail immediately prior to free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically terminates the electrical power necessary to raise the source elevator car. If this access device fails during free-air-irradiation procedures, the action of opening the Exposure Room entrance door automatically returns the source elevator car to the bottom of the pool. In either case, the radiation level within the Exposure Room is reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour.

(5) Any person attempting to enter the Exposure Room during free-air-irradiation procedures is automatically warned that a radiation hazard exists therein by a large purple beacon located at the entrance to the maze which flashes continuously when the source elevator car is not located at the bottom of the pool. The console operator is automatically notified by the Visi-Con Annunciator Monitor if the light has burned out. In addition, the action of defeating the control access device (electric lock) for the Exposure Room entrance door automatically actuates two visible and audible alarms located on the Visi-Con Annunciator Monitor that serve to warn both the console operator and the individual attempting to enter the Exposure Room that a hazardous condition exists.

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(6) Failure or removal of the Exposure Room access door automatically terminates the electrical power necessary to raise the source elevator car and automatically returns the elevator car to the bottom of the pool if it is in an elevated position. Since this action places the pool water shielding over the source elements, the radiation level in the Exposure Room is automatically reduced below that at which an individual could receive a dose in excess of 100 mrem in one hour. Visual and audible alarm signals are automatically actuated on the Visi-Con Annunciator Monitor which warn the console operator and all potentially affected individuals that the physical barrier to the Exposure Room has failed or has been removed prior to and during free-air-irradiation procedures.

(7) A fifteen second delay exists between the time the console operator actuates the elevator drive key switch and the time the elevator starts its ascent. During this fifteen second period, a horn located in the Exposure Room automatically sounds and rotating purple beacons located in the Exposure Room and Exposure Room Entrance Maze automatically flash to alert personnel located in the Exposure Room/Maze areas that free-air-irradiation procedures are in progress. This warning period allows sufficient time for an individual located in the Exposure Room to actuate any one of four control devices which prevent raising of the elevator car. Located adjacent to the Exposure Room Pool and in the Entrance Maze are switches with large red mushroom caps bearing the words "EMERGENCY SHUTDOWN". Depressing either of these switches will cause immediate shutdown of the elevator energizing system until they are manually reset by the console operator. Also located adjacent to the Exposure Room Pool is a safety air valve with a large red mushroom cap, which will vent the air supply necessary to raise the source elevator car when the valve cap is depressed. Should the individual elect to leave the Exposure Room/Maze area without first actuating one of the aforementioned elevator control devices, the action of opening the Exposure Room access door will deenergize the elevator system until the console operator enters the Exposure Room and resets the radiation safety interlock system.

(8) In order to assure that the Exposure Room and Maze are cleared of personnel prior to each free-air-irradiation procedure using the COM, the elevator control system is interlocked with an "Operate Key Switch" located adjacent to the Exposure Room Pool. Prior to each raising of the elevator car, the console operator is required to enter the Exposure Room, actuate the "Operate Key Switch" with the same key that actuates the elevator drive system switch on the console, exit from the Exposure Room, and close the access doors in a time period of 15 seconds. This operation is intended to enforce a final visual inspection of the Exposure Room/Maze areas immediately prior to each in-air-irradiation procedure. Should the console operator fail to accomplish this task in the prescribed period of time, no electrical power is available to the elevator drive system. Additionally, opening the Exposure Room access door after accomplishment of this preoperational sequence terminates electrical power for the elevator drive system until the console operator reenters the Exposure Room and repeats the procedure. If the preoperational

sequence is not successfully completed or if the Exposure Room access door is opened after successful completion, audible and visual alarms are automatically actuated on the Visi-Con Annunciator Monitor in the Control Room to notify the console operator that the safety interlock system has been violated. If the Exposure Room access doors remain closed after the pre-operational sequence, the action of operating the console key switch for the elevator drive system automatically locks the Exposure Room access doors.

(9) Three Remote Area Monitors (RAM's) for ionizing radiation detection are incorporated into the radiation safety interlock system. RAM #1 is located in the Control Room and has a four decade logarithmic meter scale from 0.1 mR/h to 1.0 R/h. RAM #2 and #3 are located in the Exposure Room and have five decade logarithmic scales from 10 mR/h to 100 R/h. All three RAM's are Nuclear Measurements Corporation Model GA-2TO plastic scintillation type ionizing radiation detectors and are installed to provide remote readouts in the Control Room. In addition to providing continuous physical radiation measurements of the Exposure Room, RAM #2 and #3 function to keep the Exposure Room access door locked when the radiation level in the Exposure Room exceeds 20 mR/h during COM free-air-irradiation procedures. RAM #2 and #3 also function to automatically cause the elevator car to return to the bottom of the pool if the radiation level in the Exposure Room exceeds 20 mR/h during activities involving the ICOM. RAM #2 and #3 automatically ensure that physical radiation measurements of the Exposure Room are accomplished prior to entry of the first individual following free-air-irradiation procedures. In addition to consulting the RAM readouts in the Control Room, the first individual to enter the Exposure Room following free-air-irradiation procedures is required to carry a portable ionizing radiation detection survey instrument and assure that the radiation level in the Exposure Room is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(10) The above enumerated and other features of the radiation safety interlock system are throughly described in Annex 5-A to this supplement. Figures 5-18 (GENERAL ARRANGEMENT, COBALT-60 FACILITY), 5-23 (ANNUNCIATOR, RAM, CONTROL CONSOLE, and SCHEMATICS), 5-24 (CONDUCTIVITY, OZONE MONITORS), and 5-25 through 5-29 (INTERLOCK SCHEMATICS) illustrate electrical circuitry and equipment incorporated into the radiation safety interlock system design.

d. Equipment for Manual, In-Pool Irradiation Procedures. Although the Cobalt-60 Facility is designed primarily for free-air-irradiations, occasionally it is desirable to place the experimental product inside a watertight experiment container and lower it to a position adjacent to the sources located at the bottom of the water-filled Exposure Room pool. The equipment necessary to safely perform this task is described in the following paragraphs.

(1) Source Holders. Permanently located at the bottom of the Cobalt-60 Exposure Room Pool are two source holding fixtures mounted on 16 gauge stainless steel stands. These fixtures are designed to hold/position the source

elements in a vertical, bolt-circle configuration when they are not being used for free-air-irradiations. As illustrated on Figure 5-17 to this supplement, holes have been drilled in the base plate of each source holder to accommodate source elements in 5, 8, and 12-inch diameter bolt-circle arrangements. A fixed upper plate contains holes to accommodate the upper end of the source elements located on the 12-inch diameter bolt-circle. This fixed upper plate has a step on its inner diameter which will accommodate a stainless steel ring containing holes used to position the source elements on an 8-inch diameter bolt-circle. This ring in turn is stepped to receive a smaller stainless steel ring containing holes used to position the source elements on a 5-inch diameter bolt-circle. In use, the innermost ring must be of the diameter appropriate for the bolt-circle arrangement used.

(2) Source Protectors. Since manual, in-pool irradiation procedures require lowering experimental materials to the bottom of the water-filled pool and positioning them in the center of, or adjacent to, the source holders, a 16 gauge stainless steel protective cover is installed over each source holder. The cover is intended to protect the cobalt-60 source elements from physical damage which could result from the positioning of experimental materials or the accidental dropping of a heavy object into the pool. Figure 5-17 to this supplement displays the protective source holder cover in the functional position.

(3) Experiment Containers. During manual in-pool irradiation procedures, it is generally desirable to protect the materials to be irradiated from the pool water. Consequently, the materials will usually be placed in water-tight metal containers. Typically, the containers are designed with a 4-inch outside diameter in order to assure that they may be positioned in the center of the source holding fixture when maximum exposure rates are desired. The containers may also be positioned at varying distances from the source holding fixtures depending on the exposure rate requirements of the experiment. Although the length and diameter of the experiment container may vary, the typical design incorporates a water-tight lid with an attachment for connecting a 15 foot handle. After the materials to be irradiated have been placed in the experiment container, the lid is secured in place and the handle is attached to the lid. Using the handle, the experiment container is lowered into the Cobalt Facility Pool and placed at a position near the cobalt-60 source elements. Duplication of source to container position may be accomplished by inserting a nipple on the container base into the holes provided in the source holder stand. All pipes serving as handles for the experiment containers are fabricated with "S" bends near the base to preclude the possibility of radiation streaming through the pipe.

(4) Radiation Warning System. As explained in Annex 5-A to this supplement, the Control and Exposure Rooms are equipped with three ionizing radiation remote area monitors (RAM's) designed, installed and operated to provide continuous monitoring of radiation levels in the facility on a 24 hour basis.

Supplement No. 5 continued.

RAM #1 detects and indicates the radiation level in the Control Room and is adjusted to provide an audio-visual alarm if the high level alarm setting of 2.5 mR/h is exceeded. RAM's #2 and #3 detect the radiation level in the Exposure Room and are adjusted to provide audio-visual alarms in the Control Room if the high level alarm setting of 20 mR/h is exceeded. All three RAM's are Nuclear Measurement Corporation Model GA-2T transistorized gamma alarms, utilizing gamma sensitive plastic phosphors in a detector probe that is connected by electrical cables to "NEMA boxes" that house an indicating meter, relays to provide high current alarm context, alarm lights, bells, and voltage supplies. The meter readings and audio-visual alarms displayed by the "NEMA Boxes" mounted on the east wall of the Control Room are also relayed to the Visi-Con Annunciator Monitor located in the Control Room. Since the alarms may be heard in the Control Room, Maze, and Exposure Room, an individual desiring to perform manual, in-pool irradiations is automatically alerted if hazardous ionizing radiation conditions exist in the Exposure Room prior to, during, and after experimental procedures are conducted at the Cobalt-60 Facility.

3. Collateral Equipment. a. Remote Handling Tool. A remote handling tool is available for the purpose of manipulating source pencils at the bottom of the 12 foot deep pool during elevator loading/unloading and during source leak testing. This tool is 15 feet long and fabricated with a pistol grip handle, dual rubber-lined grip jaw, and a mechanism that allows adjustment of the grip jaw from the pistol grip handle. This tool is conspicuously marked at a distance of 7 feet 8 inches from the uppermost section of the source-gripping jaw and displays a warning sign that instructs users not to raise the tool above the mark when it holds one of the source elements. At a distance 2 feet above the pool surface, the exposure rate from a 5500 curie source element will be less than 1.40 mR/h when the handling tool is raised to the tool warning mark. This tool contains a multiplicity of ¼ inch holes to allow a flow of water into the tool as it is inserted in the pool. Since operation of this tool is restricted to the Facility Supervisor, Chief Operator, Alternate Operator, and the HDL Radiation Protection Officer, it will be secured from unauthorized use.

b. Source Leak-Test/Isolation Containers. Figure 5-17 to this supplement illustrates the source Leak-Test/Isolation Containers. The two metal containers are designed so that they can be loaded, sealed, sampled, pumped dry, and flushed with clean water while at a depth of 9½ feet below the surface of the water. Each container is capable of holding six source elements. Both containers are mounted on a metal frame which allows both units to be lowered into and extracted from the pool. Both containers are remotely sealed by use of a handling tool which is designed to manipulate a rubber-coated, adjustable diameter, "Turn-Tite Plug". This handling tool also fills with water as it is inserted into the pool. These containers will be used to perform the required 6 month leak test of the source elements (as described in Supplement 6 of this application) and also to isolate any leaking source elements until disposition instructions are obtained.

Supplement No. 5 continued.

c. Monorail and Hoist. Figures 5-5 and 5-7 illustrate the location of the monorail used to support an 8-ton capacity trolley and motorized bridge hoist. This overhead monorail hoist will be used to manipulate the shielded containers necessary to accomplish transfer operations involving cobalt-60 source elements. The marking, construction, and installation of the monorail hoist is in accordance with American National Standard ANSI B30.16-1973. Inspection, testing, maintenance and operation of the monorail hoist will comply with the provisions of 29CFR1910.179 of the Occupational Safety and Health Act in order to assure safe, reliable operation.

d. Exposure Room Floor Track. Figure 5-5 illustrates two floor tracks extending from the north wall of the Exposure Room to the southern edge of the pool. Figure 5-6 illustrates, and provides specification for, the track supports that span the pool. All floor track installed in the Exposure Room is American Society of Civil Engineers (ASCE), 60 pounds light rail, 4¼ inches by 4¼ inches. The floor track is installed to provide stationary rails for a light-weight cart used to position experimental materials at varying distances from the cobalt-60 source elements during free-air-irradiation procedures. Although the floor tracks currently exist, a cart has not been fabricated to utilize them. Should the necessity for a cart arise in the future, the design will be reviewed by the HDL Radiation Control Committee prior to fabrication in order to assure that its design and intended use complement all safety considerations.

e. Emergency Lighting. Emergency light equipment, approved by Underwriter's Laboratory Standards for safety, provides emergency light to the Exposure Room/Maze areas automatically and instantaneously upon failure or interruption of normal electric power. The emergency power source for this unit is a maintenance-free, 6 volt, lead-acid rechargeable battery with up to 100 lamp watts output at 6 volts DC. One side of the unit has an observation post for visual inspection of battery liquid level. Additionally, the unit is equipped with a ready/off switch; a front-mounted "Press-to-Test" switch for quick testing of lamps and battery; an amber light which glows when the unit is in the ready state; a red light to indicate that the unit is on the high rate of charge; and a front mounted voltmeter to indicate battery condition.

f. Warning Signs. (1) In accordance with Section 20.203, 10 CFR Part 20, the entrance to the Cobalt-60 Exposure Room will be conspicuously posted with one sign bearing the radiation caution symbol and the words "Caution - High Radiation Area".

(2) The entrance to the Cobalt-60 Exposure Room will also be conspicuously posted with a sign bearing the radiation caution symbol, the words "Caution - Radioactive Material", isotope identification information, isotope quantity information, the date measurement of the isotope quantity was performed, and the manufacturer's trademark.

## COBALT-60 IRRADIATOR SYSTEM FOR HARRY DIAMOND LABORATORIES

TABLE OF CONTENTS




NEUTRON PRODUCTS inc

*Dickerson, Maryland 20753 U. S. A.*

*301/349-5001 TWX: 710-828-0542*


ANNEX 5-A

## I. Introduction

The cobalt-60 irradiator system designed, constructed, and installed by Neutron Products, Inc. for the Harry Diamond Laboratories consists of the following principal components:

1. Elevator and elevator drive assembly.
2. Console and in-cell elevator controls.
3. Radiation safety interlock system.
4. Status and alarm annunciator.
5. Water quality system.
6. Ozone detector.

This system is designed to be operated in two principal modes. The first is the Console Operational Mode (COM) where the operation is controlled from the console located in the control room. The source material is located on the elevator and the product to be irradiated located in the cell adjacent to the pool. The second mode of operation is the In-cell Operational Mode (ICOM) where the product to be irradiated is placed on the elevator and lowered into the pool where the source material is stored.

## II. Safety Considerations.

Cobalt-60 emits ionization radiation in the form of highly penetrating gamma photons which are capable of causing injury and death. In a cobalt-60 irradiator, therefore, there is significant potential for personal injury from the radiation and from the by-products of the interaction of this radiation with air or other materials. Supplementing administrative controls necessary to achieve the safe operation, is a radiation safety interlock system which primarily functions to subject the source/sample elevator operation to controls imposed by various mechanical and electrical safety devices. The elevator control system is interlocked with the hazard detection system and status-alarm annunciator to provide for the safety of operating personnel. The system should never be operated by persons not thoroughly familiar with basic radiation safety concepts and the functioning of all of the system's pertinent components. Under no circumstances should efforts be made to defeat any components of the radiation safety interlock system.

III. Description of the Radiation Safety Interlock System

The radiation safety interlock system functions as follows:

A. The source/sample elevator cannot be raised from the bottom of the pool in the console operational mode (COM) if any one of the following conditions exist:

1. Console power is not on;
2. The irradiator room TV monitor is not on;
3. Low pressure exists in the compressed air supply;
4. The safety air valve in the irradiator room has been pushed;
5. Any one of the three emergency stop bottoms has been pushed;
6. Any one of the three irradiation monitors is not electrically energized and operational;
7. The operator has not entered the irradiator and turned the in-cell reset switch and exited from the irradiator closing the maze entrance doors in the prescribed time period of approximately 15 seconds. This operation is intended to enforce a final visual inspection of the irradiator cell; and,

8. The maze doors are opened after the prescribed time has passed following the operation of the in-cell reset switch.

B. The source/sample elevator cannot be raised from the bottom of the pool in the in-cell operational mode (ICOM) if any one of the following conditions exist:

1. The console power is not on;
2. The irradiator room TV monitor is not on;
3. Low pressure exists in the compressed air supply;
4. The safety air valve in the irradiator room has been pushed.
5. Any one of the three irradiation monitors is not electrically energized and operational;
6. Any one of the three emergency stop buttons has been pushed;
7. The operator has not turned the in-cell reset key switch; and,
8. The operator does not hold the in-cell elevator control key switch in its "On" position.

C. Once in its up position, the source/sample elevator will immediately return to the pool bottom if any one of the following conditions occurs:

1. One of the three emergency switches is pushed;
2. A hazardous radiation level is present in the control room;
3. A maze door is opened (except during the ICOM);
4. The air supply pressure drops; and,
5. The TV monitor is turned off.

C'. Since the system also allows for using the elevator to lower product to a source array located on the pool bottom in the in-cell operational mode (ICOM), protection for the operator controlling the elevator from within the irradiator is provided by the two in-cell Radiation Area Monitors which will immediately return the elevator to the pool bottom in the event that the high radiation level in the irradiator is detected within the cell during or after elevator ascent in ICOM.

D. Additional safety features are as follows:

1. The doors are locked when the prescribed time of approximately 15 seconds has elapsed following the operation of the in-cell reset switch and the operating key switch is turned on during the Console Operational Mode (COM). The door remains locked until the switch is turned off and no high radiation level exists in the cell.
2. A visual and audible alarm sounds at the annunciator whenever the maze door is opened once the in-cell reset switch has been operated during COM. A subsequent reset operation is required.
3. Visual and audible alarm sounds when the concentration of ozone in the irradiator cell reaches a preset level.
4. The door when electrically locked to prevent entrance can be opened at all times from within the cell for unrestricted exit.
5. For a preset time before the elevator starts its ascent a horn sounds and rotating light beams located within the cell and maze are energized. A separate circuit detects a burned out light and indicates this on the annunciator.
6. A single operation key is used for all functions except the console power switch for which a separate key is provided. This key arrangement for the reset and operating switch is designed to insure that the elevator system cannot be operated in an improper sequence.

7. The elevator drive system which is composed of a pneumatic piston and counter weight assembly will operate to return the elevator to the pool bottom in the event of either an electrical power failure or a loss of operating air.

8. High and low pool water level detectors alert the operator from the annunciator in the control room and a remote monitoring station of potential unsafe conditions.

9. The water conditioning system filters and deionizes the pool water to protect the source encapsulation from corrosion. A conductivity analyzer alerts the operator of high water conductivity.

10. The status and alarm annunciating system allows the operator at a glance to check the present status (normal or abnormal) of various components of the system and notifies the operator by audible signal of a change in status. Certain key signals may be transmitted to a remote monitoring station if desired.

IV. Functional Description of Components

A. RAM #1 - Detects and indicates the radiation level in the control room and will not allow the elevator to be raised or will lower the elevator should the level exceed the high level alarm setting of 2.5 mR/hr.

B. RAM #2 - Detects and indicates the radiation level of the irradiator room. During the period that the radiation exceeds the high level setting of 20 mR/hr it will keep the irradiator door locked or in the in-cell operational mode (ICOM) of the system, will automatically cause the elevator to return to the pool bottom.

C. RAM #3 - Detects and indicates the radiation level adjacent to the demineralizer system and will alarm when this level exceeds the selected high level alarm setting of 20 mR/hr. It functions also to provide a redundant high level detection and alarm during ICOM and causes elevator to return to pool bottom position if a high radiation level is detected.

D. Emergency push button switches located on the operating console, in the maze, and in the irradiator will cause immediate shut down of the elevator energizing system, and lower the elevator.

E. Safety Air Valve located in the irradiator will vent the air supply before the elevator drive piston so that the elevator cannot be raised. This valve should be pushed in whenever working in the irradiator room.

F. Level Gauge with read out located in the control room indicates the water level in the pool and provides electrical contact openings at adjustable levels to provide alarm and control functions.

1. Contact set #1 causes a high level alarm to be initiated when the pool water level exceeds 139 inches.
2. Contact set #2 causes the demineralizer pump to shut down when the level drops to a point just above the pump intake foot valve, 134 inches.
3. Contact set #3 energizes solenoid valves to maintain the pool water level between 134 and 137 inches.
4. Contact set #4 provides a low level alarm if the pool water level drops to 133 inches.

G. Radiation Indicator Lights which flash purple are illuminated when the elevator is not in its pool bottom position, except in the in-cell operational mode (ICOM).

H. Horn - Sounds for 15 seconds before the elevator starts its ascent except in the in-cell operational mode.

I. Door Position Switches - Will not allow the elevator to ascend if a maze door is opened and more than 15 seconds has elapsed since the system has been reset. If a door opens after the elevator has ascended, it will immediately descend and remain at the bottom until the system is again reset. In the in-cell operational mode (ICOM) these switches have no function.

J. Door Lock - Prevents the entrance door from being opened once 15 seconds have passed since the in-cell reset switch has been operated but allows the emergency exit door to be opened from inside the irradiator. The lock can be bypassed by turning the Door Lock Bypass Switch in a non routine operation.

K. Door Lock Bypass Switch - Disengages the door lock except when the radiation level in the irradiator exceeds the high level alarm setting of RAM #2 or RAM #3.

L. Reset Key Switch located within the irradiator - Must be turned momentarily to reset the control circuit and provide for an elevator ascent. This operation requires that the maze door has not been opened at any time once 15 seconds have elapsed after the reset switch has been operated in the console operational mode (COM). In the in-cell operational mode (ICOM), the reset key switch must be turned before the ICOM key switch is used to lift the elevator.

M. In-cell Operational Mode Key Switch - Which must be held in position, raises and lowers the elevator from inside the irradiator as described in L, above when operating in the ICOM providing the ICOM key switch has been, and remains turned within 15 seconds of the reset switch operation.

N. Console Power Key Switch with its own key applies power to the console circuitry, and must remain on except when working on the system since it controls power to the water circulating system, and the control and alarm functions which must operate continuously.

O. Console Pump Switch - Turns the water quality pump on and off. For the pump to be on, the pool water level must be correct and the console pump key switch must be "On".

P. Console Fill Valve Push Button - Used to manually add water to the pool or prime the water quality pump.

R. Annunciator - Provides visual status indication of monitored conditions throughout the Control System. An illuminated legend indicates an abnormal status; a flashing legend (accompanied by an audible alarm) indicates a status which has changed from normal to abnormal; a nonilluminated legend indicates a normal status.

S. Annunciator Ack (Acknowledge) - Clears the audible and visual annunciator indications. The visual indications then are of present conditions.

T. Annunciator Sil (Silence) - Clears the audible annunciator indication. Visual indication remains unchanged. A flashing indication means a change from normal conditions has occurred and may still exist.

U. Annunciator Test - Tests all annunciator channels for proper operation. All channels must flash and the audible signal must be present.

V. Remote Annunciator Switch - Connects the master annunciator to a remote monitoring point if desired.

W. Ozone Monitor - Samples the ozone content in the irradiator and in conjunction with the annunciator, warns personnel of potentially hazardous concentrations.

X. Conductivity Monitor - Determines the conductivity of the pool water at the inlet of the water quality pump and in conjunction with the annunciator, warns operations personnel of water conductivity which may be detrimental to source encapsulation life expectancy.

Y. Water Quality System

1. Pump - Circulates pool water through the water quality system. Note: The pump may have to be primed if turned off for an extended period of time.
2. Filter - Removes particulate matter from the pool water.
3. Pressure Gauges - Provides visual indication of water conditioning systems performance as follows:
    a. Both readings high and approximately equal indicates restricted flow through demineralizer tanks or return line to pool.
    b. Both readings low, pulsating, or zero - pump not on or loss of prime.
    c. One reading high and the other low indicates plugged filter.
    d. Both readings moderate with 20 - 30 percent differences in reading indicates normal conditions.
4. Deionizer Tanks - Removes ionic species from the pool water.

Z. Air Control Box

1. Air Supply Shut-off Valve - When open supplies air pressure for the elevator drive cylinder and pool level gauge.
2. Pressure Regulator Assembly - Limits, regulates, and conditions the air supply for the elevator drive and pool level gauge.
3. Descent Control Valve - Limits the elevator descent speed.
4. Ascent Control Valve - Limits the elevator ascent speed.
5. Solenoid Valve (4 way) - Changes the routing of the air supply on command of the control console, to cause either ascent or descent of the elevator.
6. Reserve Tank - Supplies sufficient reserve air capacity to return to the elevator to the pool bottom in the event of power failure and/or primary air supply system failure.

V. Operating Instructions

Note 1: The following procedure assumes that the total system is operational and that all adjustments have been made and the system is on stand by (i.e. The RAMs and other instruments are calibrated and alarm levels are properly set, the compressed air supply is on, etc.). (See also Note 2 at end of Section V., Operating Instructions, for additional start up instructions.)

1. Check the console power indicating light. The light should be on.
2. Turn the remote annunciator off.
3. Turn on the closed circuit TV monitor.
4. Turn on the ozone monitor.
5. Turn on the conductivity monitor.
6. After 15 minutes has elapsed check and adjust the TV.
7. Push the annunciator test switch and verify that all the annunciator channels are working.

8. Acknowledge the annunciator.

9. Check the pool level indicator for the proper water level.

10. Check the operation of the RAMs by pushing the up scale check button. An annuciator should indicate an abnormal condition for each.

11. Acknowledge the annunciator. Hereafter, check the cause of any audible annunciator change and correct any abnormal condition.

12. Verify the following annunciator channel conditions:

| Channel | Condition |
|---|---|
| RAM Power | Out |
| RAM 1 Level | Out |
| RAM 2 Level | Out |
| RAM 3 Level | Out |
| High Water Level | Out |
| Low Water Level | Out |
| Low Air Pressure | Out |
| Sol. Circuit 1 | On |
| Sol. Circuit 2 | On |
| System Not Reset | On |
| TV Power | Out |
| Door Bypassed | Out |
| Source on Bottom | Out |
| High Ozone | Out |

13. Investigate and correct any improper condition before continuing.

14. Enter the irradiator.

15. Depress manual air vent safety valve before proceeding with any operations within the irradiator cell.

16. When ready to raise source/sample elevator close the manual air vent safety valve.

17. Clear the room of all personnel, Reset - Operate Key Switch.

18. Make a rapid exit from the irradiator.

19. After the irradiator door has closed, check the System Reset annunciator indication. The light must be out to proceed with the operation. If not, this indicates a delay between the operation of the in-cell reset and closing the door. Repeat steps 14 and 15, and make a speedier exit.

20. Turn the console operate key switch to "Operate".

21. Observe the elevator operation via the TV monitor and counterweight.

22. Return the Operate keyswitch to its off position to return the elevator to the pool bottom.

23. Observe the elevator operation via the TV monitor and/or counterweight.

24. Repeat steps 11 through 13 when re-entering the irradiator or leaving the facility.

25. Turn off the TV, conductivity monitor, and ozone monitor.

26. Acknowledge the annunciator.

27. Turn the remote annunciator on.

To irradiate materials at the pool bottom, replace steps 17 through 22 with the following:

17A. Inspect the elevator to be certain that no source material is attached.

18A. Position knowledgable co-worker with operative survey meter set on the proper range to detect any increase in dose rate as elevator rises.

19A. Turn the Reset-Operate Keyswitch.

20A. Turn the Remote Operate Keyswitch and hold in position until the elevator rises and the material is loaded or unloaded.

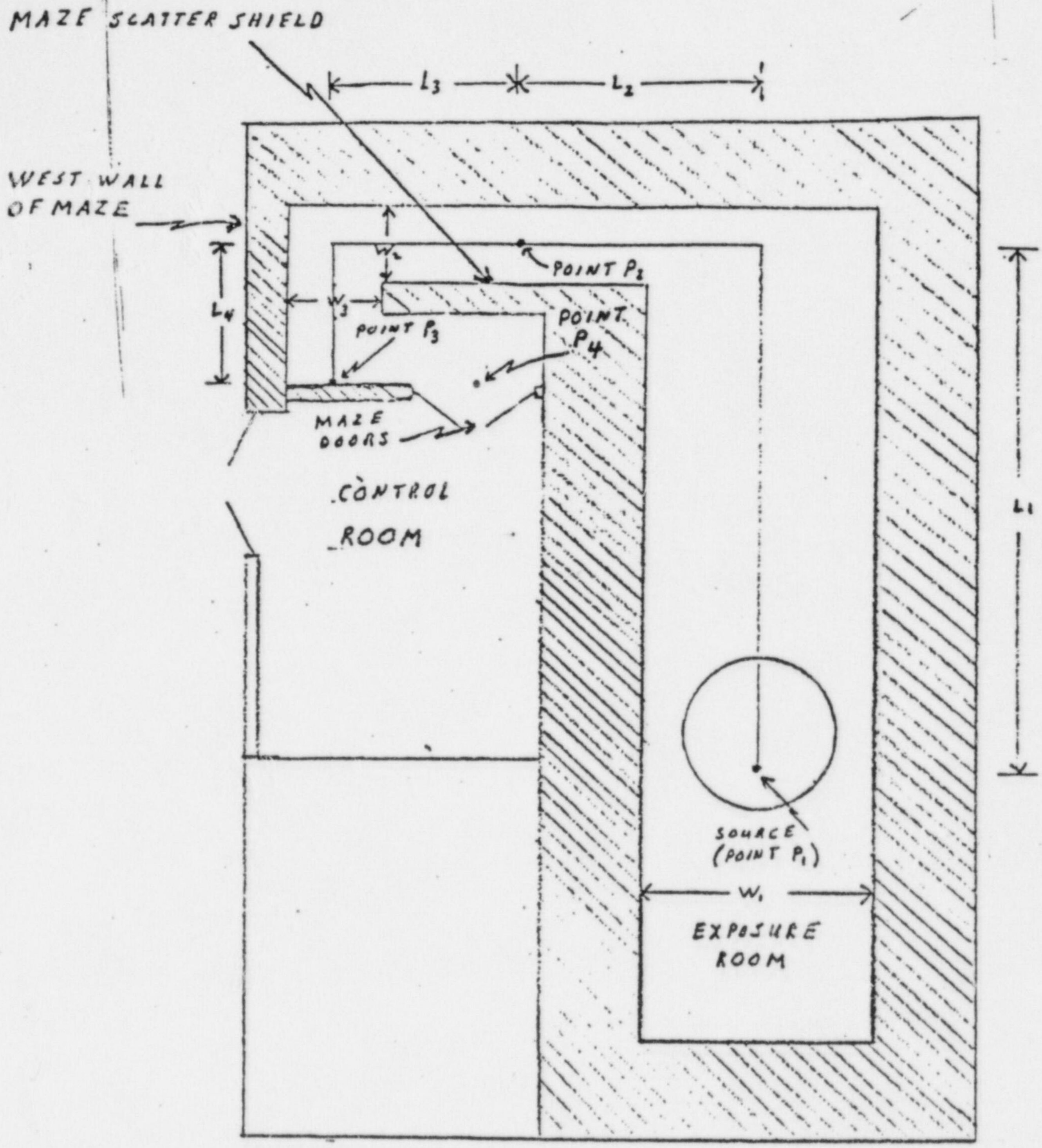
21A. Release the Remote Operate Keyswitch to lower the elevator to the bottom.

22A. To remove the material, repeat steps 14, 15, 16, 17A, 18A, 19A, 20A, and 21A. Then, proceed to step 24.

Note 2: If system is off, i.e. not stand by, the following additional steps are required:

1. Turn power on to radiation area monitors circuit breaker, control console circuit breaker, instrument rack circuit breaker, and water circulating pump circuit breaker in mechanical equipment room.
2. Turn on air supply (closing bleed valve if open).
3. Turn on console power keyswitch.
4. Perform any required scheduled maintenance.

HDI COBALT-60 FACILITY




$W_1 = 12'$

$W_2 = 4'$

$W_3 = 5'$

$L_1 = 26.33'$

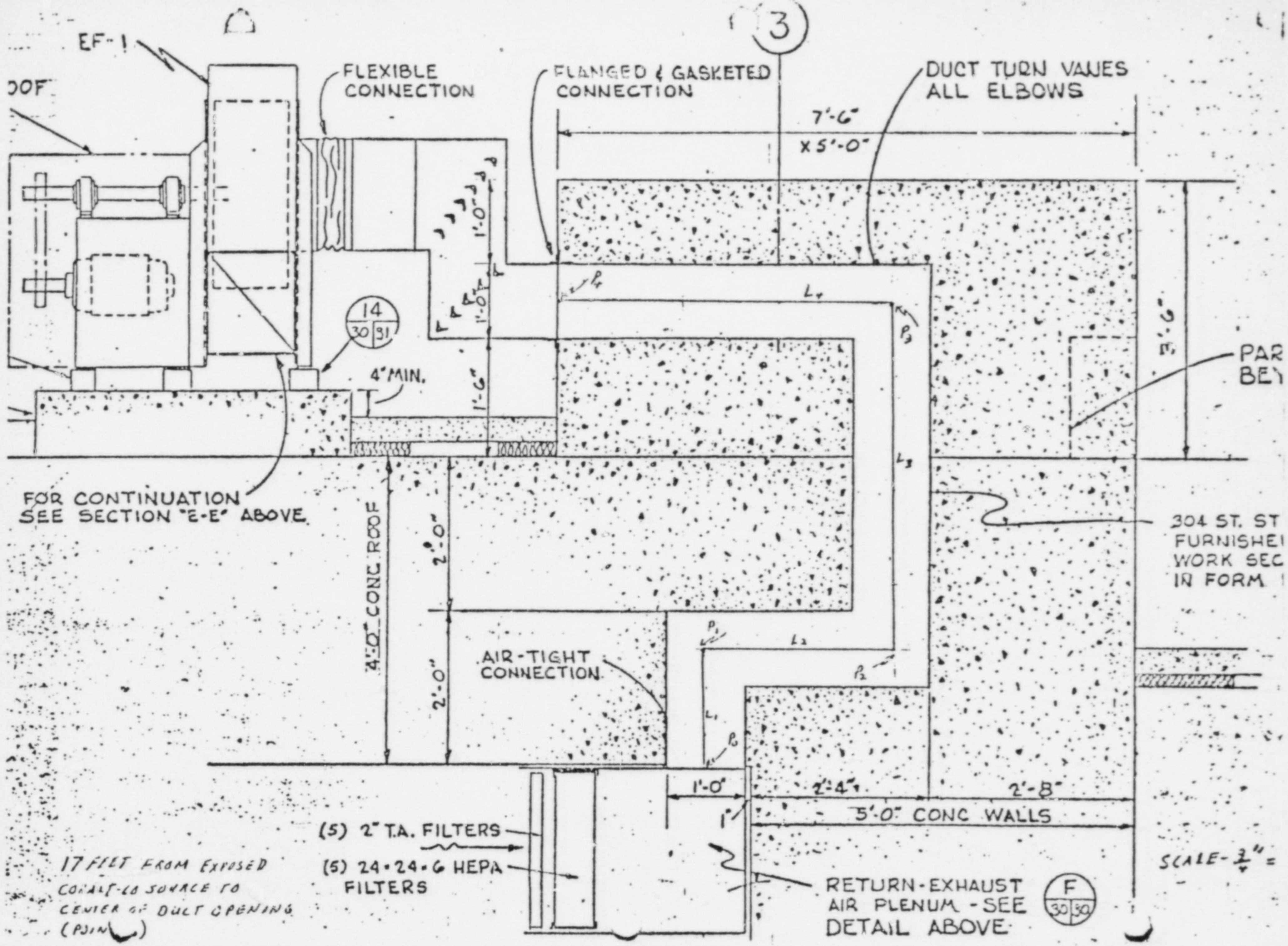
$L_2 = 12.68'$

$L_3 = 8.99'$

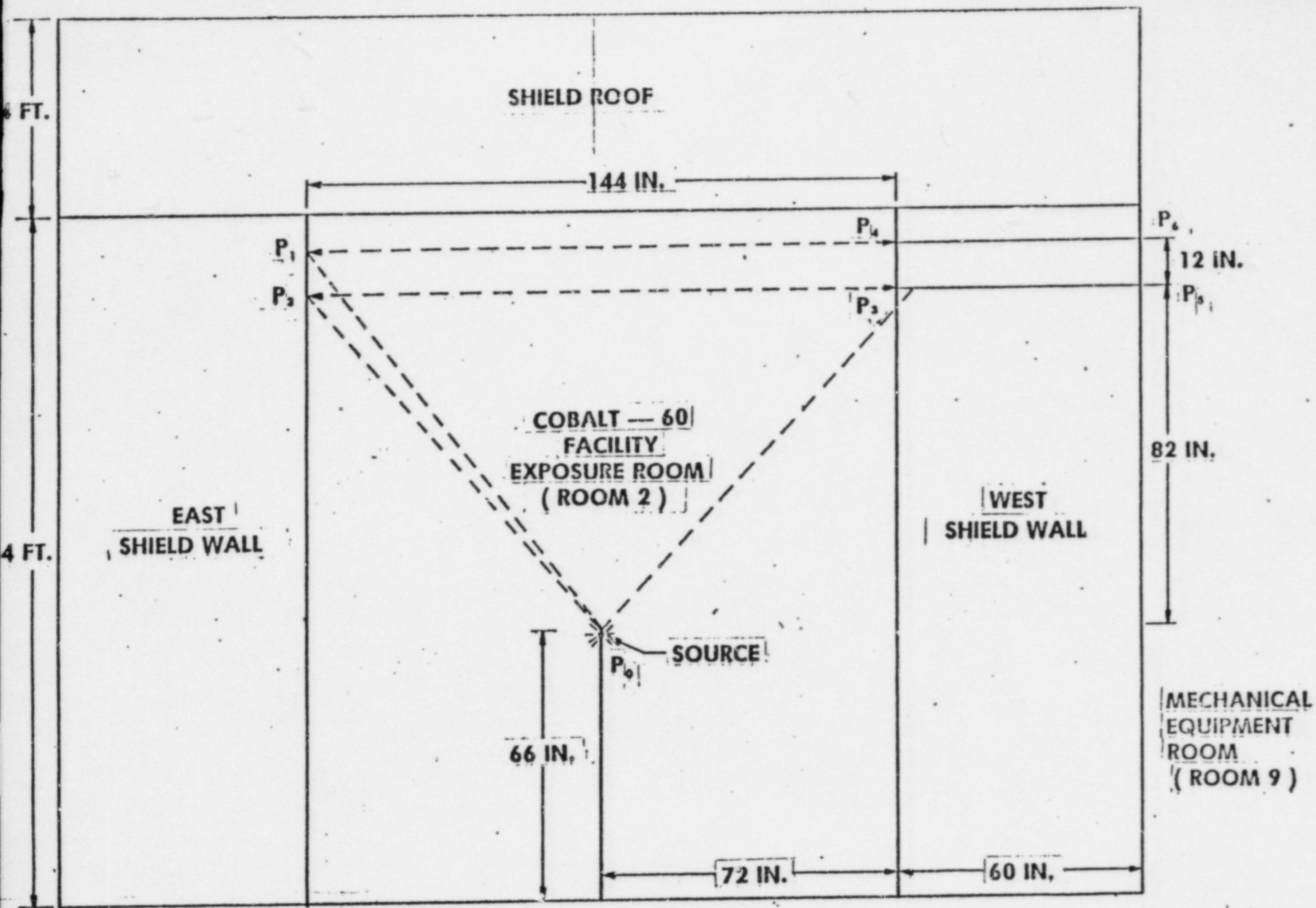
$L_4 = 7.5'$

$P_3 \rightarrow P_4 = 7.5'$

SKETCH 5-1




RADIATION TRAP FOR COBALT 60 RANGE EXHAUST SYSTEM



FT.
SHIELD ROOF
144 IN.
P1
P2
P4
P3
P6
P5
12 IN.
4 FT.
EAST
SHIELD WALL
COBALT — 60
FACILITY
EXPOSURE ROOM
( ROOM 2 )
WEST
SHIELD WALL
82 IN.
SOURCE
P0
66 IN.
MECHANICAL
EQUIPMENT
ROOM
( ROOM 9 )
72 IN.
60 IN.


SKETCH 5-3

SUPPLEMENT #6

Item 15, Form NRC 313 I, Radiation Protection Program

1. Administrative Organization and Responsibilities.

a. Harry Diamond Laboratories (HDL) functions as a research and development laboratory of the US Army Materiel Command. Consequently, the overall direction of the HDL Ionizing Radiation Safety Program is guided by AMC Regulation 385-25, w/Ch 1, "Safety - Radiation Protection" attached as Annex 6-A to this supplement. This regulation is supplemented by HDL Regulation 385-20, "Ionizing Radiation Protection Program" (attached as Annex 6-B) in order to provide local guidance to HDL personnel concerning the operational requirements and administrative procedures necessary for the control of ionizing radiation sources at HDL. A description of the organization, and how authority and responsibility is delegated to personnel directly responsible for the overall radiation protection program is found in Annex 6-B, Paragraph 5.

b. The HDL Radiation Protection Officer is responsible for the radiological safety of personnel using the Cobalt Facility. He directs all operations which involve the exposure of personnel to ionizing radiation in order to ensure that exposures are kept as low as reasonably achievable (ALARA). In addition, he maintains strict administrative control to minimize hazards during Cobalt Facility operations and ensures that all provisions of the NRC license and applicable regulations are complied with. Although, in general, the Radiation Protection Officer acts through the Cobalt Facility Supervisor, he has the authority to halt any operation at the Cobalt Facility that he considers a potential radiological or safety hazard.

c. The responsibility for operation of the Cobalt Facility is delegated by the Director, Installation Support Activity, to the Cobalt Facility Operator via the following chain of command:

Director, Installation Support Activity
Division Director, Nuclear Weapons Effects Division
Chief, Nuclear Radiation Effect Laboratory
Chief, Simulation Technology Branch
Cobalt Facility Supervisor
Cobalt Facility Chief Operator and Alternate Operator

The Cobalt Facility Supervisor, Chief Operator, and Alternate Operator are individuals authorized to manipulate the source elements, source elevator, console controls, and other equipment associated with the control, handling, and maintenance of the facility. These individuals will satisfy the HDL Radiation Control Committee as to their training and experience in the area of radiological safety and in the use of radioisotopes. Also, these individuals must demonstrate a thorough knowledge of the Cobalt Facility operating procedures and applicable safety regulations. In addition to the responsibilities outlined in Annex 6-B, Paragraph 5d, the Facility



105607

Supplement No. 6 continued.

Supervisor will ensure that the following tasks are accomplished prior to conducting experiments in the Cobalt Facility.

(1) Verify that all experiments involving the use of the Cobalt Facility have received review and approval of the HDL Radiation Control Committee in accordance with the procedures set forth in Annex 6-B, Paragraph 11, of this application.

(2) Ensure that the Cobalt Facility Standing Operating/Emergency Procedure (included as Annex 6-C to this supplement) is conspicuously posted in the Cobalt Facility and that experimenters are aware of its content.

(3) Determine that all safety equipment and devices are functioning properly.

2. Administrative Controls and Procedures.

a. All personnel entering the Cobalt Facility will be aware of and adhere to the procedures set forth in the Cobalt Facility Standing Operating/Emergency Procedure which is included as Annex 6-C to this supplement.

b. All maintenance, repair, or experimental procedures involving the manipulation of the source elements will require the presence of at least two individuals; one of which must be the HDL Radiation Protection Officer, the Cobalt Facility Supervisor, the Chief Operator, or the Alternate Operator.

c. Personnel exposures will be reviewed by the HDL Radiation Protection Officer in accordance with current NRC and Army instructions, and administrative, engineering, and procedure controls will be exercised to keep personnel exposures ALARA.

d. All proposed modifications to the Cobalt Facility, including all proposed deviations from established operational or administrative procedures shall be submitted to the HDL Radiation Control Committee. This committee shall review such proposals and determine whether or not they are advantageous to the operation of the facility. All proposals will be classified in one of the following categories.

(1) Major Safety Change: Any change which affects the degree of hazard associated with the operation of the Cobalt Facility.

(2) Minor Safety Change: Any change not classified as a major change which is directly associated with the safety of the Cobalt Facility. Included in this category are changes in the principal administration and operational procedures, health physics procedures and mechanical or electrical system alterations to the facility.

(3) Routine Change: Changes which have no bearing on the safety characteristics of the Cobalt Facility.

Supplement No. 6 continued.

e. All major and minor safety changes require the approval of the HDL Radiation Control Committee prior to requesting approval of proposed changes, through appropriate channels, from the Nuclear Regulatory Commission.

f. The Cobalt Facility Supervisor will ensure that the tasks enumerated in "Cobalt-60 Facility Weekly Checklist"(Annex 6-D), the "Periodic Maintenance Schedule" (Annex 6-E), and the "Periodic Calibration Schedule/Procedures" (Annex 6-F) are performed as specified therein.

g. The Radiation Protection Officer shall perform monthly inspections of the Cobalt Facility in order to accomplish the following:

(1) Verify that the facility is being used in accordance with prescribed operating procedures.

(2) Perform functional checks on the radiation detection alert systems.

3. Facility Operations.

a. In order to assure that only authorized persons will use or have access to the Cobalt-60 Facility, the following physical/administrative controls have been imposed.

(1) The Maze door, installed to control access from the Control Room to the Exposure Room/Maze, will be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel.

(2) The Control Room door, installed to control access from the grounds surrounding Building 504 to the Control Room, will also be locked at all times unless the Cobalt-60 Facility is occupied by authorized personnel. In addition to the door lock, the Control Room door is equipped with a high-security hasp and padlock which is controlled exclusively by the HDL Security Guards. The high-security hasp and padlock will be unlocked during working hours, and will be secured at all other times.

(3) As enumerated in the Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C), the separate keys to the Control Room door, Maze door, console power switch and elevator drive switch are rigorously controlled by the Cobalt-60 Facility Supervisor, Chief Operator and Alternate Operator.

(4) All exterior windows installed in Building 504, and any openings (such as air vents) which are 96 square inches or over are protected against intrusion by permanent, steel security grills.

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(5) The HDL Security Guards provide continuous surveillance of the Cobalt-60 Facility by performing periodic patrols and also by remotely monitoring the electromechanical intrusion alarms and ultrasonic motion detectors installed in the Cobalt-60 Facility Control Room. Actuation of a surveillance alarm transmits an audio-visual signal to an annunciator panel monitored by security personnel at the main guard office. Upon receipt of an alarm, security guards are immediately deployed to arrive at the site of intrusion in approximately 2 minutes. In addition to the security precautions presented above, the entire HDL complex is surrounded by a 9 gage chain link perimeter fence in order to restrict or impede access by unauthorized individuals.

(6) The Cobalt-60 Facility Standard Operating/Emergency Procedure (Annex 6-C) delineates the administrative/physical actions required of individuals desiring authorized access to the Exposure Room. Annex 6-C and Supplement No. 5 to this application also define the conditions which must exist within the Exposure Room/Maze Area before entry is permitted during the various operational modes.

b. The HDL Cobalt-60 Facility will be used to conduct free-air and water-well irradiation in order to perform radiation effects testing on electronic components and for the performance of radiochemistry and dosimetry experiments. Highly flammable or explosive materials will not be irradiated at the Cobalt-60 Facility regardless of the operational mode. In addition to the administrative controls on experiments and experimenters thus far described in this supplement, all the safety provisions delineated in the Cobalt-60 Facility Standing Operating/Emergency Procedures will be strictly adhered to and enforced. A complete description of the functional characteristics associated with Cobalt-60 Facility irradiator system and safety support equipment is presented in paragraphs 2 and 3 of Supplement No. 5 to this application. The step-by-step operating instructions which must be followed by the console operator in order to perform free-air irradiations or water well irradiations involving use of the elevator is presented in paragraph V of Annex 5-A to this application.

c. In order to assure that the facility is being operated only when all safety interlocks and devices are functioning properly, the Cobalt-60 Supervisor is assigned the responsibility of assuring that the equipment checks, maintenance, and calibrations set forth in Annexes 6-D, 6-E, and 6-F of this application are thoroughly performed at the time intervals specified. Should any of the primary safety support equipment fail to function properly, use of the Cobalt-60 Facility shall be terminated until the cause of the malfunction has been determined and corrected.

4. Routine Monitoring Program. a. Radiation Area Monitors (RAM):

(1) The Control Room and Exposure Room areas are equipped with three Nuclear Measurements Corporation Model GA-2T ionizing radiation area monitors installed for the purpose of detecting radiation levels in these

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areas on a 24 hour-a-day basis. These RAMs are incorporated into the Radiation Safety Interlock System and the Radiation Warning System as described in paragraph 2c and paragraph 2d(4) of Supplement No. 5 to this application. In the event of an alarm, the Cobalt Facility will be evacuated and the Radiation Protection Officer will be notified. The Exposure Room/Maze Area of the facility will not be reentered until the reason for the alarm has been ascertained or until a radiation safety survey has been performed.

b. Resin Bed Radiation Monitor (RBM).

(1) In addition to functioning as an Exposure Room Radiation Area Monitor, RAM No. 3 serves as a Resin Bed Monitor (RBM). This monitor is positioned adjacent to the pool water deionization resin bed tanks in order to provide continuous monitoring of the Cobalt-60 Facility pool water for the presence of a leaking source element.

(2) Removal of cobalt-60 from the pool water by the water purification system (a mixed resin bed) will have its greatest effect if all the activity passing through the demineralizer is removed from the water. Assuming a constant leak rate from a source element, the activity remaining in the water would be:

$$A = \frac{A_1}{F/V} \left[1 - e\ (-Ft/V)\right]$$

Where A = total activity in the water

$A_1$ = leak rate

F = water flow rate through purification system

V = pool water volume

t = time since start of leak

exp = exponential function

The fraction of activity in the water of the total released would then be:

$$\frac{A}{A_1 t} = \frac{1 - e^{-(Ft/V)}}{(F/V)\ t}$$

The fraction of activity concentrated in the resin bed of the total released is $1\text{-}A/A_1\ t$. Some calculated values of this fraction for normal values of the parameters for the facility are presented below (V = 2327 gal, F = 50 gpm).

| DURATION OF LEAK (DAYS) | FRACTION OF ACTIVITY RELEASED AND DEPOSITED IN RESIN BED |
|---|---|
| 1 | 0.968 |
| 2 | 0.983 |
| 3 | 0.989 |
| 4 | 0.992 |
| 7 | 0.995 |

(3) Since the resin bed tanks are cylindrical one may use the formulas and associated data presented in Applied Dosimetry, K. K. Aglintsev, London Iliffe Books Ltd., 1965, to calculate the exposure rate at the surface of the resin bed tank due to the presence of cobalt-60 evenly distributed in the resin. The following calculation assumes that the resin bed has accumulated 1 microcurie of cobalt-60 from a leaking source element.

$$P = P_o \Gamma f B$$

Where $P$ = exposure rate from a solid cylindrical source
$P_o$ = exposure rate from emitter if all activity were concentrated at the center
$\Gamma$ = coefficient which allows for the geometry of the source and the distance from it
$f$ = self-absorption coefficient (0.369)
$B$ = build-up factor (1.3)

$$P_o \Gamma = \pi P_\gamma q_{vol} R_o \left\{ H/R_o (1 - \ln 2H/R_o) + H/R_o \ln \left[ H/R_o + \sqrt{(H/R_o)^2 + 4} \right] + 2 - \sqrt{(H/R_o)^2 + 4} \right\} = 0.015 \text{ mR/h}$$

Where $P_o \Gamma$ = exposure rate on surface of cylindrical source
$q_{vol}$ = specific activity of source ($1.511 \times 10^{-8}$ mCi/cm$^3$)
$H$ = cylinder height (106.68 cm)
$R_o$ = cylinder radius (15.24 cm)

$P_\gamma$ = R cm$^2$/mCi h for Co-60 (13R/h mCi at 1 cm)

Now $P = P_o \Gamma f B$ = (0.015 mR/h)(0.369)(1.3) = 0.001 mR/h

The above calculations assume that the cylindrical source is homogeneous and has the density of water. In order to find the true exposure rate at the outside surface of the 1/16 inch thick steel tank one must calculate the shielding effect of the resin bed tank material.

Thus: $D = B D_o e^{-uX}$

Where $D$ = exposure rate at outside surface of resin tank
$D_o$ = exposure rate at inside surface of resin tank
$B$ = Build-up factor (1.0)
$u$ = linear absorption coefficient (0.4672 cm$^{-1}$)
$X$ = shield thickness (0.1588 cm)
exp = exponential function

$D$ = (1.0)(0.001 mR/h)(.9285) = 0.001 mR/h

(4) Since $P_\gamma$ = 13 mR/h uCi at 1 cm for Co-60, and the exposure rate at the surface of the resin bed tank is 0.001 mR/h for each microcurie of Co-60 evenly distributed inside the resin bed tank, the Resin Bed Monitor will be exposed to approximately 0.1% of the activity in the tank. Assuming a background count rate of 1000 CPM and a 6% efficiency for the detector, the Resin Bed Monitor has a minimum sensitivity of $7.12 \times 10^{-4}$ uCi as shown below:



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$$\text{Min. Sens.} = 3/\epsilon X\ (CPM_{BKG}/t)^{1/2}$$
$$= 3/(.06)(.001)\ (1000/1)^{1/2} = 1.581 \times 10^{3}\ \text{DPM}$$
$$= 7.12 \times 10^{-4}\ \text{uCi}$$

Where $\epsilon$ = counting efficiency
$X$ = fraction of total sample presented to detector
$t$ = counting time
$CPM_{BKG}$ = background count rate

(5) Considering the results of the above calculations pertaining to the Resin Bed Radiation Monitor, it appears that this system will provide adequate early warning in the case of a leaking source element between routine leak testing procedures.

c. Routine/Emergency Leak Testing.

(1) At periods not to exceed 6 months the HDL Radiation Protection Officer will perform leak tests of all source elements in order to assure that the integrity of the source elements have not been violated. The leak testing method used will be sufficiently sensitive to detect a $2 \times 10^{-4}$ uCi loss in 24 hours, which is equivalent to less than a 0.05 uCi loss in 6 months. This leak test procedure will also be initiated should the Resin Bed Radiation Monitor indicate that a source element is leaking.

(2) Procedure: The basic procedure involved in routine leak testing or in identification of a leaking element will be to isolate groups of the source elements in the sealed Leak Test/Isolation Containers described in Supplement 5 of this application. These containers are designed so that they can be loaded with 6 source elements each, sealed, sampled, pumped dry, and flushed with clean water while at a safe depth under water. Once the source elements are isolated in the Leak Test/Isolation Containers they will be steeped in clean water for a period of at least 24 hours and sampled to show an activity loss of less than $2 \times 10^{-4}$ uCi/24 hours. Should testing results indicate that a container houses a leaking element, the elements in that container will be divided up between the two leak test containers and the procedure repeated until the leaking element is located.

(3) Sampling sensitivity: An example of an available system on which the above test may be performed with the required sensitivity is the Nuclear Measurements Corporation, Model PC-4, gas flow proportional counter. A one liter water sample evaporated to dryness (conservatively assuming a 50% collection efficiency) and counted for 960 minutes, will give a minimum sensitivity of $2.24 \times 10^{-8}$ uCi/cm$^3$:

$$\text{Min. Sens.} = 3/\epsilon Vc\ (CPM_{BKG}/t)^{1/2}$$
$$= 3/(0.55)(1000)(0.5)\ (46.0/960)^{1/2} = 4.98 \times 10^{-2}\ \text{dpm/cm}^3$$
$$= 2.24 \times 10^{-8}\ \text{uCi/cm}^3$$

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Where $\epsilon$ = counting efficiency
V = sample volume
c = collection efficiency during sample reduction
t = counting time
$CPM_{BKG}$ = background count rate

(4) No servicing, maintenance, or repair of sources will be done at Harry Diamond Laboratories. Should a source element be found faulty, it will be transferred to a Source Leak Test/Isolation Container which will then be sealed. Upon receipt of instructions for disposition, the source will be shipped to a licensed facility for repair or ultimate disposal. Should waste disposal procedures be necessary, it will be handled by the US Army Armament, Munition, Chemical Command, Rock Island, IL in accordance with the procedures delineated in Army Regulation 385-11 "Ionizing Radiation Protection".

5. Emergency Organization and Procedures.

a. Organization for Emergencies:

(1) Any individual discovering fire or other hazardous conditions at the Cobalt Facility is required by the "Cobalt Facility Standing Operating/ Emergency Procedure" (attached as Annex 6-C to this supplement) to evacuate the building, report the nature of the problem to the HDL Guard Office, and muster in the Bldg. 504 parking lot to await further instructions.

(2) Upon notification of the emergency condition the HDL Disaster Control Plan specifies the following course of action.

(a) The HDL Guard Office will notify the Fire Department, the HDL Fire Chief in case of fire, the Medical Office in case of injuries, the Safety Office, Radiation Protection Officer, and the Director. The Guard Force will deploy personnel to direct emergency personnel to the scene and advise them of the fact that a radiation hazard may exist. All uninjured personnel who may have been exposed to ionizing radiation or contaminated with radioactive material will be directed and detained in a safe area by the Guard Force until monitoring and decontamination assistance is available.

(b) The Medical Office will treat injured personnel brought to the office or the Nurse will visit the scene to render First Aid assistance and summon additional assistance if necessary.

(c) The Motor Pool Officer will be alerted to stand-by to furnish transportation to hospitals.

(d) The Radiological Protection Officer will represent the Safety Office at the scene of the emergency in order to advise emergency personnel of the radiological hazards associated with the incident and assist in evaluating plans for remedial actions.

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(e) The Safety Branch, HDL Fire Chief (in case of fire) and the Branch Chief of involved personnel will investigate the accident after measures to eliminate the hazardous condition have been performed.

b. Hazard Due to Abnormal Water Levels or Non-Returning Exposed Source.

(1) The exposure rate at a point 2 ft above the pool grating has been calculated for lowered pool water levels, and "stuck" elevator positions. The calculations were performed using tabulated buildup factors taken from Reference 8 of Supplement 5, and using buildup factors empirically derived from actual measurements at the Co-60 Facility (see para 1d, Supplement 5 for calculations). The results of the calculations are presented in Figures 6-1 and 6-2 at the end of this supplement. As illustrated in Figures 6-1 & 2, the pool would have to loose 32 inches of water, or the elevator would have to stick 29 inches above it's normal resting position before a "High-Radiation Area" would be present over the pool. A lose of 32 inches of water from the pool would be immediately available to personnel as (a) the "low level water alarm" (switch #4) would be activated on the control room annunciator panel, (b) RAM's #2 and #3, located in the exposure room would detect elevated levels, and would lock the maze door if either RAM detected levels exceeding 20 mR/hr, and (c) upon entry into the exposure room carrying a hand-held G-M instrument equipped with a "chirper", the operator would detect elevated levels. In the event the elevator stuck in the raised position, the operator would immediately become aware as (a) the counterbalance conspicuously located in the control room near the operating console would not have returned to normal position, (b) RAM's #2 and 3 would remain at elevated levels, not unlocking the maze door if either RAM 2 or 3 detected levels in excess of 20 mR/hr, and (c) upon entry into the exposure room carrying a hand-held G-M instrument equipped with a "chirper", the operator would detect elevated levels. In the extreme case, emergency personnel have the capability of flooding the pool from a location external to the Exposure Room by utilizing the emergency fill water system installed specifically for that purpose; this system is described and illustrated in Supplement No. 5 to this application. Consequently, the size of the leak required to maintain the sources in an unshielded condition (ie, a dry pool) would require the occurrence of a very improbable event.

(2) Actions taken in the event of an abnormal water level or source position are predicated on the assumption that as long as the Exposure Room remains secured, there is no problem with regard to personnel radiation hazards. The only personnel exposure hazards that might arise would be created by the process of correcting the problem. In the case of a non-returning, fully exposed source, any procedure which might be initiated, other than those built into the system, would be transmitted to the US Nuclear Regulatory Commission prior to implementation. However, considering the free fall design of the source elevator and the back-up emergency haul-down capability (described in paragraph 2b of Supplement No. 5 to this application) the likelihood of this possibility is very minuscule.

c. Remote Emergency Situations:

(1) The possibility of personnel exposure from falling into the Cobalt 60 Facility pool is minimized by pool design and administrative procedure. As recommended by the Occupational Safety and Health Act Regulations,

29 CFR, Part 1910, the pool is guarded by a standard railing with standard toeboard on all sides and a hinged floor hole cover of standard strength (see Supplement No. 5). The Cobalt-60 Facility Standing Operating/Emergency Procedure (Annex 6-C of this supplement) requires that at least two persons be in the facility when a task requires standing over the exposed tank. Restricted access to the pool surface and the requirement that two persons be present when work involves removal of the pool cover minifies the possibility that an unaided individual could fall into the pool.

(2) Rupture or shifting and tilting of the Cobalt-60 Facility due to earth movement is unlikely due to the extremely remote possibility of a destructive earthquake in the Washington area. The seismic analysis, presented in paragraph 1i of Supplement No. 5 to this application, indicates that the structural characteristics of the Cobalt-60 Facility are adequate to cope with any probable seismic phenomena.

6. Source Installation.

a. The shipment and installation of all presently licensed Co-60 sources at the Co-60 Facility was performed by the source manufacturer, i.e., Neutron Products Inc., of Dickerson, Maryland. The shipment and installation of the additional Co-60 sources that are the subject of this amendment will also be performed by Neutron Products Inc., the manufacturer of the new sources. Neutron Products will perform the shipment and installation in accordance with Neutron Products Procedure P-5, attached as Annex 6-G to this supplement. The names of the Neutron Products personnel who will be unloading the shipping containers and a description of their training and experience in performing such operations is presented in Annex 6-H to this supplement. Neutron Products will employ a General Electric Model 1500 shipping cask during installation and shipping. Annex 6-I to this supplement is the DOT authorization for Neutron Products to use the GE 1500 shipping cask. Annex 6-J to this supplement is the NRC Certificate of Compliance for the GE 1500 shipping cask. Annex 6-K to this supplement is the handling and loading procedure for the GE 1500 shipping cask. Annex 6-L is the NRC approval of Neutron Products Quality Assurance Program for radioactive material packages. As indicated in Annex 6-G, the Department of Transportation approved source transfer container will be lowered to the bottom of the 12 feet deep water filled pool prior to removal of the source elements from the transfer container. The remote handling tool described in Supplement 5 to this application will then be used to extract the source elements from the transfer container and install them in the source holding fixtures located at the bottom of the same pool. Prior to the installation of the source elements in the irradiation facility the following conditions shall prevail:

(1) The transfer will not be attempted until the HDL Radiation Protection Officer is present and certain that all individuals are competent in all phases of the operation and are familiar with the loading and monitoring procedures.

(2) The HDL Radiation Control Committee must approve all source transfer procedures prior to their implementation.

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(3) An exclusion area shall be established and cleared of all personnel not directly involved with the source transfer operation.

During the actual installation of source elements into the source holding fixtures the following precautions shall be taken:

(1) The HDL Radiation Protection Officer shall perform a series of shipping cask wipe tests to check for leakage that may have occurred while the sources were in transit to HDL. Wipe test smears will be removed to non-radiation areas and checked with a G-M survey meter. If no significant activity is detected on the smears they will be placed in a gas flow proportional counter for accurate analysis and documentation of activity levels. If significant activity is found on smears, the transfer operation will cease until the source of contamination is found and appropriate corrective action taken.

(2) Continuous monitoring of the radiation levels inside the exclusion zone will be made during the transfer operation. This monitoring will be accomplished by use of portable survey meters and also by the remote area monitors installed in the Control and Exposure Rooms.

b. After all source elements have been loaded into the source holding fixtures at the bottom of the pool a complete radiation monitoring survey will be performed by the HDL Radiation Protection Officer. All areas of the building normally occupied by personnel will be checked with portable survey meters. All equipment used to transfer the source elements and the surface area over which the source transfer operation was conducted will be checked for radioactive contamination by wiping the surfaces with filter paper and analyzing the filter paper in a gas flow proportional counter. Pool water samples will also be analyzed for contamination. The level of contamination present will be compared to levels that were measured before the source installation. Decontamination procedures will be the responsibility of Neutron Products if post-installation contamination levels exceed either 100 dpm/100 $cm^2$ , or twice the pre-installation levels, whichever is smaller.

7. Initial Shielding Survey. The shield survey will be performed in two steps. A cursory survey of the areas adjacent to the Exposure Room/Maze Areas, such as the Control Room, Mechanical Equipment Room, Radioactive Materials Storage Room, HIFX Exposure Room, HIFX RF Shielded Room, roof and exterior building walls, will be made while the source elevator car sustains approximately 5 kCi of Cobalt-60 in the free-air-irradiation position. Following this, a more comprehensive survey will be performed with the maximum loading of the irradiator elevator allowed by this application. With the maximum loading of Cobalt-60 sustained in the free-air-irradiation position by the elevator, all areas adjacent to the Exposure Room/Maze Area, the bulk shielding, and shielded penetrations such as conduits and air ventilation ducts will be surveyed. These locations will be surveyed with the sources raised to the most hazardous positions with respect to the particular area being surveyed.