Rec. 7/30/80

FORM NRC-313M (8-78) 10 CFR 35	U.S. NUCLEAR REGULATORY COMMISSION **APPLICATION FOR MATERIALS LICENSE – MEDICAL**	Approved: GAO R0557

INSTRUCTIONS – *Complete Items 1 through 26 if this is an initial application or an application for renewal of a license. Use supplemental sheets where necessary. Item 26 must be completed on all applications and signed. Retain one copy. Submit original and one copy of entire application to: Director, Office of Nuclear Materials Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Upon approval of this application, the applicant will receive a Materials License. An NRC Materials License is issued in accordance with the general requirements contained in Title 10, Code of Federal Regulations, Part 30, and the Licensee is subject to Title 10, Code of Federal Regulations, Parts 19, 20 and 35 and the license fee provision of Title 10, Code of Federal Regulations, Part 170. The license fee category should be stated in Item 26 and the appropriate fee enclosed.*

1.a. NAME AND MAILING ADDRESS OF APPLICANT *(institution, firm, clinic, physician, etc.)* INCLUDE ZIP CODE

Richard A. Morrison, M.D.
The Radiarium
17525 Medical Center Parkway
Independence, Missouri 64057

TELEPHONE NO.: AREA CODE (Not yet installed) See item 2 below

1.b. STREET ADDRESS(ES) AT WHICH RADIOACTIVE MATERIAL WILL BE USED *(If different from 1.a.)* INCLUDE ZIP CODE

Same as in item 1.a.

30-17782
02200
L&L 19486

2. PERSON TO CONTACT REGARDING THIS APPLICATION

Richard A. Morrison, M.D.
9021 Delmar
Prairie Village, Kansas 66207

TELEPHONE NO.: AREA CODE (913) 649 6592

3. THIS IS AN APPLICATION FOR: *(Check appropriate item)*

a. [X] NEW LICENSE
b. [ ] AMENDMENT TO LICENSE NO. ______
c. [ ] RENEWAL OF LICENSE NO. ______

4. INDIVIDUAL USERS *(Name individuals who will use or directly supervise use of radioactive material. Complete Supplements A and B for each individual.)*

Richard A. Morrison, M.D.

5. RADIATION SAFETY OFFICER (RSO) *(Name of person designated as radiation safety officer. If other than individual user, complete resume of training and experience as in Supplement A.)*

a. On Site: Richard A. Morrison, M.D.
b. Consulting: Peter J. Debus, M.S.

6.a. RADIOACTIVE MATERIAL FOR MEDICAL USE

RADIOACTIVE MATERIAL LISTED IN:	ITEMS DESIRED "X"	MAXIMUM POSSESSION LIMITS (In millicuries)	ADDITIONAL ITEMS:	MARK ITEMS DESIRED "X"	MAXIMUM POSSESSION LIMITS (In millicuries)
10 CFR 31.11 FOR IN VITRO STUDIES			IODINE-131 AS IODIDE FOR TREATMENT OF HYPERTHYROIDISM		
10 CFR 35.100, SCHEDULE A, GROUP I		AS NEEDED	PHOSPHORUS-32 AS SOLUBLE PHOSPHATE FOR TREATMENT OF POLYCYTHEMIA VERA, LEUKEMIA AND BONE METASTASES		
10 CFR 35.100, SCHEDULE A, GROUP II		AS NEEDED	PHOSPHORUS-32 AS COLLOIDAL CHROMIC PHOSPHATE FOR INTRACAVITARY TREATMENT OF MALIGNANT EFFUSIONS.		
10 CFR 35.100, SCHEDULE A, GROUP III			GOLD-198 AS COLLOID FOR INTRACAVITARY TREATMENT OF MALIGNANT EFFUSIONS.		
10 CFR 35.100, SCHEDULE A, GROUP IV		AS NEEDED	IODINE-131 AS IODIDE FOR TREATMENT OF THYROID CARCINOMA		
10 CFR 35.100, SCHEDULE A, GROUP V		AS NEEDED	XENON-133 AS GAS OR GAS IN SALINE FOR BLOOD FLOW STUDIES AND PULMONARY FUNCTION STUDIES.		
10 CFR 35.100, SCHEDULE A, GROUP VI					

6.b. RADIOACTIVE MATERIAL FOR USES NOT LISTED IN ITEM 6.a. *(Sealed sources up to 3 mCi used for calibration and reference standards are authorized under Section 35.14(d), 10 CFR Part 35, and NEED NOT BE LISTED.)*

ELEMENT AND MASS NUMBER	CHEMICAL AND/OR PHYSICAL FORM	MAXIMUM NUMBER OF MILLICURIES OF EACH FORM	DESCRIBE PURPOSE OF USE
Cobalt-60	Teletherapy sealed sources (AECL C-146 or C-151).	17,000 curies (2 sources of not more than 8500 curies each. Each source is rated at 7500 RHM.)	One source to be used in an AECL Theratron 780 teletherapy unit for the treatment of humans. One source in its shipping container to be in possession of licensee as source replacement.

71 pp

8009040229 release from hold

04676

INFORMATION REQUIRED FOR ITEMS 7 THROUGH 23

For Items 7 through 23, check the appropriate box(es) and submit a detailed description of all the requested information. Begin each item on a separate sheet. Identify the item number and the date of the application in the lower right corner of each page. If you indicate that an appendix to the medical licensing guide will be followed, do not submit the pages, but specify the revision number and date of the referenced guide: Regulatory Guide 10.8 , Rev. ____________ Date: ________________

7. MEDICAL ISOTOPES COMMITTEE Not Applicable		15. GENERAL RULES FOR THE SAFE USE OF RADIOACTIVE MATERIAL *(Check One)*	
	Names and Specialties Attached; and		Appendix G Rules Followed; or
	Duties as in Appendix B; or *(Check One)*	X	Equivalent Rules Attached
	Equivalent Duties Attached	16. EMERGENCY PROCEDURES *(Check One)*	
8. TRAINING AND EXPERIENCE See alternate appl and Annex A			Appendix H Procedures Followed; or
	Supplements A & B Attached for Each Individual User; and	X	Equivalent Procedures Attached
	Supplement A Attached for RSO.	17. AREA SURVEY PROCEDURES *(Check One)*	
9. INSTRUMENTATION *(Check One)*			Appendix I Procedures Followed; or
	Appendix C Form Attached; or	X	Equivalent Procedures Attached
X	List by Name and Model Number	18. WASTE DISPOSAL *(Check One)* Not Applicable	
10. CALIBRATION OF INSTRUMENTS See Alt. Appl			Appendix J Form Attached; or
	Appendix D Procedures Followed for Survey Instruments; or *(Check One)*		Equivalent Information Attached
	Equivalent Procedures Attached; and	19. THERAPEUTIC USE OF RADIOPHARMACEUTICALS *(Check One)* Not Applicable	
	Appendix D Procedures Followed for Dose Calibrator; or *(Check One)*		Appendix K Procedures Followed; or
	Equivalent Procedures Attached		Equivalent Procedures Attached
11. FACILITIES AND EQUIPMENT		20. THERAPEUTIC USE OF SEALED SOURCES Not Applicable for this application	
X	Description and Diagram Attached		Detailed Information Attached; and
12. PERSONNEL TRAINING PROGRAM Not Applicable			Appendix L Procedures Followed; or *(Check One)*
	Description of Training Attached		Equivalent Procedures Attached
13. PROCEDURES FOR ORDERING AND RECEIVING RADIOACTIVE MATERIAL Not Applicable		21. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE GASES (e.g., Xenon – 133) Not Applicable	
	Detailed Information Attached		Detailed Information Attached
14. PROCEDURES FOR SAFELY OPENING PACKAGES CONTAINING RADIOACTIVE MATERIALS *(Check One)* Not Applicable		22. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE MATERIAL IN ANIMALS Not Applicable	
			Detailed Information Attached
	Appendix F Procedures Followed; or	23. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE MATERIAL SPECIFIED IN ITEM 6.b	
	Equivalent Procedures Attached	X	Detailed Information Attached

INFORMATION REQUIRED FOR ITEMS 7 THROUGH 23

For Items 7 through 23, check the appropriate box(es) and submit a detailed description of all the requested information. Begin each item on a separate sheet. Identify the item number and the date of the application in the lower right corner of each page. If you indicate that an appendix to the medical licensing guide will be followed. do not submit the pages, but specify the revision number and date of the referenced guide: Regulatory Guide 10.8 , Rev. ________ Date: ________

7. MEDICAL ISOTOPES COMMITTEE Not Applicable	
	Names and Specialties Attached; and
	Duties as in Appendix B; or *(Check One)*
	Equivalent Duties Attached
8. TRAINING AND EXPERIENCE See alternate appl and Annex A	
	Supplements A & B Attached for Each Individual User; and
	Supplement A Attached for RSO.
9. INSTRUMENTATION *(Check One)*	
	Appendix C Form Attached; or
X	List by Name and Model Number
10. CALIBRATION OF INSTRUMENTS See Alt. Appl	
	Appendix D Procedures Followed for Survey Instruments; or *(Check One)*
	Equivalent Procedures Attached; and
	Appendix D Procedures Followed for Dose Calibrator; or *(Check One)*
	Equivalent Procedures Attached
11. FACILITIES AND EQUIPMENT	
X	Description and Diagram Attached
12. PERSONNEL TRAINING PROGRAM Not Applicable	
	Description of Training Attached
13. PROCEDURES FOR ORDERING AND RECEIVING RADIOACTIVE MATERIAL Not Applicable	
	Detailed Information Attached
14. PROCEDURES FOR SAFELY OPENING PACKAGES CONTAINING RADIOACTIVE MATERIALS *(Check One)* Not Applicable	
	Appendix F Procedures Followed; or
	Equivalent Procedures Attached

15. GENERAL RULES FOR THE SAFE USE OF RADIOACTIVE MATERIAL *(Check One)*	
	Appendix G Rules Followed; or
X	Equivalent Rules Attached
16. EMERGENCY PROCEDURES *(Check One)*	
	Appendix H Procedures Followed; or
X	Equivalent Procedures Attached
17. AREA SURVEY PROCEDURES *(Check One)*	
	Appendix I Procedures Followed; or
X	Equivalent Procedures Attached
18. WASTE DISPOSAL *(Check One)* Not Applicable	
	Appendix J Form Attached; or
	Equivalent Information Attached
19. THERAPEUTIC USE OF RADIOPHARMACEUTICALS *(Check One)* Not Applicable	
	Appendix K Procedures Followed; or
	Equivalent Procedures Attached
20. THERAPEUTIC USE OF SEALED SOURCES Not Applicable for this application	
	Detailed Information Attached; and
	Appendix L Procedures Followed; or *(Check One)*
	Equivalent Procedures Attached
21. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE GASES (e.g., Xenon – 133) Not Applicable	
	Detailed Information Attached
22. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE MATERIAL IN ANIMALS Not Applicable	
	Detailed Information Attached
23. PROCEDURES AND PRECAUTIONS FOR USE OF RADIOACTIVE MATERIAL SPECIFIED IN ITEM 6.b	
X	Detailed Information Attached

24. PERSONNEL MONITORING DEVICES

TYPE (Check appropriate box)			SUPPLIER	EXCHANGE FREQUENCY
a. WHOLE BODY	X	FILM	Searle Health Physics Services	Monthly
		TLD		
		OTHER (Specify)		
b. FINGER		FILM		
		TLD		
		OTHER (Specify)		
c. WRIST		FILM		
		TLD		
		OTHER (Specify)		

d. OTHER *(Specify)*

Applicant 1563
Check No. #300 (7A)
Amount/Fee Category
Type of Fee APPLICATION
Date Check Rec'd AUG 7 1980
Received By Brown

RECEIVED BY LFMB
Date AUG 7 1980
Log AUG P61 N.L.
By Brown
Orig. To
Action Compl. 8/7/80

25. FOR PRIVATE PRACTICE APPLICANTS ONLY

a. HOSPITAL AGREEING TO ACCEPT PATIENTS CONTAINING RADIOACTIVE MATERIAL

NAME OF HOSPITAL
Not applicable for teletherapy

MAILING ADDRESS

CITY | STATE | ZIP CODE

b. ATTACH A COPY OF THE AGREEMENT LETTER SIGNED BY THE HOSPITAL ADMINISTRATOR.

c. WHEN REQUESTING THERAPY PROCEDURES, ATTACH A COPY OF RADIATION SAFETY PRECAUTIONS TO BE TAKEN AND LIST AVAILABLE RADIATION DETECTION INSTRUMENTS.

26. CERTIFICATE

(This item must be completed by applicant)

The applicant and any official executing this certificate on behalf of the applicant named in Item 1a certify that this application is prepared in conformity with Title 10, Code of Federal Regulations, Parts 30 and 35, and that all information contained herein, including any supplements attached hereto, is true and correct to the best of our knowledge and belief.

a. LICENSE FEE REQUIRED
(See Section 170.31, 10 CFR 170)

RECEIVED '80 JUL 30 PM 1 20

(1) LICENSE FEE CATEGORY:
7A: New License Sealed Sources in Teletherapy

(2) LICENSE FEE ENCLOSED: $ 300.00

b. APPLICANT OR CERTIFYING OFFICIAL *(Signature)*
Richard A. Morrison

(1) NAME *(Type of Print)*
Richard A. Morrison, M.D.

(2) TITLE
Director, The Radiarium

c. DATE
July 15, 1980

FORM NRC-313M (8-78)

PRIVACY ACT STATEMENT

Pursuant to 5 U.S.C. 552a(e)(3), enacted into law by section 3 of the Privacy Act of 1974 (Public Law 93-579), the following statement is furnished to individuals who supply information to the Nuclear Regulatory Commission on Form NRC-313M. This information is maintained in a system of records designated as NRC-3 and described at 40 Federal Register 45334 (October 1, 1975).

1. **AUTHORITY** Sections 81 and 161(b) of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2111 and 2201(b)).

2. **PRINCIPAL PURPOSE(S)** The information is evaluated by the NRC staff pursuant to the criteria set forth in 10 CFR Parts 30-36 to determine whether the application meets the requirements of the Atomic Energy Act of 1954, as amended, and the Commission's regulations, for the issuance of a radioactive material license or amendment thereof.

3. **ROUTINE USES** The information may be used: (a) to provide records to State health departments for their information and use; and (b) to provide information to Federal, State, and local health officials and other persons in the event of incident or exposure, for their information, investigation, and protection of the public health and safety. The information may also be disclosed to appropriate Federal, State, and local agencies in the event that the information indicates a violation or potential violation of law and in the course of an administrative or judicial proceeding. In addition, this information may be transferred to an appropriate Federal, State, or local agency to the extent relevant and necessary for a NRC decision or to an appropriate Federal agency to the extent relevant and necessary for that agency's decision about you. A copy of the license issued will routinely be placed in the NRC's Public Document Room, 1717 H Street, N.W., Washington, D.C.

4. **WHETHER DISCLOSURE IS MANDATORY OR VOLUNTARY AND EFFECT ON INDIVIDUAL OF NOT PROVIDING INFORMATION** Disclosure of the requested information is voluntary. If the requested information is not furnished, however, the application for radioactive material license, or amendment thereof, will not be processed.

5. **SYSTEM MANAGER(S) AND ADDRESS** Director, Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

FORM NRC-313M
(8-78)

Alternate to Form NRC-313M
(8-78)

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

1.a. NAME AND MAILING ADDRESS OF APPLICANT:

Richard A. Morrison, M.D.
The Radiarium
17525 Medical Center Parkway
Independence, Missouri 64057

TELEPHONE NO.: Not yet installed - See Item 2 below.

1.b. STREET ADDRESS(ES) AT WHICH RADIOACTIVE MATERIAL WILL BE USED:

See Item 1.a above.

2. PERSON TO CONTACT REGARDING THIS APPLICATION:

Richard A. Morrison, M.D.
9021 Delmar
Prairie Village, Kansas 66207

TELEPHONE NO.: (913) 649-6592

3. THIS IS AN APPLICATION FOR A NEW LICENSE.

4. INDIVIDUAL USER(S):

Richard A. Morrison, M.D.
Licensed Physician in the State of Kansas - No. 12645; July 15, 1961; Registered in Wyandotte County. OK
Licensed Physician in the State of Missouri - No. 28338; June 24, 1961; Registered in Jackson County.
Certified by the American Board of Radiology in General Radiology on June 14, 1968. OK
Certified by the American Board of Radiology in Therapeutic Radiology on June 6, 1969. OK
See Annex A for CURRICULUM VITAE.

5. RADIATION SAFETY OFFICER (RSO):

a. ON SITE: Richard A. Morrison, M.D.
See Annex A for training and experience.

b. CONSULTING: Peter J. Debus, M.S.
Certified by the American Board of Radiology in Radiological Physics - December 1978.

6.a. RADIOACTIVE MATERIAL FOR MEDICAL USE:

Not Applicable, since this is an application for a teletherapy license.

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APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

6.b. RADIOACTIVE MATERIAL FOR USES NOT LISTED IN ITEM 6.a.:

ELEMENT AND MASS NUMBER	CHEMICAL AND/OR PHYSICAL FORM	MAXIMUM POSSESSION LIMITS IN CURIES OF ACTIVITY
Cobalt-60	Teletherapy sealed sources (AECL C-146 or C-151).	17,000 curies (2 sources of not more than 8,500 curies each). Each source is rated at 7,500 RHM.

DESCRIBE PURPOSE OF USE: One source to be used in an AECL Theratron 780 teletherapy unit for the treatment of humans. One source in its shipping container to be in possession of the licensee as necessary to the replacement of the source in the teletherapy unit only.

7. THE MECHANICAL AND/OR ELECTRICAL BEAM STOPS:

The mechanical and electrical beam stops, which will be operational at the time of installation of the AECL Theratron 780 teletherapy unit, are discussed in Annex B.

8. PLAN AND ELEVATION DETAILS OF TELETHERAPY FACILITY:

Annex C includes a description of the shielding material, thickness, and density of each barrier in the teletherapy room, as well as a floor plan and elevation drawing of the room itself. The location of the teletherapy unit isocenter and the distances from the iso-center to areas adjacent to the shielded facility are indicated on the drawings.

9. PATIENT VIEWING SYSTEM:

Two completely independent closed circuit television systems will be installed to view the patient during treatment. One television camera and monitor will serve as a backup to the other television camera and monitor. Both systems will be operated during treatment. The teletherapy unit will not be used for treatment, if both patient viewing systems become inoperable.

10. PENETRATIONS AND VOIDS:

Annex D includes drawings of the teletherapy room entrance, ventilation ducts, pipes, conduits and all other penetrations and voids in the treatment room walls, ceiling or floor. A description of the shielding used to compensate for the voids is included in Annex D.

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THE RADIARIUM

11. Door Interlocks:
The door leading into the teletherapy room will be provided with an interlock to control the "ON-OFF" mechanism of the Theratron-780 unit. The interlock will cause the source to move to the "OFF" condition if the door is opened during source exposure. The mechanism will be so wired that the source cannot be returned to the "ON" condition until the system is reset at the control panel.

12. Calculations of Radiation Levels:
Annex E provides a general description of the assumptions and parameters which were utilized in calculating the radiation levels that will exist in each area adjacent to the shielded facility. This annex also contains a floor plan and elevation drawing, showing the locations of the various points used in calculating the radiation levels, as well as the calculation sheets themselves.

While occupancy factors were not considered in evaluating the exposure rates at the various locations, workload was included in determining whether the requirement to keep the dose equivalent to any individual continuously present in an UNRESTRICTED area at or less than two millirem in any one hour would be met. Shielding for first order scattered and leakage radiation was designed to keep the maximum instantaneous exposure rates at or below 5 mR per hour for a 7,500 RHM source. At this maximum output, the greatest number of individual ports to be treated in an hour would be eight, with an approximate total "ON" time of 16 minutes in one hour. Therefore, if the maximum exposure rate were 5 mR/hour at an area adjacent to the shielded facility, even with continuous occupancy, the maximum dose equivalent to an individual in any one hour would be 1.33 millirem.

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12. Calculations of Radiation Levels (continued):

The second criterion for an UNRESTRICTED area is that an individual continuously present in the area would not receive more than 100 millirems in any seven consecutive days. It would be most unlikely that this facility would treat forty hours per week at such a high workload as eight individual ports per hour; however, if such an assumption relative to the workload were made, an individual present in the area would not receive more than 54 millirem in seven consecutive days.

As discussed in Annex C, the density of the shielding material, namely concrete, was estimated by the architect to be not less than 145 pounds per cubic foot. Since the standard density of concrete is normally listed as 147 pounds per cubic foot, the shielding calculations and the calculated radiation levels took this slightly lower density into account. However, it is likely that the actual radiation levels will be slightly lower because, subsequently, the concrete supplier has specified a concrete density of 152 pounds per cubic foot.

Radiation levels, from multiple scattered radiation to that section of the West wall containing the door, were not calculated but rather were approximated.

THE RADIARIUM

13. Radiation Safety Program:
Annex F is the Radiarium Program for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable (ALARA). This program is based on the Model Program which was enclosed with the NRC letter to all medical licensees dated June 16, 1980. Since this is an application for a private practice physician to be licensed for use of a Co-60 teletherapy unit, references in the Model Program to a Radiation Safety Committee do not apply. In particular, Section II of the Model Program has been modified in the Radiarium Program for the following reasons:

a. Review of Proposed Users and Uses. Since the Radiation Safety Committee does not exist in this private practice environment, and since the Radiation Safety Officer is also the Director and the only User (for the near future) and since, for the purpose of this license, the only use will be external beam teletherapy, it is unlikely that paragraphs 1, 2, and 3 of Section IIa could apply.

b. Delegation of Authority. It is assumed that in the case of a private practice, such as exists here, the authority normally vested with the Radiation Safety Committee will rest with the Radiation Safety Officer since the RSC does not exist.

c. Review of ALARA Program. The three items mentioned in this section overlap into the responsibilities of the Radiation Safety Officer, which are outlined in Section III.

The Radiarium Program will be general enough to allow for expansion of staff to include a radiation safety committee.

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14. Personnel Monitoring Devices:
Searle Diagnostics, Inc., Health Physics Services, will provide clip-on film badges for all occupationally exposed personnel to determine "whole body and skin" X-, gamma and beta dose. Badges are changed and reported monthly.

15. Radiation Survey and Monitoring Instruments:
The Radiarium will be equipped with a Victoreen Model 470 Panoramic Survey Meter with an unsealed air ionization chamber which is capable of detecting Alpha (greater than 8 MeV), Beta (greater than 120 keV), Gamma, and X-ray with a window thickness of 17 mg/cm^2. This meter has both a rate and an integrate mode and has the following exposure rate ranges:

i)	0 - 3	mR/hr	and	R/hr
ii)	0 - 10	mR/hr	and	R/hr
iii)	0 - 30	mR/hr	and	R/hr
iv)	0 - 100	mR/hr	and	R/hr
v)	0 - 300	mR/hr	and	R/hr
vi)	0 - 1000	mR/hr	and	R/hr

This survey meter will be calibrated annually. It is equipped with a long-lived check source which is read:

i) before each use

ii) after each maintenance and/or battery change

iii) at least quarterly

The Nuclear Associates Model 05-433 "PRIMALERT 10" area radiation monitor with Model 05-440 back-up battery pack will be installed within the teletherapy room as an aid in early detection of teletherapy machine malfunctions with accompanying hazardous radiation levels.

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16. Calibration of Survey Meter:
The Victoreen Model 470 Panoramic Survey Meter will be calibrated annually in accordance with Appendix D, Section I, "Methods for Calibration of Survey Meters, Including Procedures, Standards and Frequency", which was provided with "Licensing Guide for Teletherapy Programs". This annual calibration and quarterly checks will be performed by:

R. Emory Larimore, Health Physicist
Radiation Consultants of Mid-America
4955 Westwood Terrace
Kansas City, Missouri 64112
NRC License No. 24-18831-01

17. Semi-Annual Leak Test of the Teletherapy Source:
The cobalt-60 teletherapy source will be tested for leakage every sic months by:

R. Emory Larimore, Health Physicist
Radiation Consultants of Mid-America
4955 Westwood Terrace
Kansas City, Missouri 64112
NRC License No. 24-18831-01

The leak test performed by the above named consultant shall be sufficiently sensitive to detect 0.05 microcurie of contamination on the test sample.

18. Emergency Procedures:
A copy of the Emergency Procedures, which will be posted at the console, is enclosed as Annex G.

19. Service:
Any service operations on the teletherapy source, including the required five year service and maintenance inspection, as well as source exchanges, will be performed by persons or organizations licensed by the Nuclear Regulatory Commission to perform these services. At this time, it is anticipated that Atomic Energy of Canada Limited, Ottawa, Canada, or its regional service office

THE RADIARIUM

in Dallas, Texas, will perform the required maintenance or source exchanges.

20. Radiation Survey Report:

Prior to initiation of a treatment program, and subsequent to each installation of a teletherapy source, radiation surveys and operational tests will be performed by a qualified expert and a copy of the results in a radiation survey report will be furnished to the NRC for evaluation. The surveys and tests to be conducted will be performed in accordance with Appendix A "Teletherapy Survey Reports" to this Licensing Guide.

Applicant's or Certifying Official's Signature: Richard A Morrison

Name: Richard A. Morrison, M.D.

Title: Director, The Radiarium

DATE: July 15, 1980

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

ANNEX A - ITEMS NOS. 4 AND 5.

CURRICULUM VITAE

of

Richard A. Morrison, M.D.

Date and Place of Birth: July 25, 1934;
Kansas City, Missouri

Marital Status:
Married 1958, 3 children

Education:
University of Kansas, Lawrence, Kansas;
1952-54.
William Jewel College; Liberty, Missouri
1954-56; A.B. (Chemistry), June 1956.
University of Kansas School of Medicine;
Kansas City, Kansas; 1956-60;
M.D. June 6, 1960.

Postgraduate Training:
Internship (Rotating); University of Kansas
Medical Center; Kansas City, Kansas;
1960-61.
Residency (Internal Medicine); St. Luke's
Hospital; Kansas City, Missouri; 1961-62.
Residency (General Radiology); University of
Kansas Medical Center; Kansas City,
Kansas; July 1-31, 1962 and Aug. 17, 1964-
June 30, 1967.
USPHS Senior Clinical Traineeship in Cancer Control
(Therapeutic Radiology)
University of Kansas Medical Center;
Kansas City, Kansas; July 1, 1967-June 30, 1969.

Specialty Certification:
Diplomate, American Board of Radiology
(General Radiology); June 14, 1968.
Diplomate, American Board of Radiology
(Therapeutic Radiology); June 6, 1969.

Military Service:
Captain, United States Air Force, 3640th
U.S.A.F. Hospital; Laredo AFB, Texas; 1962-64.

Medical Licensure:
Kansas - No. 12645; July 15, 1961;
Registered in Wyandotte County.
Missouri - No. 28338; June 24, 1961;
Registered in Jackson County.

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ANNEX A - ITEMS NOS. 4 AND 5 (continued).

Past Appointments:
- Chief, Radiology & Internal Medicine, 3640th U.S.A.F. Hospital; Laredo AFB, Texas; 1962-64.
- Head, Division of Radiation Therapy; University of Kansas Medical Center; Oct. 1, 1969-June 30, 1972.
- Member, Research Committee, Mid-America Cancer Center Program, University of Kansas Medical Center; 1974-77.
- Acting Chairman, Department of Radiation Therapy; University of Kansas Medical Center; July 1, 1972-Oct. 31, 1976.

Present Appointments:
- Assistant Professor, University of Kansas Medical Center; July 1, 1967-present.
- Associate Scientist, Mid-America Cancer Center Program, University of Kansas Medical Center, Aug. 1, 1975-present.
- Consultant, Kansas City VA Hospital; K.C., MO; 1968-present.
- Consultant, Bethany Medical Center; K.C., KS; 1974-present.
- Consultant, Providence-St. Margaret Medical Center; K.C., KS; 1974-present.
- Consultant, Kansas City Tumor Institute Foundation, 1974-present.
- Member, Committee for Radiation Therapy, Kansas Radiologic Society, 1974-present.
- Member (full), Southwest Oncology Group; 1975-present.
- Medical Liaison Officer Network Representative for Kansas, U.S. Environmental Protection Agency; 1970-present.

Professional Society Memberships:
- Wyandotte County Medical Society
- Kansas Medical Society
- American Medical Association
- Greater Kansas City Radiologic Society
- Kansas Radiologic Society
- American College of Radiology
- Radiologic Society of North America
- American Society of Therapeutic Radiologists
- American Radium Society

Publications:

1. Morrison, R.A.: The Radius-dose Relationship in Linear-Source Therapy. Amer. J. Roent. 123: 179-181, Jan. 1975.

DATE: July 15, 1980

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ANNEX A - ITEMS NOS. 4 AND 5 (continued).

2. Morrison, R.A.: A Drop-in Treatment Shell Support. Radiology 114: 734-735, Mar. 1975.

3. Morrison, R.A.: The Total Biological Dose. Radiology 114: 717-721, Mar. 1975.

4. Oliver, L.M. and Morrison, R.A.: Automatic Correction of On-Off Error in Telecobalt Therapy. Radiologic Technology 47: 250-251, Jan - Feb 1976.

5. Morrison, R.A.: Spherical Lead Shields for Megavoltage Radiotherapy. Radiology 127: 546-547, May 1978.

6. Morrison, R.A.: The Total Biological Effect. (Abst.) Proceedings of the American Radium Society's 61st Annual Meeting, Los Angeles, Calif., Mar. 4-8, 1979.

7. Morrison, R.A.: Surgery, Radiotherapy, And Chemotherapy In A Hospital-based Cancer Practice. (Abst.) Proceedings of the American Radium Society's 61st Annual Meeting, Los Angeles, Calif., Mar. 4-8, 1979.

Scientific Papers Presented At National Meetings:

1. Morrison, R.A.: A Drop-in Treatment Shell Support. XVI Annual Meeting of the American Society of Therapeutic Radiologists, Key Biscayne, Florida, Oct. 30-Nov. 3, 1974.

2. Morrison, R.A.: Spherical Lead Shields. XIX Annual Meeting of the American Society of Therapeutic Radiologists, Denver, Colorado, Nov. 1-5, 1977.

Scientific Exhibits and Films:

1. Morrison, R.A.: Radiation Treatment of Cancer of the Larynx, Stage I. University of Kansas Medical Center Film Library, 1968.

2. Morrison, R.A.: A Drop-in Treatment Shield Support. XVI Annual Meeting of the American Society of Therapeutic Radiologists. Key Biscayne, Florida, Oct. 30-Nov. 3, 1974.

DATE: July 15, 1980

THE RADIARIUM

3. Morrison, R.A.: Spherical Lead Shields. XIX Annual Meeting of the American Society of Therapeutic Radiologists. Denver, Colorado, Nov. 1-5, 1977.

4. Morrison, R.A.: The Total Biological Effect. XX Annual Meeting of the American Society of Therapeutic Radiologists. Los Angeles, Calif., Oct. 31-Nov. 4, 1978.

Patents:

1. Morrison, R.A. and Johnston, C.W.: Method and Apparatus For Making A Focused Shield. U.S. Patent No. 3937971 granted Feb. 10, 1976.

2. Morrison, R.A.: Biplane Radiographic Localization Of The Target Center For Radiotherapy. U.S. Patent No. 3991310 granted Nov. 9, 1976.

3. Morrison, R.A.: Method and Apparatus For Automatically Providing Radiation Therapy Treatment Conforming To A Desired Volume Of Tissue. U.S. Patent Application Pending.

4. Morrison, R.A.: Method and Apparatus For Homogeneously Irradiating The Vaginal Mucosa With A Linear Source Uterovaginal Applicator. U.S. Patent Application Pending.

DATE: July 15, 1980

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

Annex B - Item No. 7
The Mechanical and/or Electrical Beam Stops

According to Section B.3.3 of Specification No. GS2200 for the AECL Theratron 780 Teletherapy Unit, "on a Beamstopper unit and with the head at 180°, the beamstopper will absorb an average of 99.7% of the primary beam, and up to 35° of scatter radiation regardless of collimator setting". The beamstopper would intercept the entire primary beam for a collimator setting of 30 cm x 30 cm even if the head were swiveled 5° either side of center.

- not on Cal. Sheet

The primary beam will be limited to the beamstopper with provision for off beamstopper radiation only when the primary beam is directed to the floor (vertical down).

DATE: July 15, 1980

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

Annex C - Item No. 8
Plan and Elevation Details of Teletherapy Facility

Much of this information will be repeated in Annex E - Item No. 12 as part of the assumptions used in calculating radiation levels.

The shielding design was based on the architect's initial assumption that the concrete used in the walls and ceiling would have a density of at least 145 pounds per cubic foot. This led to a conservatively safe shielding design since the actual concrete density was 148.52 pounds per cubic foot. Copies of the Mix Design and the Concrete Cylinder Test Data are enclosed with this annex. Gypsum wall board, which is 5/8 inch thick, lines the interior surface of all vertical barriers, as well as the outer surface of the West and near North walls. The manufacturer listed the weight of his gypsum wall board as 2.375 pounds per square foot, while, for comparison, the weight of a one inch thick, one square foot slab of concrete would be 12.08 pounds. For shielding purposes, we may assume the 5/8 inch gypsum wall board is equivalent to 0.2 inch of concrete and that the double thickness on the West and near North walls have the equivalent shielding of 0.4 inch of concrete.

The West wall, adjacent to Superficial X-Ray Room/Mold Room, has 26 inches of concrete plus two thicknesses of gypsum board for a total shielding equivalent of 26.4 inches of concrete.

The near North wall, adjacent to the Control Desk, has 20 inches of concrete plus two thicknesses of gypsum board for a total shielding equivalent of 20.4 inches of concrete.

The West wall, containing the entry door, has 12 inches of concrete plus two thicknesses of gypsum board for a total shielding equivalent of 12.4 inches of concrete.

DATE: July 15, 1980

Annex C - Item No. 8 (continued):

The four foot wide entry door has 5 mm of lead shielding.

The far North wall, an outside wall, has 14 inches of concrete plus one thickness of gypsum board for a total shielding equivalent of 14.2 inches of concrete.

The East wall, an outside wall, has 22 inches of concrete plus one thickness of gypsum board for a total shielding equivalent of 22.2 inches of concrete. A major portion of the southern half of this wall is below ground, that is, covered by earth.

The South wall, an outside wall, has 18 inches of concrete plus one thickness of gypsum board for a total shielding equivalent of 18.2 inches of concrete. With the exception of a small area near the ceiling, this entire wall is below ground, that is, covered by earth.

The ceiling has at least 20 inches of concrete throughout, with an additional seven inches of concrete in a 10 foot x 10 foot slab centered over the teletherapy unit isocenter. This ceiling is the unoccupied roof of the building.

There are enclosed with this annex, a 1/4 inch to the foot scale floor plan of the teletherapy room, a 1/4 inch to the foot scale elevation plan of the teletherapy room, and a 1/8 inch to the foot scale floor plan to show the teletherapy room in relation to other rooms within The Radiarium. Distances from the source or isocenter to the various barriers are shown on the 1/4 inch to the foot scale drawings.

DATE: July 15, 1980

ANNEX - C - ITEM NO. 8

HUB MATERIALS, INC.

Plant Location
1700 North 291 Highway
Sugar Creek, Missouri 64054

Telephone
257-5300

May 22, 1980

Crowley Construction Company
3200 South M-291
Independence, Missouri 64057

Re: Radiarium Center Building
Medical Center Park
Independence, Missouri

Gentlemen,

As per your request, we are pleased to submit the following mix design used for the above mentioned job.

Cement - Type 1	575
Limestone rock	1650
Missouri River sand	1650
Water	225

Yield-- 27.0 cubic ft. Weight 152 lbs per cubic ft

Hoping this meets with your approval and may we be of further service to you.

Yours truly,

HUB MATERIALS, INC.

by, Ralph W. Klein
Ralph W. Klein

RWK/mgw

04676

DATE: July 15, 1980

ANNEX C - ITEM NO. 8

KANSAS CITY TESTING LABORATORY

P.O. Box 6323
SHAWNEE MISSION, KANSAS 66206
TELEPHONE 648-2303

Laboratory No. 3492 Date 6-10-80

TEST DATA
CONCRETE CYLINDERS

Received 6-6-80 From CROWLEY WADE MILSTEAD, INC. ENGINEERS

Project RADIARIUM

Location of Pour INFORMATION NOT AVAILABLE WITH CYLINDERS

Height, ins. 12

Diameter, ins. 6

Area, sq. ins. 28.27

Cylinder marking	A	B	C
Date cast	6-2-80	6-2-80	6-2-80
Date crushed	6-9-80	6-30-80	6-30-80
Age, days	7	28	28
Crushing load, lbs.	118500	163250	162500
Compressive strength lbs./sq. in.	4192	5774	5748
	*148.83	*148.62	*148.10
Fracture	CA	CA	CA

(Code: C—conical, D—diagonal, I—irregular, M—mortar, A—aggregate)

Slump, ins. Air % Unit Wt. lb./cu. ft.

Supplier HUB Class Tkt. No. Trk. No.

Coarse aggregate, lbs.: Dispensing time
Fine aggregate, lbs.: Sampling time
Cement, lbs.: Weather
Water, gals.: Water added

REMARKS: MADE BY CONTRACTOR
*UNIT WT. IN LBS/FT^3

CC: CROWLEY, WADE, MILSTEAD-BRADD CROWLEY-4
DS/cjm

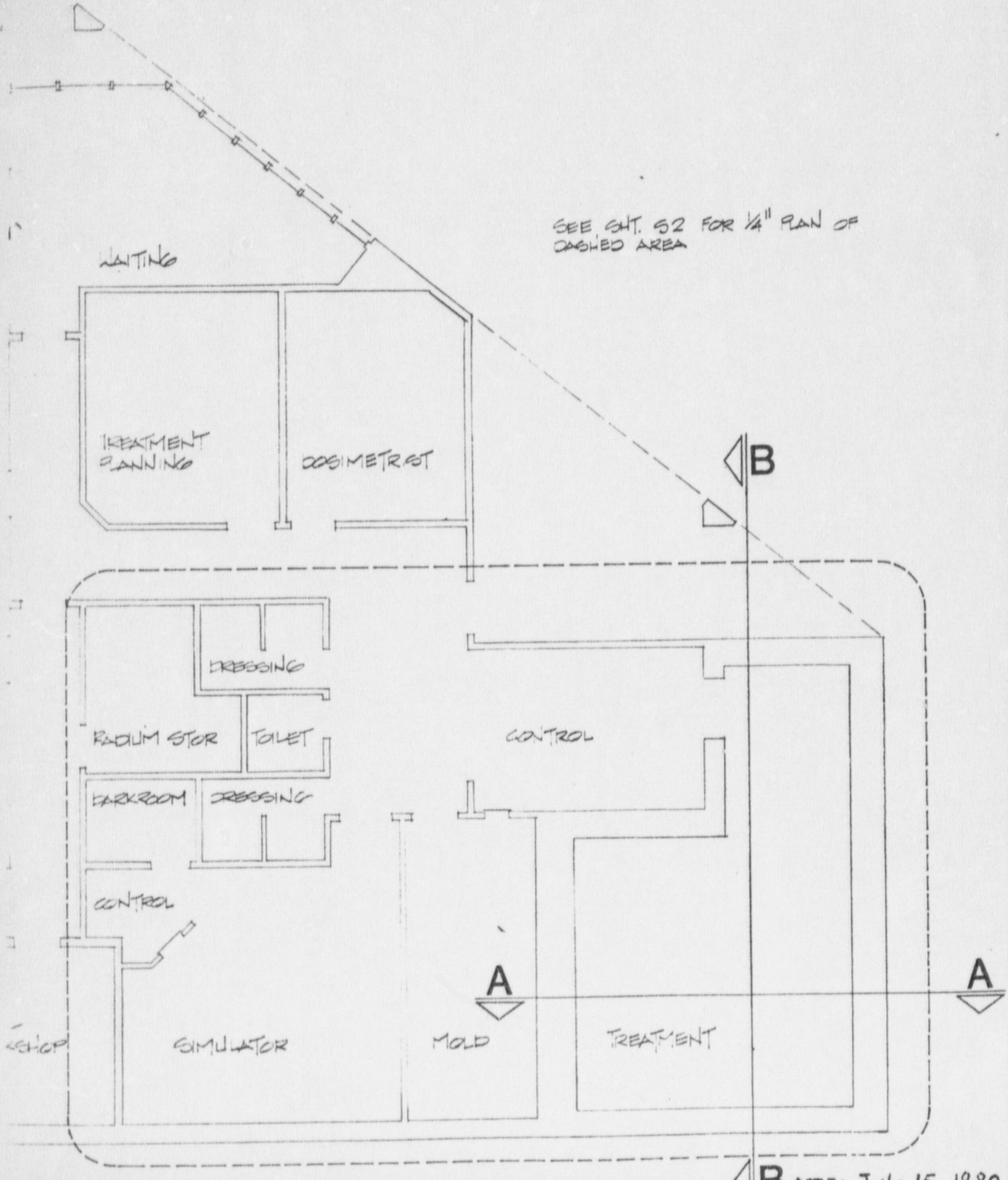
Kansas City Testing Laboratory
(Original Signed by)

[signature]

DATE: July 15, 1980

ANNEXES C+E ITEMS NOS. 8+12

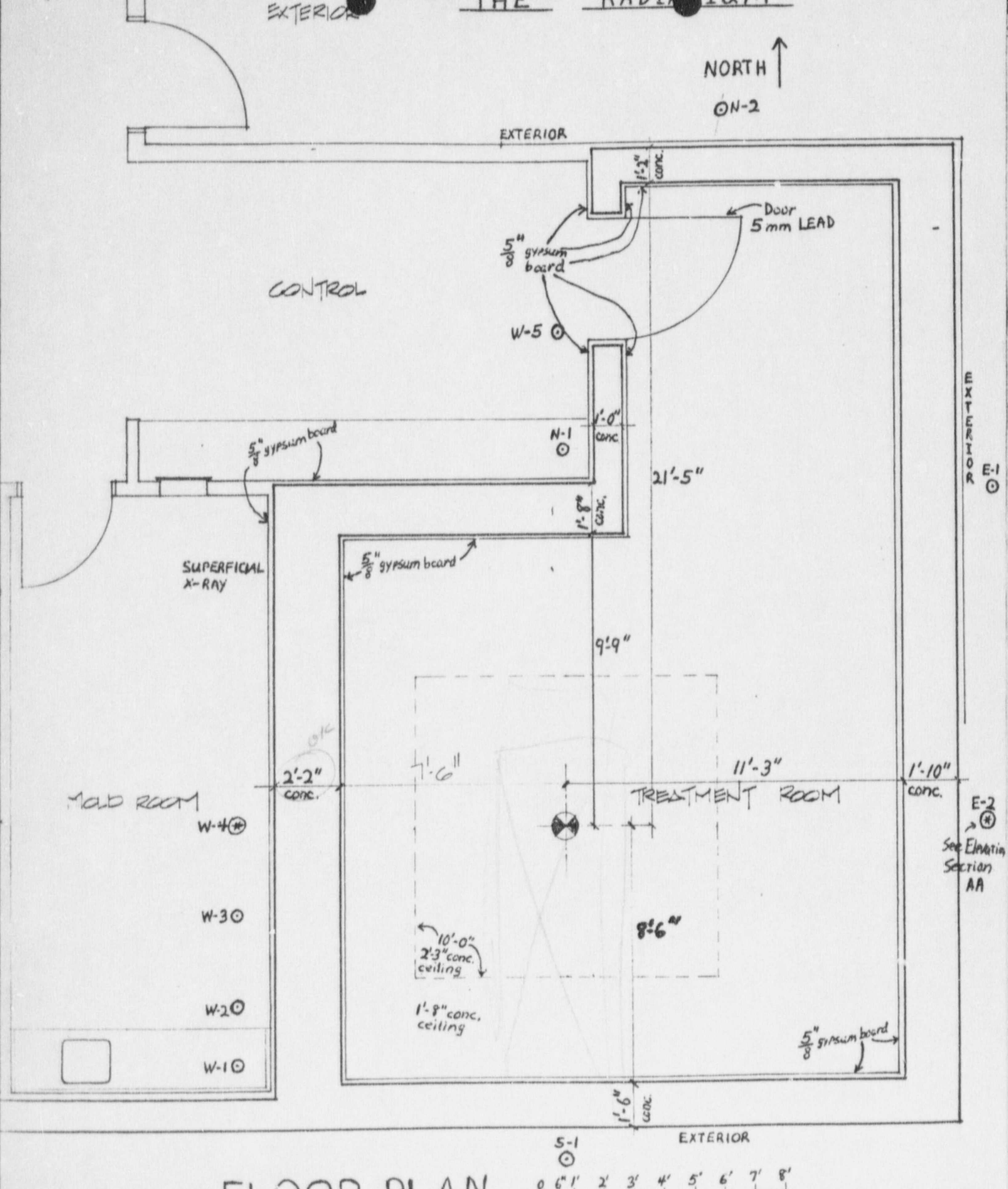
THE RADIARIUM



DATE: July 15, 1980

ANNEXES C+E ITEMS NOS. 8+12

THE RADIA[illegible]IUM



FLOOR PLAN

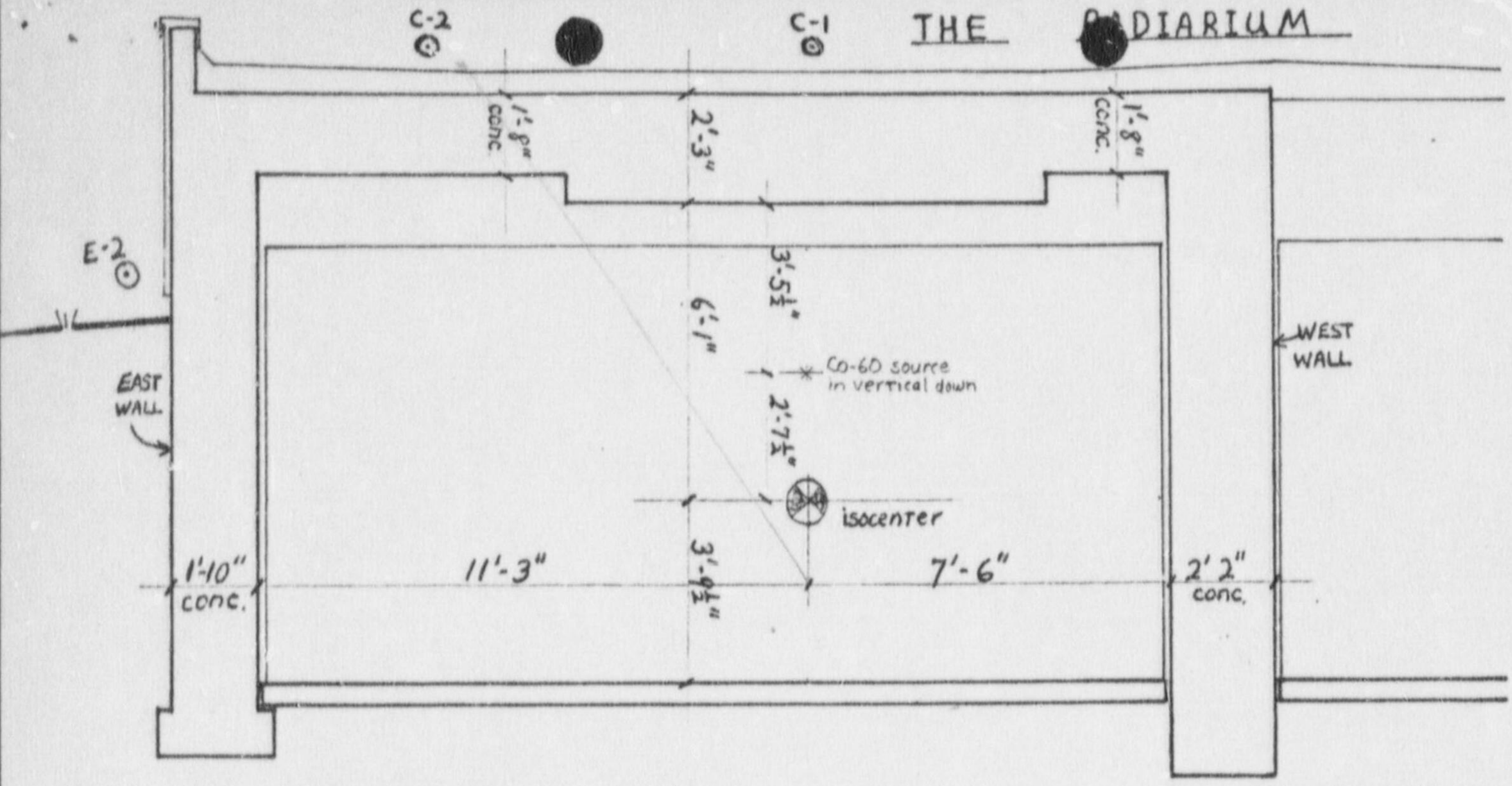
0 3" 6" 9" 1' 2' 3' 4' 5' 6' 7' 8'

1/4" = 1'-0"

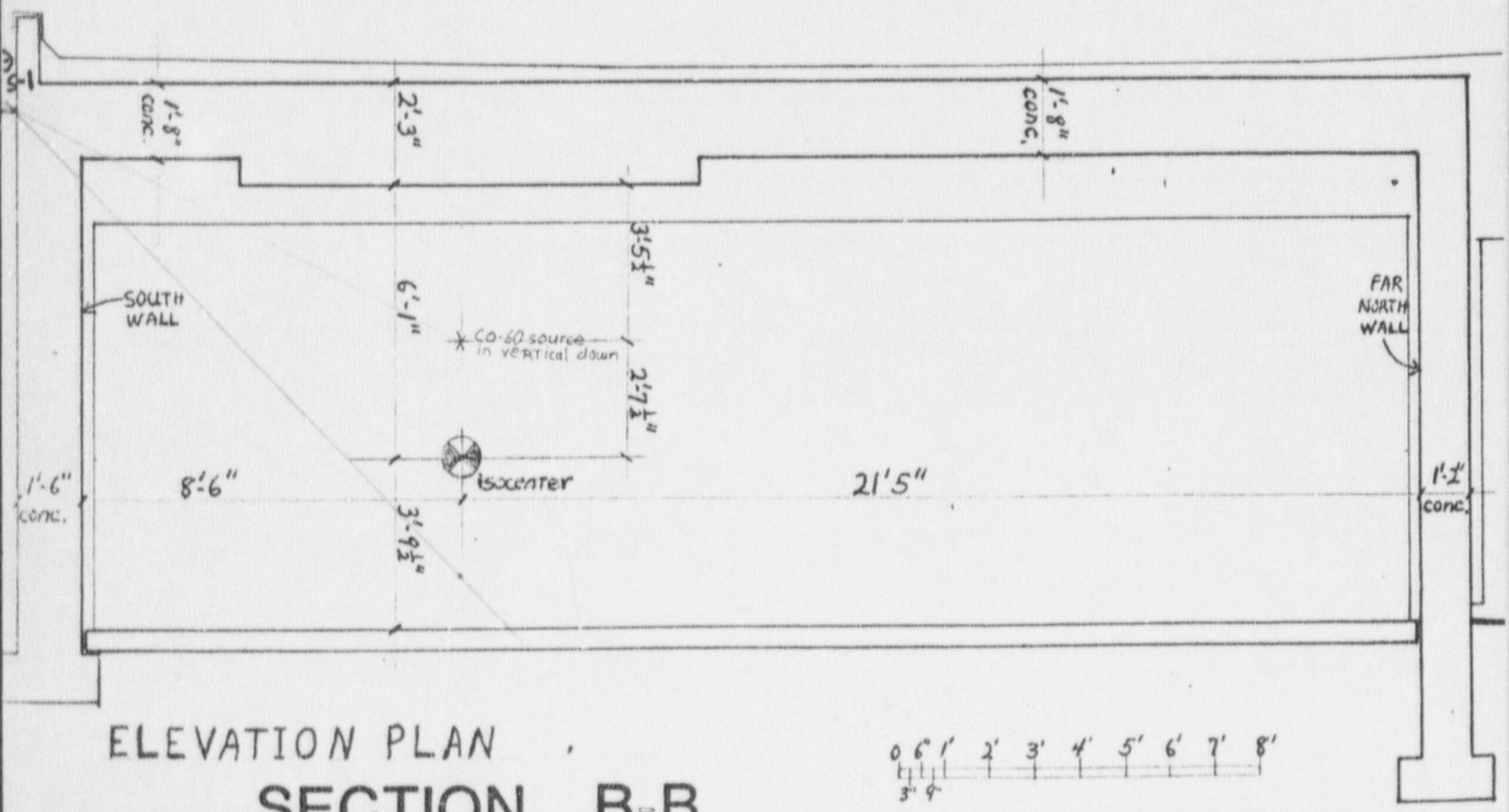
DATE: July 15, 1980

ANNEXES C + E ITEMS NOS. 8+12

THE RADIARIUM



SECTION A-A
1/4" = 1'-0"



SECTION B-B
1/4" = 1'-0"

DATE: July 15, 1980

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

Annex D - Item No. 10
Penetrations and Voids

Sheets S13 and S14 show details of duct penetrations in the West wall over the entry door. The supply duct, which is south of the return duct, is lined with 6 mm lead while the return duct, which is located in the north corner of the West wall, is lined with 5 mm lead. These penetrations are located above the acoustical ceiling.

Sheet S14 also shows conduit penetrations through the West wall between the supply and return ducts. Sheet S15 demonstrates these penetrations in a different perspective. Since less than 3 inches of concrete were lost in the wall shielding, no compensating shielding was used. At these locations, 9 inches of concrete were considered adequate shielding.

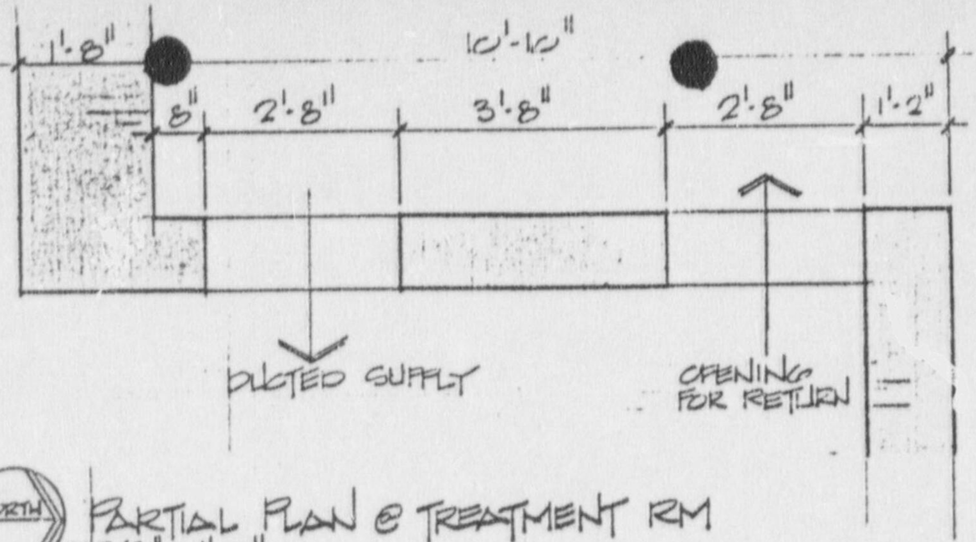
Sheet S15 shows penetration of the East wall by conduit for exterior lighting. At that location, the remaining concrete thickness was considered to offer adequate shielding without compensating shielding.

Sheet S16 shows conduit entering the treatment room from the near North wall in a trench cut into the footing under the near North wall. The conduit then passes under the concrete slab floor to the Theratron 780 pit. This arrangement does not interrupt the integrity of the existing shielding.

The conduit running vertically inside the South wall does not require compensating shielding, since its entire run is below finished grade. (See sheet S16 for illustration).

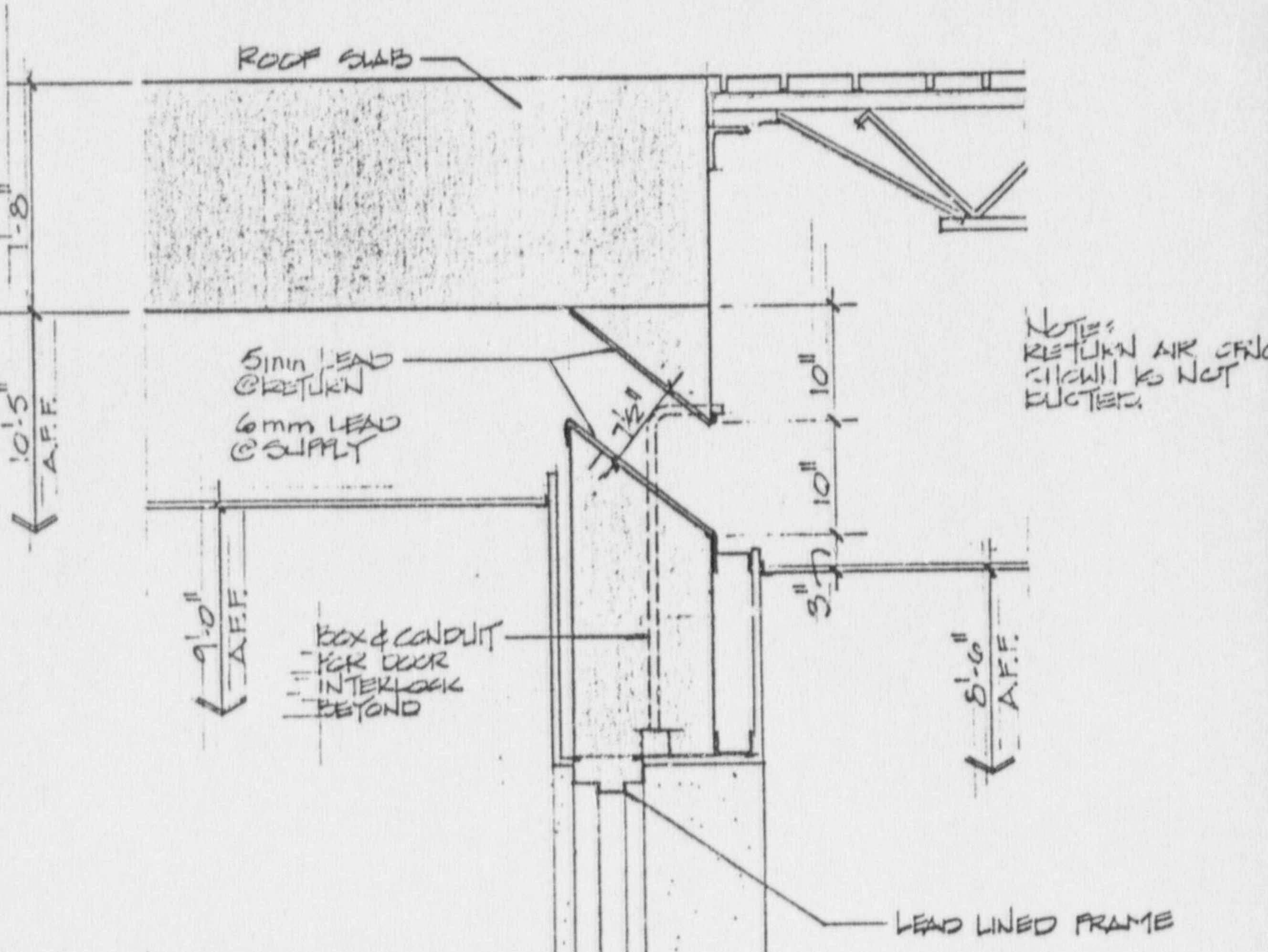
DATE: July 15, 1980

ANNEX. D
ITEM. NO. 10



NORTH

PARTIAL PLAN @ TREATMENT RM
3/8" = 1'-0"



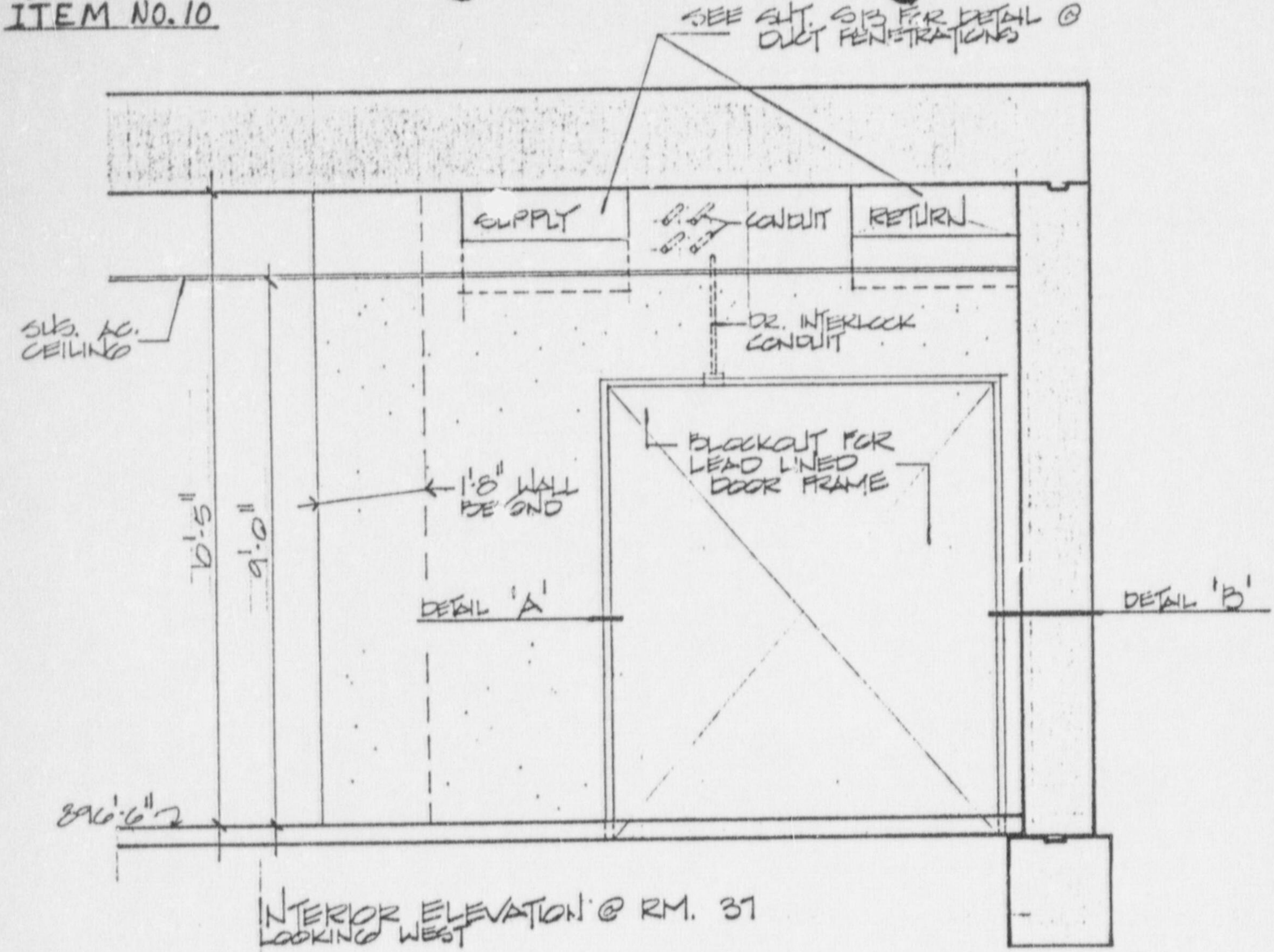
SECTION @ DUCT PENETRATIONS
3/4" = 1'-0"

DATE: July 15, 1980

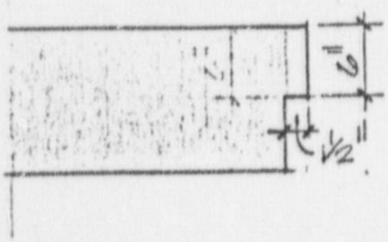
Duct Penetrations at Treatment Room #37 **The Radiarium** Medical Center Park, Independence, Missouri	**Crowley, Wade, Milstead, Inc.**	May 28, 1980 1621-1	**S13**

ANNEX D

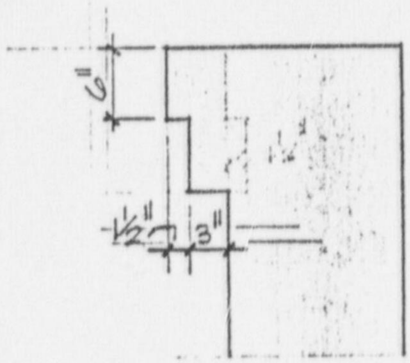
ITEM NO. 10



INTERIOR ELEVATION @ RM. 37
LOOKING WEST



DETAIL 'A'

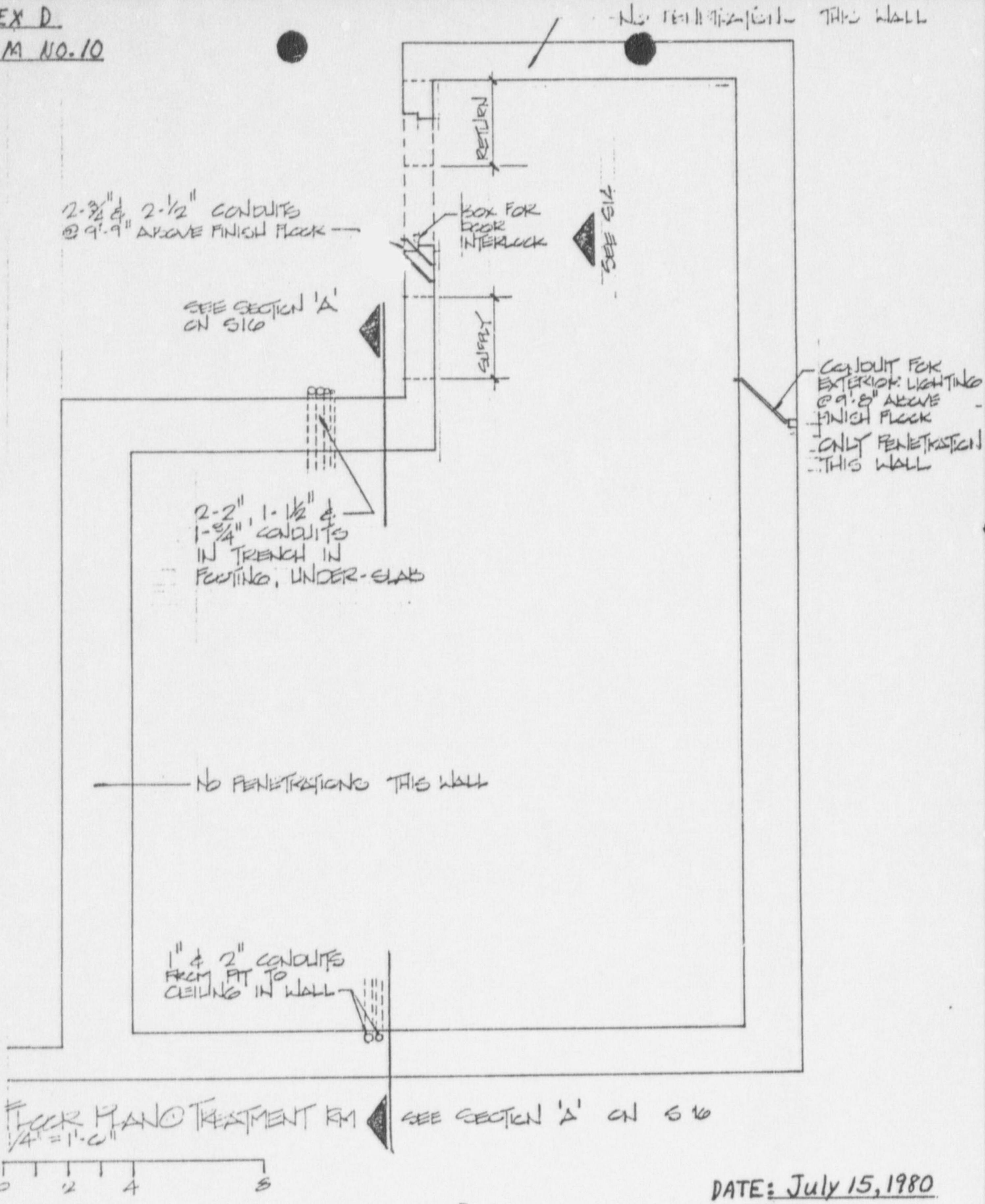


DETAIL B

DATE: July 15, 1980

Blockout for Door Frame **The Radiarium** Medical Center Park, Independence, Missouri	**Crowley, Wade, Milstead, Inc.**	May 30, 1980 1621-1	**S14**

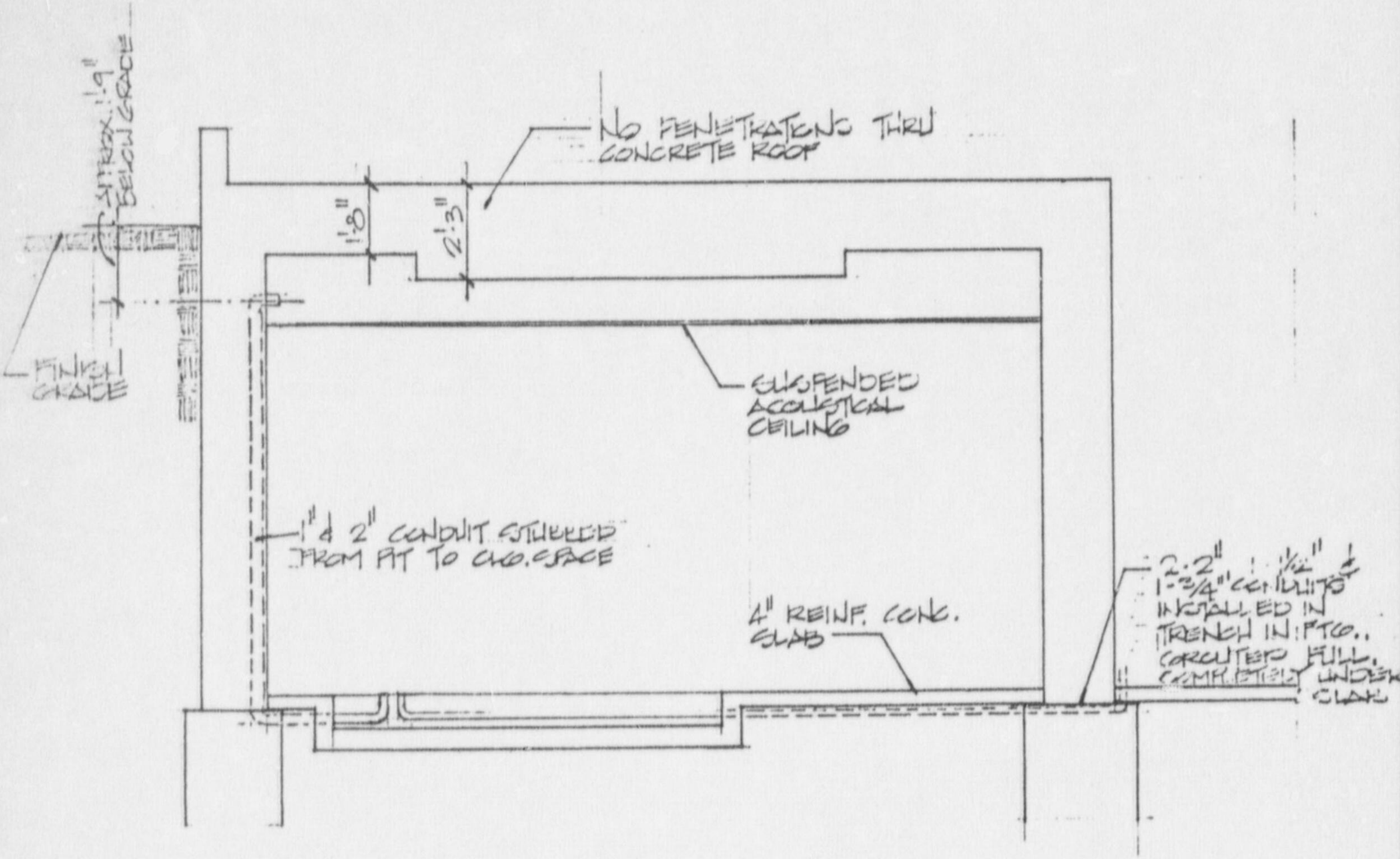
ANNEX D
ITEM NO. 10



DATE: July 15, 1980

Floor Plan Showing Treatment Room Penetrations **The Radiarium** Medical Center Park, Indepence, Missouri	**Crowley, Wade, Milstead, Inc.**	June 13, 1980 1621-1	**S 15**

ANNEX D
ITEM NO. 10



A SECTION THRU TREATMENT ROOM
1/4" = 1'-0"

0 2 4 8

NOTE: SEE SHT S15 FOR FLOOR PLAN LOCATIONS OF TREATMENT ROOM PENETRATIONS.

DATE: July 15, 1980

Section at Treatment Room Showing Conduit Configuration **The Radiarium** Medical Center Park, Independence, Missouri	**Crowley, Wade, Milstead, Inc.**	June 13, 1980 1621-1	**S 16**

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

Annex E - Item No. 12
Assumptions for Calculations of Radiation Levels

Equipment:

The AECL Theratron 780 Cobalt-60 Teletherapy Unit with beamstopper is to be installed in the Southeast corner room of the Radiarium. This unit is designed for fixed field or moving beam techniques, with an isocenter at 80 cm from the source. "The sourcehead capacity of the unit is guaranteed at a minimum of 125 Rmm". (This corresponds to 7500 Roentgens per hour at one meter or a maximum activity of 8375 Curies of Cobalt-60). From this statement, it has been assumed that the sourcehead of this unit meets the criteria for a protective source housing in accordance with paragraphs 4.2.1(a) and (b) of National Council on Radiation Protection and Measurements (NCRP) Report Number 33. This means that in the "OFF" position, the average exposure rate at one meter from the "stored" source is 2.0 mR/hour or less, and the maximum exposure rate at any single location one meter from the source will not exceed 10 mR/hour. This should not be a concern for shielding of the walls. However, leakage with the source in the "ON" position is of concern. Since the specifications for the Theratron 780 do not guarantee a lower leakage figure than that recommended by NCRP Report No. 33, leakage of 0.1% has been assumed, which would mean that a potential exposure rate of 7.5 R/hour could be experienced at a distance of one meter from the source in all directions except the collimator zone (which would be much higher, but fortunately intercepted by the beamstopper). With regard to the beamstopper, assumptions have been based on the following quotation from NCRP Report No. 49, section 6.4: "When a beam interceptor is provided, it should transmit not more than 0.1 percent of the useful beam. It also should reduce, by the same factor, the radiation scattered by the patient

Annex E - Item No. 12
Equipment (continued):
through an angle of up to 30 degrees from the isocenter. Unless it is established that the beam interceptor attenuates radiation scattered more than 30 degrees, the computation of radiation barrier thickness should be based on the assumption that there is no interceptor attenuation beyond 30 degrees." It should be noted that Paragraph 8.3.3 of the AECL Specifications for the Theratron 780 contains the following statement: "On a Beamstopper unit and with the head at 180^{o}, the beamstopper will absorb an average of 99.7% of the primary beam,..." This would indicate that the transmission of the primary beam through the beamstopper is 0.3%. With the patient in the beam, the net transmission would be reduced to 0.1% in accordance with the recommendation of NCRP Report No. 49 quoted above.

Workload:
NCRP Report No. 49 in Table 2 of Appendix C suggests that a typical weekly workload for busy installations is 32 patients per day for a Cobalt-60 teletherapy unit. At 80 cm SSD, this would be equal to 40,000 Roentgens per week at one meter. It was suggested that this facility be shielded for a maximum workload of 40 patients per day which would be equivalent to 50,000 R/week at one meter.

50,000/7500 6.7 hr ON/wk = 6.7/40 = .16 hr ON/hr or 10 min ON/hr but earlier they said 16 min ON/hr

Nature of Barriers:
All barriers are designed to shield for stray radiation, which includes both leakage and scattered radiation. It is assumed that the floor or the beamstopper will always intercept the primary beam. Separate calculations have been done for leakage radiation and for scattered radiation at a specified angle. According to paragraph B.2.3 of NCRP Report No. 49, "If the required barrier thickness for leakage and scattered radiations are found to be approximately the same, one HVL (Half Value Layer) should be added to the larger one to

Use latter figure

DATE: July 15, 1980

Annex E - Item No. 12

Nature of Barriers (continued):

obtain the required total secondary barrier thickness. If the two differ by at least one TVL (Tenth Value Layer), the thicker of the two will be adequate".

Occupancy:

All controlled areas, which include the hall and console area adjacent to the near North wall and the section of the West wall containing the door and the superficial x-ray/mold room, are assumed to have a full time occupancy (T = 1.0) with an exposure limit of 100 mR (0.1R) per week. The East wall and South wall are both outside walls with a very low occupancy (T = 1/16). The roof is also assumed to have a very low occupancy (T = 1/16); and the areas adjacent to these barriers are assumed to be noncontrolled areas with exposure limits of 10 mR (0.01R) per week.

Use:

The use (U) factor for 90° scatter to all walls except that section of the West wall containing the door is 1.0, and to the ceiling it is 0.5. The use factor for leakage radiation to all walls and ceiling, except for that section of the West wall containing the door, is 1.0. The use factor for 30° scatter to the East wall, West wall, and ceiling is assumed to be 0.25 in each case.

Radiation Areas:

With respect to all walls and the ceiling, an evaluation has been made of the shielding requirements to limit the exposure rate to 5 milliroentgens per hour under the worst beam orientation at points of anticipated maximum radiation levels. For example, the worst irientation for the West wall would be with the beam directed toward the West wall (beamstopper in place), 30° below horizontal, with an SSD of 65 cm (isocentric technique). Thirty degree scattered radiation would strike the wall perpendicularly at point W-4. It might be

Annex E - Item No. 12
Radiation Areas (continued):
interesting to note the following comment from Section 8.3 of NCRP Report No. 49 regarding the radiation protection survey: "For the determination of the adequacy of secondary protective barriers, measurements shall be made employing a suitable phantom to simulate the patient. The near surface of the phantom should be placed at the usual source - skin distance." With this teletherapy unit, the usual source - skin distance - would probably be 80 cm for fixed fields, and the exposure rate from 30° scattered radiation would be even lower than that calculated for point W-4. The criteria for an UNRESTRICTED area have been discussed in ITEM No. 12 in the main body of the application. If the maximum instantaneous exposure rate were 5 mR/hour at an area adjacent to the shielded facility, even with continuous occupancy, the maximum dose equivalent to an individual in any one hour would be 1.33 millirem and not more than 54 millirem in any seven consecutive days.

Location:
The locations of the pit and isocenter are shown in the attached floor plan and elevation drawings. The isocenter is 7 feet 6 inches from the interior surface of the concrete West wall and 8 feet 6 inches from the interior surface of the concrete South wall. Exposure rate points have been marked on the drawings and have been located at a distance of 30 centimeters (12 inches) beyond the gypsum wall or concrete barrier, whichever is farther. On the elevation drawing, the isocenter is 115.6 centimeters (45.5) inches above the finished floor.

Shielding Material:
Initially, the architect specified that the concrete to be used in the walls and ceiling would have a density of at least 145 pounds per cubic foot. This density is slightly less than that specified in NCRP Report No. 49. Consequently, the minimum barrier thicknesses as determined from Appendix D, figures 12 and 15 of

Annex E - Item No. 12
Shielding Material (continued):
this report, have been corrected by the factor 1.0138 which is the ratio of 147:145. Gypsum wall board, which is 5/8 inch thick, lines the interior surface of all vertical barriers except the door, as well as the outer surface of the West and near North (adjacent to the Control Desk) walls. The manufacturer lists the weight of his gypsum wall board as 2.375 pounds per square foot, while for comparison, the weight of a one inch thick, one square foot slab of concrete would be 12.08 pounds. For shielding purposes, we may assume that the 5/8 inch thick gypsum wall board is equivalent to 0.2 inch of concrete and that the double thickness on the West and near North walls have the equivalent shielding of 0.4 inch of concrete.

The shielding design, which is discussed below, and the maximum radiation levels were calculated on the assumption that the concrete had a density of 145 pounds per cubic foot. The attached report from the Kansas City Testing Laboratory indicates that the actual average density of the concrete was 148.52 pounds per cubic foot. The last column of summary sheet for CALCULATED RADIATION LEVELS contains the calculated maximum radiation levels for a concrete density of 148.52 pounds per cubic foot.

Shielding Design:
The West wall, adjacent to the Superficial X-Ray Room/Mold Room, has 26 inches of concrete plus two thicknesses of gypsum board for a total equivalent concrete thickness of 26.4 inches.

The near North wall, adjacent to the Control Desk, has 20 inches of concrete plus two thicknesses of gypsum board for a total equivalent concrete thickness of 20.4 inches.

The West wall, containing the entry door, has 12 inches of concrete plus two thicknesses of gypsum board for a total equivalent concrete thickness of 12.4 inches. The entry door has 5 millimeters of lead shielding.

Annex E - Item No. 12

Shielding Design (continued):

The far North wall, an outside wall, has 14 inches of concrete plus one thickness of gypsum board for a total equivalent concrete thickness of 14.2 inches.

The East wall, an outside wall, has 22 inches of concrete plus one thickness of gypsum board for a total equivalent concrete thickness of 22.2 inches. Part of this wall is below ground, that is, covered by earth. The shielding and maximum radiation level calculations did not take this into account. In several areas along this wall, however, the radiation protection survey will be measured at elevations above the isocenter so that measured exposure rates will be at lower radiation levels than those calculated.

The South wall, an outside wall, has 18 inches of concrete plus one thickness of gypsum board for a total equivalent concrete thickness of 18.2 inches. With the exception of a small area above the suspended acoustical ceiling, this wall is below ground. The shielding and maximum radiation level calculations did not take this into account. However, the radiation protection survey will be measured at elevations above the isocenter so that measured exposure rates will be at lower radiation levels than those calculated.

The ceiling is the roof and has a minimum thickness of 20 inches of concrete throughout. However, there is an additional 7 inch thick slab below the ceiling but integral with it which measures 10 feet by 10 feet and which is centered over the isocenter of the teletherapy unit. Total thickness of concrete in this area is 27 inches.

Beam Orientation:

The exposure rates at various points have been calculated for some of the following beam orientations:

Annex E - Item No. 12
Beam Orientation (continued):

(1) Beam directed vertically to the floor with the surface of the phantom at 65 cm from the source (SSD = 65 cm).

(2) Beam directed at 30° below horizontal toward the West wall, with the phantom at an SSD = 65 cm.

(3) Beam directed at 30° below horizontal toward the East wall, with the phantom at an SSD = 65 cm.

(4) Beam directed 30° either side of vertical toward the ceiling, with the phantom at an SSD = 65 cm.

ANNEX E - ITEM NO. 12

HUB MATERIALS, INC.

Plant Location
1700 North 291 Highway
Sugar Creek, Missouri 64054

Telephone
257-5300

May 22, 1980

Crowley Construction Company
3200 South M-291
Independence, Missouri 64057

Re: Radiarium Center Building
Medical Center Park
Independence, Missouri

Gentlemen,

As per your request, we are pleased to submit the following mix design used for the above mentioned job.

Cement - Type 1	575
Limestone rock	1650
Missouri River sand	1650
Water	225

Yield-- 27.0 cubic ft. Weight 152 lbs per cubic ft

Hoping this meets with your approval and may we be of further service to you.

Yours truly,

HUB MATERIALS, INC.

by, Ralph W. Klein
Ralph W. Klein

RWK/mgw

DATE: July 15, 1980

ANNEX E - ITEM No. 2

KANSAS CITY TESTING LABORATORY
P.O. Box 6323
SHAWNEE MISSION, KANSAS 66206
TELEPHONE 648-2303

Laboratory No. 3492 Date 6-10-80

TEST DATA
CONCRETE CYLINDERS

Received 6-6-80 From CROWLEY WADE MILSTEAD, INC. ENGINEERS

Project RADIARIUM

Location of Pour INFORMATION NOT AVAILABLE WITH CYLINDERS

Height, ins. 12

Diameter, ins. 6

Area, sq. ins. 28.27

Cylinder marking	A	B	C
Date cast	6-2-80	6-2-80	6-2-80
Date crushed	6-9-80	6-30-80	6-30-80
Age, days	7	28	28
Crushing load, lbs.	118500	163250	162500
Compressive strength lbs./sq. in.	4192 *148.83	5774 *148.62	5748 *148.10
Fracture	CA	CA	CA

(Code: C—conical, D—diagonal, I—irregular, M—mortar, A—aggregate)

Slump, ins. Air % Unit Wt. lb./cu. ft.

Supplier HUB Class Tkt. No. Trk. No.

Coarse aggregate, lbs.: Dispensing time
Fine aggregate, lbs.: Sampling time
Cement, lbs.: Weather
Water, gals.: Water added

REMARKS: MADE BY CONTRACTOR
*UNIT WT. IN LBS/FT^3

CC: CROWLEY, WADE, MILSTEAD-BRADD CROWLEY-4
DS/cjm

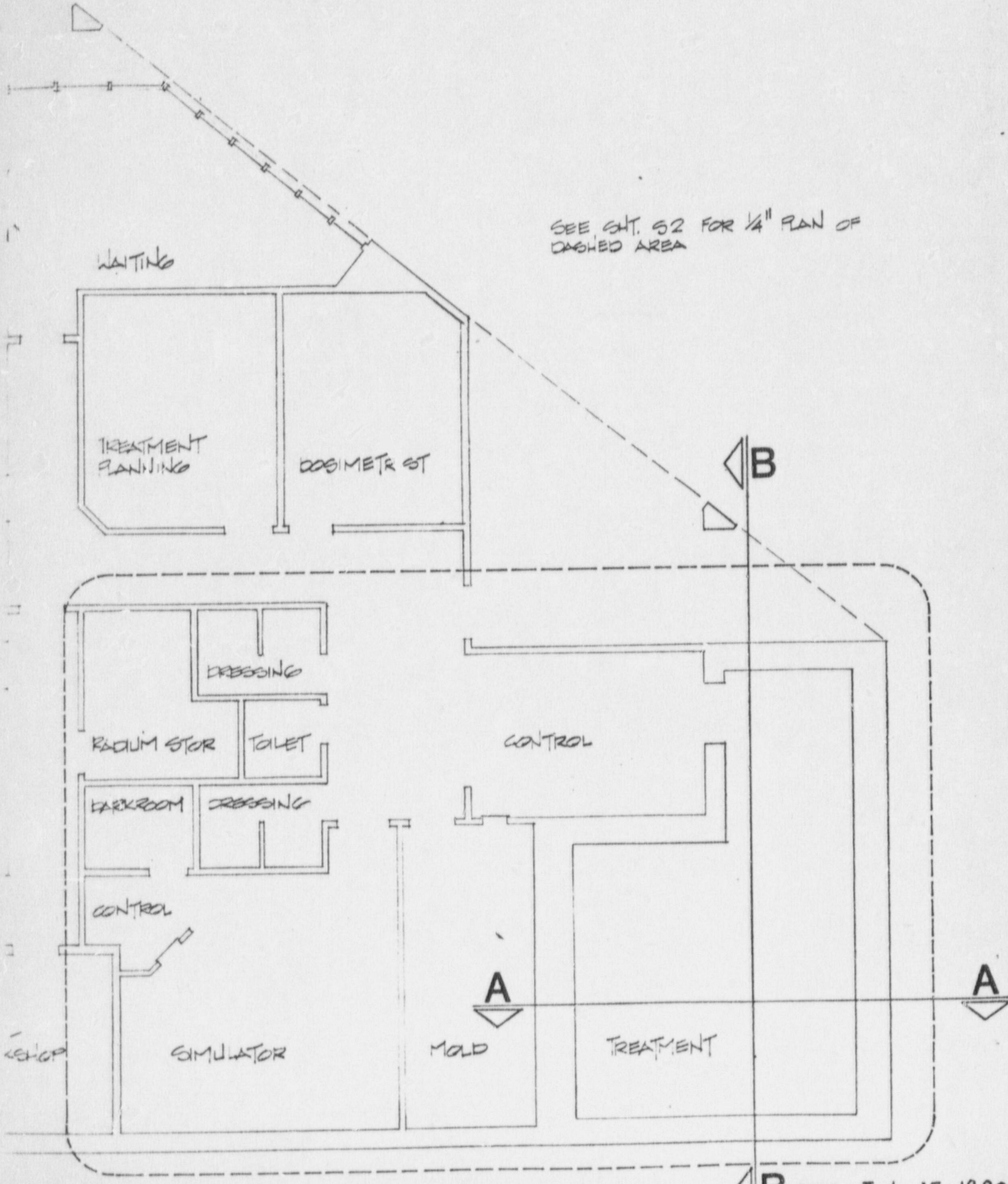
Kansas City Testing Laboratory
(Original Signed by)

[signature]

DATE: July 15, 1980

ANNEXES C+E ITEMS NOS. 8+12

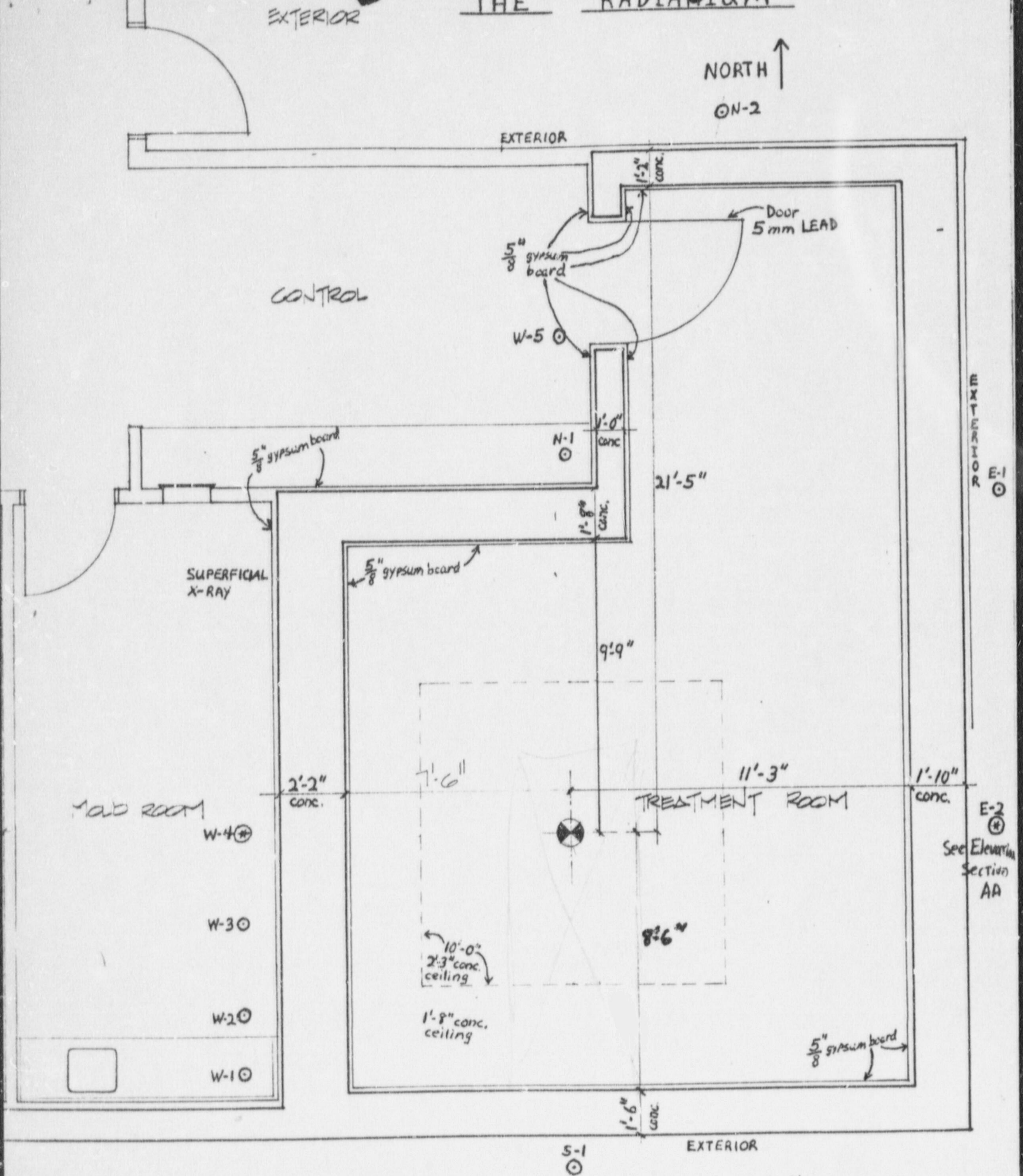
THE RADIARIUM



DATE: July 15, 1980

ANNEXES C+E ITEMS NOS. 8+12

THE RADIA[illegible]IUM



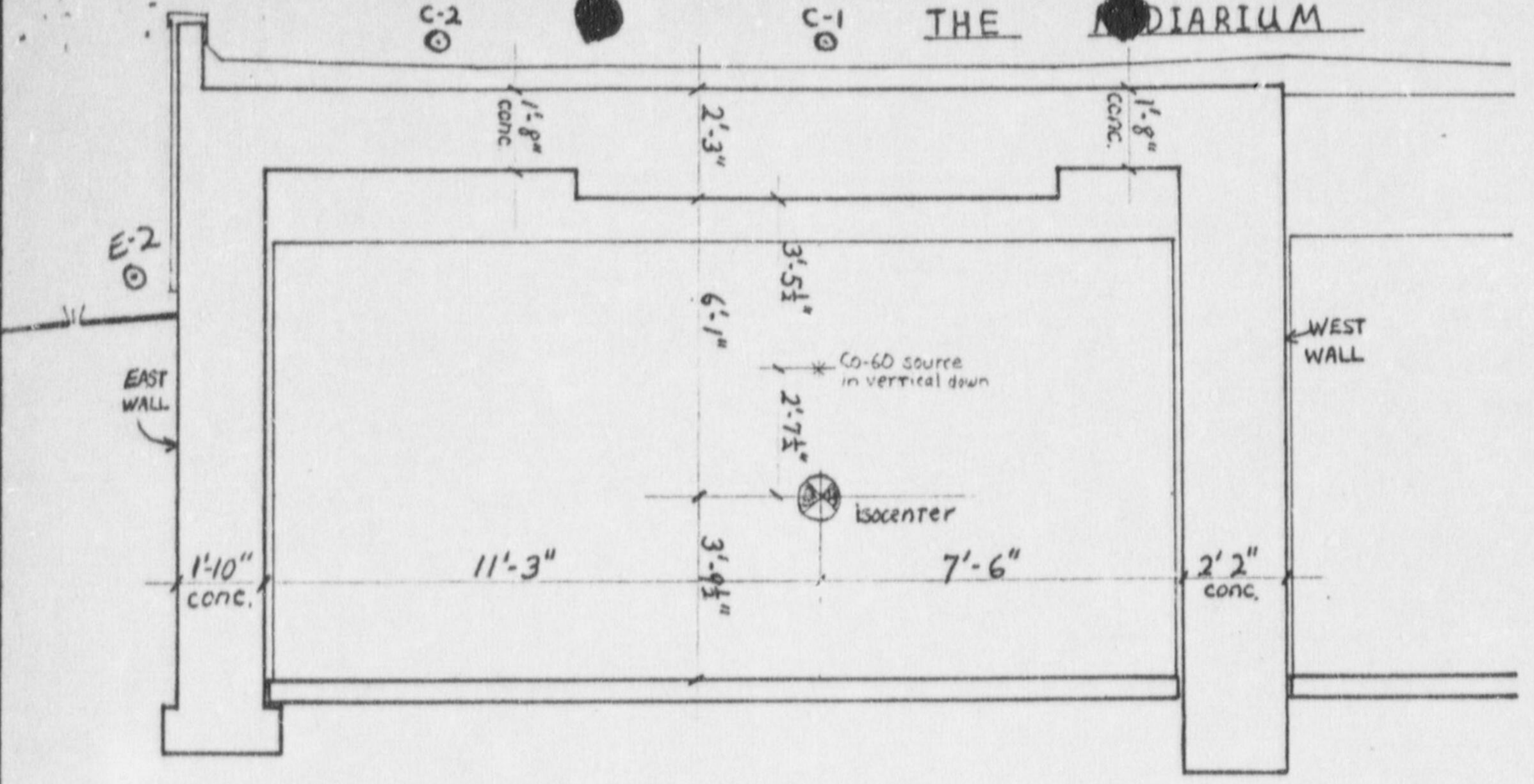
FLOOR PLAN

0 6" 1' 2' 3' 4' 5' 6' 7' 8'
3" 9"
1/4" = 1'-0"

DATE: July 15, 1980

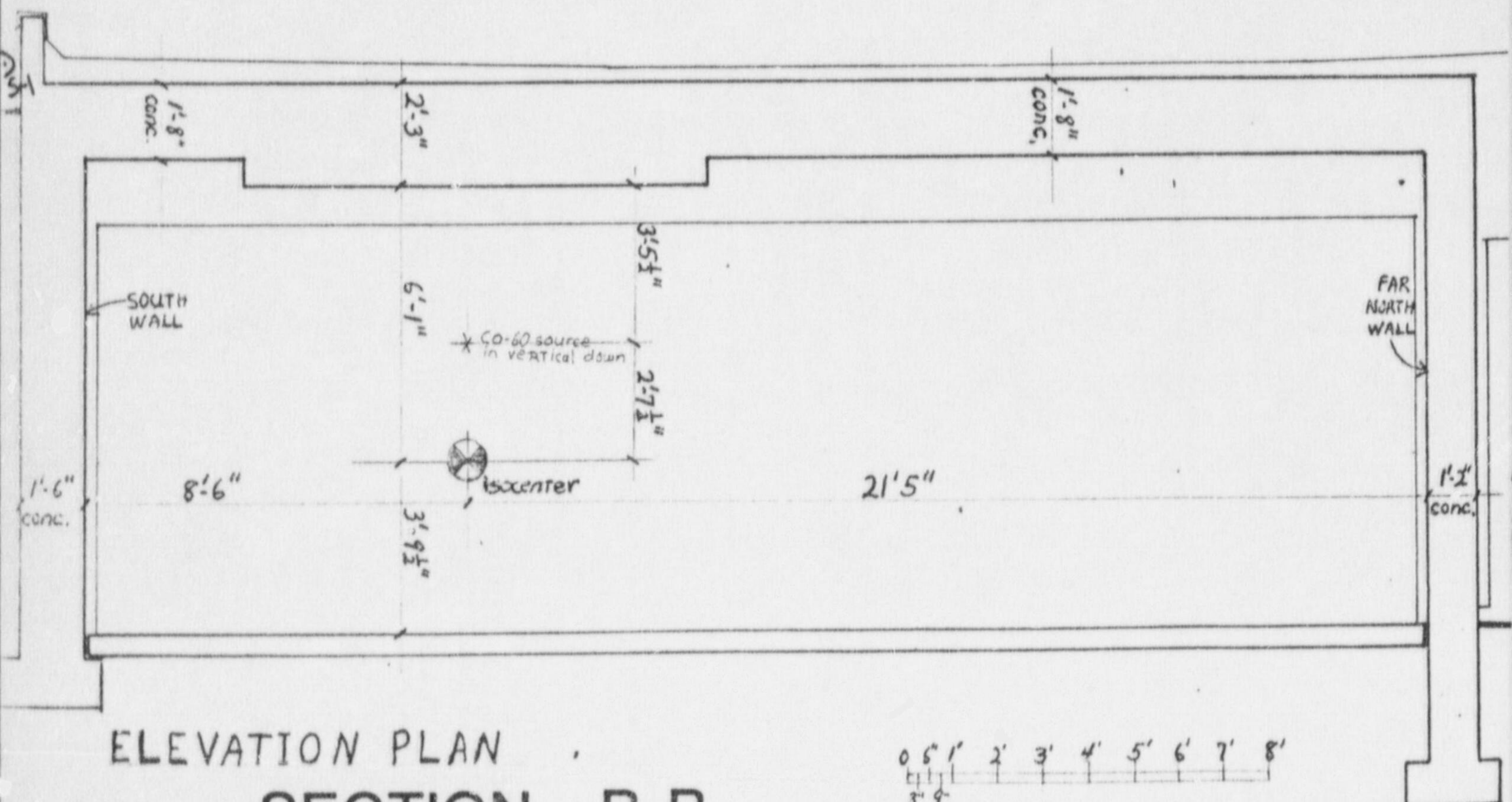
ANNEXES C + E ITEMS NOS. 8+12

THE [illegible]DIARIUM



SECTION A-A

1/4" = 1'-0"



ELEVATION PLAN

SECTION B-B

1/4" = 1'-0"

DATE: July 15, 1980

Annex E - Item No. 12

Summary of Calculated Radiation Levels

LOCATION (Point)	BEAM ORIENTATION	EXP. RATE ($\rho = 145\ lb/ft^3$)	EXP. RATE ($\rho = 148.52\ lb/ft^3$)
W-1	(1)	0.052 mR/hr.	
W-1	(3)	0.036 mR/hr.	
W-1	(2)	0.525 mR/hr.	0.420 mR/hr.
W-2	(1)	0.125 mR/hr.	
W-2	(3)	0.084 mR/hr.	
W-2	(2)	1.495 mR/hr.	1.217 mR/hr.
W-3	(1)	0.348 mR/hr.	
W-3	(3)	0.403 mR/hr.	
W-3	(2)	3.695 mR/hr.	3.057 mR/hr.
W-4	(1)	0.493 mR/hr.	
W-4	(3)	0.658 mR/hr.	
W-4	(2)	5.155 mR/hr.	4.294 mR/hr.
N-1	(1)	2.207 mR/hr.	1.901 mR/hr.
N-2	(1)	3.487 mR/hr.	3.120 mR/hr.
N-2	(2)	5.489 mR/hr	4.918 mR/hr
E-1	(3)	1.040 mR/hr	0.858 mR/hr.
E-2	(1)	0.822 mR/hr	0.701 mR/hr.
E-2	(3)	5.809 mR/hr.	4.934 mR/hr.
S-1	(1)	0.126 mR/hr.	0.103 mR/hr.
S-1	(2)	0.104 mR/hr.	0.084 mR/hr.
C-1	(1)	0.919 mR/hr.	0.765 mR/hr.
C-1	(4)	4.862 mR/hr.	4.033 mR/hr.
C-2	(4)	4.444 mR/hr.	3.722 mR/hr.
W-5	Multiple Scatter NO CALCULATION	Probably less than 5.0 mR/hr but will modify if necessary to bring below 5.0 mR/hr.	

THE RADIARIUM COBALT-60 TELETHERAPY ROOM

PERTINENT INFORMATION FOR SHIELDING CALCULATIONS

WALL-LOC. POINT	TYPE OF RADIATION	NONCONTROL or CONTROL	WORKLOAD (RM^2/WK)	USE FACTORS	OCCUP. FACTORS	W·U·T (RM^2/WK)	DISTANCE (FT. & IN./M.)
W-1 (a)	Leakage	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 13ft 5½ in./4.10m.
W-1 (b)	90° Scatter	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 13ft 5½ in./4.10m. dsca = 0.65m.
W-1 (c)	36° Scatter	CONTROLLED	50,000	0.25	1.0	12,500	dsec = 13ft 10in./4.22m. dsca = 0.65m.
W-1 (d) worst orient.	Leakage (only)	5mR/hr. Limit	7.5 $\frac{R}{hr}$ @ 1m.	—	—	—	dsec = 11ft 6in./3.51m.
W-1 (e) worst orient.	36° Scatter	5mR/hr. Limit		—	—	—	dsec = 13ft 10in./4.22m. dsca = 0.65m.
W-1 (f)	Leakage		7.5 $\frac{R}{hr}$ @ 1m.	—	—	—	dsec = 15ft 8in./4.78m.
W-2 (a)	Leakage	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 12ft. 5in./3.78m.
W-2 (b)	90° Scatter	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 12ft. 5in./3.78m. dsca = 0.65m.
W-2 (c)	30° Scatter	CONTROLLED	50,000	0.25	1.0	12,500	dsec = 12ft. 11in./3.94m. dsca = 0.65m.
W-2 (d) worst orient.	Leakage (only)	5mR/hr. Limit	7.5 $\frac{R}{hr}$ @ 1m.	–	–	–	dsec = 10ft. 2in./3.10m.
W-2 (e) worst orient.	30° Scatter	5mR/hr. Limit		–	–	–	dsec = 12ft. 11in./3.94m. dsca = 0.65m.
W-2 (f)	Leakage		7.5 $\frac{R}{hr}$ @ 1m.	–	–	–	dsec = 14ft. 9in./4.50m.
W-3 (a)	Leakage	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 11ft. 3in./3.43m.
W-3 (b)	90° Scatter	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 11ft. 3in./3.43m. dsca = 0.65m.
W-3 (c)	30° Scatter	CONTROLLED	50,000	0.25	1.0	12,500	dsec = 11ft. 9in./3.58m. dsca = 0.65m.
W-3 (d) worst orient.	Leakage (only)	5mR/hr. Limit	7.5 $\frac{R}{hr}$ @ 1m.	-	-	-	dsec = 8ft. 9in./2.67m.
W-3 (e) worst orient.	30° Scatter	5mR/hr. Limit		-	-	-	dsec = 11ft. 9in./3.58m. dsca = 0.65m.
W-3 (f)	Leakage		7.5 $\frac{R}{hr}$ @ 1m.	-	-	-	dsec = 13ft. 10in./4.22m.

See page-2 for point W-4

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THE RADIARIUM COBALT-60 TELETHERAPY ROOM

PERTINENT INFORMATION FOR SHIELDING CALCULATIONS

WALL-LOC. POINT	TYPE OF RADIATION	NONCONTROL or CONTROL	WORKLOAD (RM^2/WK)	USE FACTORS	OCCUP. FACTORS	W·U·T (RM^2/WK)	DISTANCE (FT. & IN./M.)
W-4 (a)	Leakage	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 10 ft. 10 in./3.30 m.
W-4 (b)	90° Scatter	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 10 ft. 10 in./3.30 m. dsca = 0.65 m.
W-4 (c)	30° Scatter	CONTROLLED	50,000	0.25	1.0	12,500	dsec = 11 ft. 4 in./3.45 m. dsca = 0.65 m.
W-4 (d)	worst orient. Leakage (only)	5 mR/hr. Limit	7.5 R/hr. @ 1m.	–	–	–	dsec = 8 ft. 8 in./2.65 m.
W-4 (e)	worst orient. 30° Scatter	5 mR/hr. Limit		–	–	–	dsec = 11 ft. 4 in./3.45 m. dsca = 0.65 m.
W-4 (f)	Leakage		7.5 R/hr @ 1m.	–	–	–	dsec = 13 ft. 5 in./4.10 m.
N-1 (a)	Leakage	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 12 ft. 6 in./3.81 m.
N-1 (b)	90° Scatter	CONTROLLED	50,000	1.0	1.0	50,000	dsec = 12 ft. 6 in/3.81 m. dsca = 0.65 m
N-1 (c)	worst orient. Leakage	5 mR/hr Limit	7.5 R/hr @ 1m.	–	–	–	dsec = 12 ft. 6 in/3.81 m
N-1 (d)	90° Scatter			–	–	–	dsec = 12 ft. 6 in./3.81 m. dsca: 0.65 m
N-2 (a)	Leakage (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 24 ft. 4 in./7.42 m.
N-2 (b)	90° Scatter (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec: 24 ft. 4 in./7.42 m. dsca = 0.65 m.
N-2 (c)	Leakage (2)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec: 24 ft. 0 in./7.32 m
N-2 (d)	78° Scatter (2)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec: 24 ft. 3 in./7.39 m. dsca: 0.65 m.
N-2 (e)	worst orient. Leakage (2)	5 mR/hr. Limit	7.5 R/hr @ 1m.	–	–	–	dsec: 24 ft. 0 in./7.32 m
N-2 (f)	78° Scatter (2)			–	–	–	dsec: 24 ft 3 in./7.39 m dsca: 0.65 m.
E-1 (a)	Leakage (3)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec: 20 ft. 4 in./6.20 m.
E-1 (b)	37° Scatter (3)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec: 18 ft. 7 in./5.66 m. dsca: 0.65 m.
E-1 (c)	worst orient. Leakage (3)	5 mR/hr Limit	7.5 R/hr @ 1m	–	–	–	dsec: 20 ft. 4 in./6.20 m.
E-1 (d)	37° Scatter (3)			–	–	–	dsec: 18 ft. 7 in/5.66 m. dsca: 0.65 m.

THE RADIARIUM COBALT-60 TELETHERAPY ROOM

PERTINENT INFORMATION FOR SHIELDING CALCULATIONS

WALL-LOC. POINT	TYPE OF RADIATION	NONCONTROL or CONTROL	WORKLOAD (RM^2/WK)	USE FACTORS	OCCUP. FACTORS	W·U·T (RM^2/WK)	DISTANCE (FT. & IN./M.)
E-2(a)	Leakage (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 14 ft. 4 in./4.37 m.
E-2(b)	107° Scatter (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 14 ft. 10 in./4.52 m. dsca = 0.65 m
E-2(c)	Leakage (3)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 17 ft. 4 in./5.28 m.
E-2(d)	35° Scatter (3)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 15 ft. 5 in/4.70 m. dsca = 0.65 m.
E-2(e) worst orient.	Leakage (3)	> 5 $\frac{mR}{hr}$ Limit	7.5 $\frac{R}{hr}$ @ 1m.	—	—	—	dsec = 17 ft. 4 in./5.28 m.
E-2(f)	35° Scatter (3)			—	—	—	dsec = 15 ft. 5 in./4.70 m. dsca = 0.65 m
S-1 (a)	Leakage (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 12 ft 3 in./3.73 m.
S-1 (b)	127° Scatter (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 13 ft 5 in./4.09 m. dsca = 0.65 m.
S-1 (c)	Leakage (2)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 14 ft 0 in/4.28 m.
S-1 (d)	90° Scatter (2)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 13 ft 5 in/4.09 m. dsca = 0.65 m.
C-1 (a)	Leakage (1)	NONCONTROLLED	50,000	1.0	$\frac{1}{16}$ = 0.0625	3,125	dsec = 6 ft 9 in./2.06 m.
C-1 (b)	Leakage (4)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 11 ft 10 in./3.61 m.
C-1 (c)	35° Scatter (4)	NONCONTROLLED	50,000	0.25	$\frac{1}{16}$ = 0.0625	782	dsec = 9 ft. 11 in./3.02 m. dsca = 0.65 m.
C-1 (d) worst orient.	Leakage (4)	> 5 $\frac{mR}{hr}$ Limit	7.5 $\frac{R}{hr}$ @ 1m	—	—	—	dsec = 11 ft. 10 in./3.61 m.
C-1 (e)	35° Scatter (4)			—	—	—	dsec = 9 ft. 11 in./3.02 m. dsca = 0.65 m.
C-2 (a) worst orient	Leakage (4)	> 5 $\frac{mR}{hr}$ Limit	7.5 $\frac{R}{hr}$ @ 1m	—	—	—	dsec = 14 ft. 6 in/4.42 m.
C-2 (b)	35° Scatter (4)			—	—	—	dsec = 12 ft. 7½ in./3.85 m. dsca = 0.65 m.

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SHIELDING CALCULATIONS FOR THE RADIARIUM COBALT-60 TELETHERAPY ROOM

WALL-LOC. POINT	TYPE OF RADIATION	TRANSMISSION FORMULA or LK & SCA EXP RATE	CALCULATIONS	REQUIRED PATH LENGTH	ENTRY ANGLE	MIN. THICK	DENS. COR (1.0138)	ACTUAL THICK.	EXP. RATE (mR/hr.)
W-1(a)	Leakage	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1,000 \times 0.1 \times (4.10m)^2}{50,000} = 0.0336$	36cm or 14.2in.	36°	11.5in.	11.7in.	26.4in.	(1) 0.052 mR/hr.
W-1(b)	90° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \times (d_{sec})^2 \times (d_{sca})^2$	$\frac{0.1 \times (4.10m)^2 \times (0.65m)^2}{0.0009 \times 50,000} = 0.0158$	27.3cm or 10.75in.	36°	8.7in.	8.8in.	26.4in.	
W-1(c)	36° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \times (d_{sec})^2 \times (d_{sca})^2$	$\frac{0.1 \times (4.22m)^2 \times (0.65m)^2}{0.005 \times 12,500} = 0.0120$	41cm or 16.14in.	36°	13.1in.	13.3in.	26.4in.	
W-1(d) worst orient	Leakage (only)	$7.5\frac{R}{hr.} \times \frac{1}{(3.51m)^2} = 608.8\frac{mR}{hr}$	$\frac{5\frac{mR}{hr}}{608.8\frac{mR}{hr}} = e^{-\frac{.693}{6.2cm} \times t}$	43cm or 16.91in.	45°	12.0in. + 2.5in. HVL = 14.5in.	14.7in.	26.4in.	(3) 0.036 mR/hr.
W-1(e) worst orient	36° Scatter	$\frac{0.005 \times 7500\frac{R}{hr.}}{(0.65m)^2 \times (4.22m)^2} = 4,984\frac{mR}{hr.}$	$\frac{5\frac{mR}{hr}}{5,312\frac{mR}{hr.}} = e^{-\frac{.693 \times t}{6.1cm}}$	61.3cm or 24.15in.	36°	24.15 x cos 30° = 20.91in.	21.2in.	26.4in.	(2) 0.525 mR/hr.
W-1(f)	Leakage	$7.5\frac{R}{hr} \times \frac{1}{(4.78m)^2} = 328\frac{mR}{hr}$			30°			26.4in.	
Since (a), (b) and (c) are within a tenth value layer, add 1 HVL: 13.3in. + 2.0in. = 15.3inches. Since the space being shielded receives radiation from two sources, add one HVL: 15.3in. + 2.0in. = 17.3 inches. To keep the exposure rate below 5mR/hr, the wall should be 21.2 inches thick.									
W-2(a)	Leakage	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.1 \times (3.78m)^2}{50,000} = 0.0286$	37cm or 14.6in.	29°	12.77in.	13.0in.	26.4in.	(1) 0.125 mR/hour
W-2(b)	90° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.78m)^2 \times (0.65m)^2}{0.0009 \times 50,000} = 0.0134$	28.6cm or 11.26in.	29°	9.85in.	10.0in.	26.4in.	
W-2(c)	30° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.94m)^2 \times (0.65m)^2}{0.0060 \times 12,500} = 0.00875$	44cm or 17.32in.	28°	15.29in.	15.5in.	26.4in.	
W-2(d) worst orient	Leakage (only)	$7.5\frac{R}{hr.} \times \frac{1}{(3.10m)^2} = 780.4\frac{mR}{hr}$	$\frac{5mR/hr.}{780.4mR/hr} = e^{-\frac{.693 \times t}{6.2cm}}$	45.18cm or 17.79in.	36°	14.39in.	14.6in.	26.4in.	(3) 0.084 mR/hour
W-2(e) worst orient	30° Scatter	$\frac{0.006 \times 7500\frac{R}{hr}}{(0.65m)^2 \times (3.94m)^2} = 6,861\frac{mR}{hr}$	$\frac{5\frac{mR}{hr}}{7,232\frac{mR}{hr}} = e^{-\frac{.693 \times t}{6.1cm}}$	64.05cm or 25.22in.	28°	25.22 x cos 24 = 23.04in.	23.4in.	26.4in.	(2) 1.495 mR/hour
W-2(f)	Leakage	$7.5\frac{R}{hr} \times \frac{1}{(4.50m)^2} = 371\frac{mR}{hr}$			24°			26.4in.	
Since (a), (b) and (c) are within a tenth value layer, add 1 HVL: 15.5in. + 2.2in. = 17.7in. Since the space being shielded receives radiation from two sources, add one HVL: 17.7in + 2.2in = 19.9inches. To keep the exposure rate below 5mR/hr, the wall should be 23.4inches thick.									
W-3(a)	Leakage	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.1 \times (3.43m)^2}{50,000} = 0.0235$	39.5cm or 15.55in.	15°	15.02in.	15.2in.	26.4in.	(1) 0.348 mR/hr.
W-3(b)	90° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.43m)^2 \times (0.65m)^2}{0.0009 \times 50,000} = 0.01105$	29.5cm or 11.61in.	15°	11.22in.	11.4in.	26.4in.	
W-3(c)	30° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.58m)^2 \times (0.65m)^2}{0.0060 \times 12,500} = 0.00722$	45.7cm or 17.99in.	15°	17.38in.	17.6in.	26.4in.	
W-3(d) worst orient	Leakage (only)	$7.5\frac{R}{hr} \times \frac{1}{(2.67m)^2} = 1,052\frac{mR}{hr}$	$\frac{5mR/hr.}{1,052mR/hr} = e^{-\frac{.693 \times t}{6.2cm}}$	47.86cm or 18.84in.	20°	17.70in.	17.9in.	26.4in.	(3) 0.403 mR/hr.
W-3(e) and W-3(f) continued on page -2									

SHIELDING CALCULATIONS FOR THE RADIARIUM COBALT-60 TELETHERAPY ROOM

WALL-LOC. POINT	TYPE OF RADIATION	TRANSMISSION FORMULA or LK & SCA EXP RATE	CALCULATIONS	REQUIRED PATH LENGTH	ENTRY ANGLE	MIN. THICK	DENS. COR (1.0138)	ACTUAL THICK.	EXP. RATE (mR/hr.)
W-3(e) WORST ORIENT.	30° Scatter	$\frac{0.006 \times 7500 \frac{R}{hr}}{(0.65m)^2 \times (3.58m)^2} = 8{,}310 \frac{mR}{hr}$	$\frac{5 mR/hr}{8731 \frac{mR}{hr}} = e^{-\frac{.693 \times t}{6.1cm}}$	65.71cm or 25.87in	15°	25.87" (calc)	25.6 in.	26.4 in.	(2) 3.695 $\frac{mR}{hr}$
W-3(f)	Leakage	$7.5 \frac{R}{hr} \times \frac{1}{(4.22m)^2} = 421 \frac{mR}{hr}$			12.5°	=25.26in.	25.6 in.	26.4 in.	
Since (a), (b) and (c) are within a tenth value layer, add 1 HVL: 17.6 in. + 2.4 in. = 20.0 in. Since the space being shielded receives radiation from two sources, add one HVL: 20.0 in. + 2.4 in. = 22.4 inches. To keep the exposure rate below 5 mR/hr, the wall should be 25.6 inches thick.									
W-4 (a)	Leakage	$B_{LG} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.1 \times (3.30m)^2}{50{,}000} = 0.02178$	39.5 cm or 15.55 in	0°	15.55 in.	15.8 in.	26.4 in.	(1) 0.493 $\frac{mR}{hr}$
W-4 (b)	90° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.30m)^2 \cdot (0.65m)^2}{0.0009 \times 50{,}000} = 0.01022$	30.3 cm or 11.93 in.	0°	11.93 in.	12.1 in.	26.4 in.	
W-4 (c)	30° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.45m)^2 \cdot (0.65m)^2}{0.0060 \times 12{,}500} = 0.006705$	46.3 cm or 18.23 in.	0°	18.23 in.	18.5 in.	26.4 in.	
W-4 (d) WORST ORIENT.	Leakage (only)	$7.5 \frac{R}{hr} \times \frac{1}{(2.65m)^2} = 1{,}068 \frac{mR}{hr}$	$\frac{5 mR/hr}{1{,}068 mR/hr} = e^{-\frac{.693 \times t}{6.2cm}}$	48.0 cm or 18.89 in	0°	18.89 in.	19.2 in.	26.4 in.	(3) 0.658 $\frac{mR}{hr}$
W-4(e) WORST ORIENT.	30° Scatter	$\frac{0.006 \times 7500 \frac{R}{hr}}{(0.65m)^2 \times (3.45m)^2} = 8{,}948 \frac{mR}{hr}$	$\frac{5 mR/hr}{9{,}394 \frac{mR}{hr}} = e^{-\frac{.693 \times t}{6.8cm}}$	66.4 cm or 26.12 in	0°	26.12 in	26.48 in.	26.4 in.	(2) 5.155 $\frac{mR}{hr}$ *
W-4(f)	Leakage	$7.5 \frac{R}{hr} \times \frac{1}{(4.10m)^2} = 446 \frac{mR}{hr}$						26.4 in.	
Since (a), (b) and (c) are within a tenth value layer, add 1 HVL: 18.5 in + 2.4 in = 20.9 in. Since the space being shielded receives radiation from two sources, add one HVL: 20.9 in + 2.4 in = 23.3 inches. To keep the exposure rate below 5 mR/hr, the wall should be ~ 26½ inches thick.									
*NOTE:	Actual density of concrete was 148.52 pounds per cubic ft, vice the 145 lb/ft³ used in calculations. This revises W-4(e)+(f) as:			66.4 cm or 26.12 in.	0°	26.12 in.	Dens. Corr.: $\frac{147}{148.52}$ (0.9898) 25.85 in.	26.4 in.	4.294 $\frac{mR}{hr}$
N-1 (a)	Leakage	$B_{LG} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.1 \times (3.81m)^2}{50{,}000} = 0.02903$	36.5 cm or 14.37 in.	0°	14.37 in.	14.6 in.	20.4 in.	
N-1 (b)	90° Scatter	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.1 \times (3.81m)^2 \times (0.65m)^2}{0.0009 \times 50{,}000} = 0.0136$	28.5 cm or 11.22 in	0°	11.22 in.	11.4 in.	20.4 in.	
N-1 (c) WORST ORIENT.	Leakage	$7.5 \frac{R}{hr} \times \frac{1}{(3.81m)^2} = 517 \frac{mR}{hr}$	$\frac{5 mR/hr}{1618 mR/hr} = e^{-\frac{.693 \times t}{6.2cm}}$	51.7 cm or 20.35 in	0°	20.35 in.	20.6 in. **	20.4 in.	(1) 2.207 $\frac{mR}{hr}$
N-1 (d)	90° Scatter	$\frac{0.0009 \times 7500 \frac{R}{hr}}{(0.65m)^2 \times (3.81m)^2} = 1{,}101 \frac{mR}{hr}$	**NOTE: The HVL for 90° Scatter is 4.6cm; for Leakage it is 6.2cm; Since leakage accounts for only ⅓ of the beam, the calc. shielding of 20.6" is quite conservative on the safe side.						
Since (a) and (b) are within a tenth value layer, add 1 HVL: 14.6 in + 2.4 in = 17.0 in. Since the space being shielded receives radiation from two sources, add one HVL: 17.0 in + 2.4 in. = 19.4 inches.									
*NOTE:	Actual density of concrete was 148.52 pounds per cubic ft, vice the 145 lb/ft³ used in calculations. This revises N-1(c)+(d) as:			51.7 cm or 20.35 in	0°	20.35 in.	Dens. Corr.: $\frac{147}{148.52}$ (0.9898) 20.14 in.	20.4 in.	1.901 $\frac{mR}{hr}$

SHIELDING CALCULATIONS FOR THE RADIARIUM COBALT-60 TELETHERAPY ROOM

WALL-LOC. POINT	TYPE OF RADIATION	TRANSMISSION FORMULA or LK & SCA EXP RATE	CALCULATIONS	REQUIRED PATH LENGTH	ENTRY ANGLE	MIN. THICK	DENS. COR (1.0138)	ACTUAL THICK.	EXP. RATE (mR/hr.)
N-2 (a)	Leakage (1)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (7.42m)^2}{3125} = 0.176$	20.0cm ≅ 7.88in.	13°	7.68in.	7.78in.	14.2in.	(1) 3.487 mR/hr (N-2 (a) + (b))
N-2 (b)	90° Scatter (1)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (7.42m)^2 \times (0.65m)^2}{0.0009 \times 3125} = 0.0827$	16.4cm ≅ 6.46in.	13°	6.29in.	6.38in.	14.2in.	
N-2 (c)	Leakage (2)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (7.32m)^2}{782} = 0.685$	6.0cm ≅ 2.36in.	7°	2.34in.	2.37in.	14.2in.	
N-2 (d)	78° Scatter (2)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (7.39m)^2 \times (0.65m)^2}{0.0014 \times 782} = 0.211$	12.0cm ≅ 4.72in.	12°	4.62in.	4.68in.	14.2in.	
N-2 (e) worst orient	Leakage (2)	$7.5 \frac{R}{hr} \times \frac{1}{(7.32m)^2} = 140 \frac{mR}{hr}$	$\frac{5 mR/hr}{595 mR/hr} = e^{\frac{-.693 \times t}{6.2cm}}$ (N-2 (e) + (f))	42.75cm or 16.83in.*	7°	16.70in.	16.9in.	14.2in.	(2) 5.489 mR/hr ** (N-2 (e) + (f))
N-2 (f)	78° Scatter (2)	$\frac{0.0014 \times 7500 \frac{R}{hr}}{(0.65m)^2 \times (7.39m)^2} = 455 \frac{mR}{hr}$			12°			14.2in.	
* Note: The HVL for 78° Scatter is approximately 5.0cm; for Leakage, the HVL is 6.2cm. Since leakage accounts for only ¼ of the exposure rate of the beam in question, the calculated shielding, based on 6.2cm HVL + 7° entry angle is too conservative, as shown by calc. radiation levels. Since (a) and (b) are within a tenth value layer, add 1 HVL: 7.7in + 2.4in. = 10.1in. If we assume a density of 145 lbs/ft³, then, to keep the exposure rate below 5 mR/hr, the wall should be ~ 14½ inches. The floor plan shows an exterior surface covering the concrete wall. Since the plan did not include specifics on its density and thickness, it was not included in the shielding calculations. If the concrete had a density of 145 lbs/ft³, the exterior surface would have had to add 0.3 inch concrete									
** NOTE:	Actual density of concrete was 148.52 lbs/ft³, vice the 145 lbs/ft³ used in calculations. This revises N-2(e)+(f) as follows:					Min Thickness at a dens.: 145 lbs/ft³: 14.5in.	Dens. Corr.: 145/148.52 : (0.9763) 14.16in.	14.2in.	(2) 4.918 mR/hr.
E-1 (a)	Leakage (3)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (6.2m)^2}{782} = 0.492$	10.0cm ≅ 3.94in.	34°	3.27in.	3.31in.	22.2in.	
E-1 (b)	37° Scatter (3)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (5.66m)^2 \times (0.65m)^2}{0.0049 \times 782} = 0.035$	30.0cm ≅ 11.81in.	37°	9.43in.	9.56in.	22.2in.	
E-1 (c) worst orient	Leakage (3)	$7.5 \frac{R}{hr} \times \frac{1}{(6.2m)^2} = 195 \frac{mR}{hr}$	$\frac{5 mR/hr}{2910 \frac{mR}{hr}} = e^{\frac{-0.693 \times t}{6.05cm}}$ (E-1 (c) + (d))	55.58cm ≅ 21.88in.	34°	18.14in.	18.39in.	22.2in.	(3) 1.04 mR/hr. (E-1 (c) + (d))
E-1 (d)	37° Scatter (3)	$\frac{0.0049 \times 7500 \frac{R}{hr}}{(0.65m)^2 \times (5.66m)^2} = 2{,}715 \frac{mR}{hr}$			37°			22.2in.	
NOTE:	Actual density of concrete was 148.52 lbs/ft³, vice the 145 lbs/ft³ used in calculations. This revises E-1 (c)+(d) as follows:					18.14in.	Dens. corr.: 147/148.52 : 0.9898 17.95in.	22.2in.	(3) 0.858 mR/hr.
E-2 (a)	Leakage (1)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (4.37m)^2}{3125} = 0.0611$	30cm ≅ 11.81in.	8.5°	11.68in.	11.84in.	22.2in.	(1) 0.822 mR/hr. (E-2 (a) + (b))
E-2 (b)	107° Scatter (1)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (4.52m)^2 \times (0.65m)^2}{0.0008 \times 3125} = 0.0345$	21cm ≅ 8.27in.	17°	7.91in.	8.02in.	22.2in.	
E-2 (c)	Leakage (3)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (5.28m)^2}{782} = 0.357$	13.7cm ≅ 5.39in.	14°	5.23in.	5.31in.	22.2in.	
E-2 (d)	35° Scatter (3)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (4.71m)^2 \times (0.65m)^2}{0.00[illegible]3 \times 782} = 0.0[illegible]$	36.3cm ≅ 14.29in.	18°	13.59in.	13.78in.	22.2in.	

SHIELDING CALCULATIONS FOR THE RADIARIUM COBALT-60 TELETHERAPY ROOM

WALL-LOC. POINT	TYPE OF RADIATION	TRANSMISSION FORMULA or LK & SCA EXP RATE	CALCULATIONS	REQUIRED PATH LENGTH	ENTRY ANGLE	MIN. THICK	DENS. COR (1.0138)	ACTUAL THICK.	EXP. RATE (mR/hr.)
E-2(e) worst orient.	Leakage (3)	$7.5\frac{R}{hr} \times \frac{1}{(5.28m)^2} = 269\frac{mR}{hr}$	$\frac{5\frac{mR}{hr}}{4,528\frac{mR}{hr}} = e^{-\frac{.693 x t}{6.1cm}}$	59.93cm ≅ 23.59in.	14°	22.44in.	22.75 in	22.2in.	(3) 5.809 $\frac{mR}{hr}$ *
E-2(f)	35° Scatter (3)	$\frac{0.0053 \times 7500\frac{R}{hr}}{(0.65m)^2 \times (4.70m)^2} = 4,259\frac{mR}{hr}$			18°				
*NOTE:	Actual density of concrete was 148.52 lbs/ft³, vice the 145 lbs/ft³ used in calculations. This revises E-2(e)+(f) as follows:					22.44in.	Dens. Corr.: $\frac{147}{148.52}$ = 0.9898 22.2in.	22.2in.	(3) 4.934 $\frac{mR}{hr.}$
	This revises E-2(a)+(b) as follows:					11.68in.	11.56in.	22.2in.	(1) 0.701 $\frac{mR}{hr.}$
S-1 (a)	Leakage (1)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (3.73m)^2}{3,125} = 0.0445$	32.5cm ≅ 12.8in.	30°	11.09in.	11.24in.	South Wall + Roof 18+ in.	(1) 0.126 $\frac{mR}{hr}$
S-1 (b)	127° Scatter (1)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (4.09m)^2 \times (0.65m)^2}{0.000653 \times 3125} = 0.0346$	20.5cm ≅ 8.07in.	37°	6.45in.	6.54in.	18+ in.	
S-1 (c)	Leakage (2)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (4.28m)^2}{782} = 0.234$	17.5cm ≅ 6.89in.	37°	5.50in.	5.58in.	18+ in.	(2) 0.104 $\frac{mR}{hr}$
S-1 (d)	90° Scatter (2)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (4.09)^2 \times (0.65)^2}{0.0009 \times 782} = 0.100$	15.0cm ≅ 5.91in.	37°	4.72in.	4.79in.	18+ in.	
NOTE:	Actual density of concrete was 148.52 lbs/ft³, vice the 145 lbs/ft³ used in calculations. This revises S-1(a)+(b) as follows:					11.1in + 1HVL = 13.5in.	Dens. Corr.: $\frac{147}{148.52}$ = 0.9898 13.36in.	18+ in.	(1) 0.103 $\frac{mR}{hr.}$
	This revises S-1(c)+(d) as follows:					5.5 + 2.4in = 7.9in.	7.82in.	18+ in.	(2) 0.084 $\frac{mR}{hr.}$
C-1 (a)	Leakage (1)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (2.06m)^2}{3125} = 0.0136$	44cm ≅ 17.32in	0°	17.32in.	17.56 in.	27.0in.	(1) 0.919 $\frac{mR}{hr}$
C-1 (b)	Leakage (4)	$B_{Lg} = \frac{1000 \times P \times (d_{sec})^2}{WUT}$	$\frac{1000 \times 0.01 \times (3.61m)^2}{782} = 0.167$	20cm ≅ 7.87in.	0°	7.87in.	7.98in.	27.0in.	
C-1 (c)	35° Scatter (4)	$B_{sg} = \frac{P}{a \cdot WUT} \cdot (d_{sec})^2 \cdot (d_{sca})^2$	$\frac{0.01 \times (3.02m)^2 \times (0.65)^2}{0.0053 \times 782} = 0.0093$	43cm ≅ 16.93in	0°	16.93in.	17.16 in.	27.0in.	
C-1 (d) worst orient.	Leakage (4)	$7.5\frac{R}{hr} \times \frac{1}{(3.61m)^2} = 575.5\frac{mR}{hr}$	$\frac{5\frac{mR}{hr}}{10,891.5\frac{mR}{hr}} = e^{-\frac{.693 x t}{6.1cm}}$	67.66cm ≅ 26.64in	0°	26.64in.	27.0 in.	27.0in.	(4) 4.862 $\frac{mR}{hr}$
C-1 (e)	35° Scatter (4)	$\frac{0.0053 \times 7500\frac{R}{hr}}{(0.65m)^2 \times (3.02m)^2} = 10,316\frac{mR}{hr}$							
NOTE:	Actual density of concrete was 148.52 lbs/ft³, vice the 145 lbs/ft³ used in calculations. This revises C-1(a) as follows:					17.3in + 1HVL = 19.7in.	Dens. Corr.: $\frac{147}{148.52}$ = 0.9898 19.5in.	27.0in.	(1) 0.765 $\frac{mR}{hr.}$
	This revises C-1(d)+(e) as follows:					26.64in.	26.37in.	27.0in.	(4) 4.033 $\frac{mR}{hr.}$
C-2 (a) worst orient.	Leakage (4)	$7.5\frac{R}{hr} \times \frac{1}{(4.42m)^2} = 384\frac{mR}{hr.}$	$\frac{5\frac{mR}{hr}}{6,731\frac{mR}{hr}} = e^{-\frac{.693 x t}{6.1cm}}$	63.42cm ≅ 24.97in	35° / 37°	19.94in.	Dens. Corr 1.0138 20.22in.	20.0in.	(4) 4.444 $\frac{mR}{hr}$
C-2 (b)	35° Scatter (4)	$\frac{0.0053 \times 7500\frac{R}{hr}}{(0.65m)^2 \times (3.85m)^2} = 6,347\frac{mR}{hr.}$			39°		Dens. Corr. 0.9898 19.74in.	20.0in.	(4) 3.722 $\frac{mR}{hr}$

THE RADIARIUM COBALT-60 TELETHERAPY ROOM

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
W-1 (a)+(b)	(1)	(a) Leakage 26.4 inches concrete corrected for density $= \frac{26.4}{1.0138} = 26.04$ inches Path length: $\frac{26.04 in.}{\cos 36°} = 32.19$ inches or 81.76 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.10m)^2} = 446.16 \frac{mR}{hr}$ $I_L = 446.16 \frac{mR}{hr} \times e^{-\frac{.693 \times 81.76cm}{6.2cm}}$ $I_L = 446.16 \frac{mR}{hr} \times e^{-9.1387}$ $I_L = 446.16 \frac{mR}{hr} \times (1.0743 \times 10^{-4})$ $I_L = 0.048$ mR/hr. (b) 90° Scatter Path Length: 81.76 cm as above. $\frac{7500 \frac{R}{hr} \times 0.0009}{(0.65m)^2 \times (4.10m)^2} = 950.4 \frac{mR}{hr.}$ $I_{90° Scatter} = 950.4 \frac{mR}{hr} \times e^{-\frac{.693 \times 81.76cm}{4.6cm}}$ $I_{90° Scatter} = 950.4 \frac{mR}{hr} \times e^{-12.3173}$ $I_{90° Scatter} = 950.4 \frac{mR}{hr} \times (4.4735 \times 10^{-6})$ $I_{90° Scatter} = 0.00425 \frac{mR}{hr.}$ Total Exposure Rate from beam orientation (1) at Point W-1 is $0.048 \frac{mR}{hr} + 0.004 \frac{mR}{hr}$ = 0.052 mR/hour	$0.052 \frac{mR}{hour}$
W-1 (d)	(3)	(d) Leakage (only) Path Length: Since the incident angle is large (45°), subtract one HVL from the path length. $\frac{26.04 in.}{\cos 45°} = 36.83$ in. -2.5 in. = 34.3 inches or 87.12 cm. $7500 \frac{mR}{hr} \times \frac{1}{(3.51m)^2} = 608.8 \frac{mR}{hr}$ $I_L = 608.8 \frac{mR}{hr} \times e^{-\frac{.693 \times 87.12cm}{6.2cm}}$ $I_L = 608.8 \frac{mR}{hr} \times e^{-9.7378}$ $I_L = 608.8 \frac{mR}{hr} \times (5.9012 \times 10^{-5})$ $I_L = 0.036 \frac{mR}{hr}$	$0.036 \frac{mR}{hour}$
W-1 (e)+(f)	(2)	(e) 36° Scatter Path Length: 32.19 inches or 81.76 cm as in (a) and (b) above. $\frac{7500 \frac{R}{hr} \times 0.005}{(0.65m)^2 \times (4.22m)^2} = 4,984 \frac{mR}{hr.}$ $I_{36° Scatter} = 4,984 \frac{mR}{hr} \times e^{-\frac{.693 \times 81.76cm}{6.1cm}}$ $I_{36° Scatter} = 4,984 \frac{mR}{hr} \times e^{-9.2885}$ $I_{36° Scatter} = 4,984 \times (9.2484 \times 10^{-5})$ $I_{36° Scatter} = 0.461 \frac{mR}{hr}$ (f) Leakage Path Length: $\frac{26.04 in}{\cos 30°} = 30.068$ inches or 76.37 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.78m)^2} = 328 \frac{mR}{hr}$ $I_L = 328 \frac{mR}{hr} \times e^{-\frac{.693 \times 76.37cm}{6.2cm}}$ $I_L = 328 \frac{mR}{hr} \times e^{-8.5362}$ $I_L = 328 \frac{mR}{hr} \times (1.9623 \times 10^{-4})$ $I_L = 0.064 \frac{mR}{hour}$ Total Exposure Rate from beam orientation (2) at Point W-1 is: [0.461 + 0.064] mR/hr $= 0.525 \frac{mR}{hour}$	$0.525 \frac{mR}{hour}$

THE RADIARIUM COBALT-60 TELETHERAPY ROOM

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS		EXPOSURE RATE
W-2 (a)+(b)	(1)	(a) Leakage 26.4 inches concrete corrected for density $= \frac{26.4 in.}{1.0138} = 26.04$ inches Path Length: $\frac{26.04 in}{\cos 29°} = 29.77$ inches or 75.62 cm. (b) 90° Scatter Path Length = 75.62cm as above. Total Exposure Rate from beam orientation (1) at point W-2 is: $0.112 \frac{mR}{hr} + 0.013 \frac{mR}{hr} = 0.125 \frac{mR}{hour}$	$7500 \frac{mR}{hr} \times \frac{1}{(3.78m)^2} = 524.9 \frac{mR}{hr}$ $I_L = 524.9 \frac{mR}{hr} \times e^{-\frac{.693 \times 75.62 cm}{6.2 cm}}$ $I_L = 524.9 \frac{mR}{hr} \times e^{-8.4524}$ $I_L = 524.9 \frac{mR}{hr} \times [2.1339 \times 10^{-4}]$ $I_L = 0.112 \frac{mR}{hour}$ $\frac{7500 \frac{R}{hr} \times 0.0009}{(0.65m)^2 \times (3.78m)^2} = 1,118 \frac{mR}{hr}$ $I_{90° scatter} = 1,118 \frac{mR}{hr} \times e^{-\frac{.693 \times 75.62 cm}{4.6 cm}}$ $I_{90° scatter} = 1,118 \frac{mR}{hr} \times e^{-11.3923}$ $I_{90° scatter} = 1,118 \frac{mR}{hr} \times [1.1281 \times 10^{-5}]$ $I_{90° scatter} = 0.0126 \frac{mR}{hour}$	$0.125 \frac{mR}{hour}$
W-2 (d)	(3)	(d) Leakage (only) Path Length: $\frac{26.04 in.}{\cos 36°} = 32.19$ inches or 81.76 cm	$7500 \frac{mR}{hr} \times \frac{1}{(3.10m)^2} = 780.4 \frac{mR}{hr.}$ $I_L = 780.4 \frac{mR}{hr} \times e^{-\frac{.693 \times 81.76 cm}{6.2 cm}}$ $I_L = 780.4 \frac{mR}{hr} \times e^{-9.1387}$ $I_L = 780.4 \times [1.0743 \times 10^{-4}]$ $I_L = 0.084 \frac{mR}{hour}$	$0.084 \frac{mR}{hour}$
W-2 (e)+(f)	(2)	(e) 30° Scatter Path Length: $\frac{26.04 in.}{\cos 28°} = 29.49$ inches or 74.91cm (f) Leakage Path Length: $\frac{26.04 in.}{\cos 24°} = 28.50$ inches or 72.40cm Total Exposure Rate from beam orientation (2) at Point W-2 is: $1.382 \frac{mR}{hr}$ 0.113 mR/hr = 1.495 mR/hr	$\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.94m)^2} = 6,861 \frac{mR}{hr}$ $I_{30° scatter} = 6,861 \frac{mR}{hr} \times e^{-\frac{.693 \times 74.91 cm}{6.1 cm}}$ $I_{30° scatter} = 6,861 \frac{mR}{hr} \times e^{-8.5103}$ $I_{30° scatter} = 6,861 \frac{mR}{hr} \times [2.0139 \times 10^{-4}]$ $I_{30° scatter} = 1.382 \frac{mR}{hour}$ $7500 \frac{mR}{hour} \times \frac{1}{(4.50m)^2} = 371 \frac{mR}{hr}$ $I_L = 371 \frac{mR}{hr} \times e^{-\frac{.693 \times 72.4 cm}{6.2 cm}}$ $I_L = 371 \frac{mR}{hr} \times e^{-8.0925}$ $I_L = 371 \frac{mR}{hr} \times [3.0583 \times 10^{-4}]$ $I_L = 0.113 \frac{mR}{hour}$	$1.495 \frac{mR}{hour}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS		EXPOSURE RATE
W-3(a)+(b)	(1)	(a) <u>Leakage</u> 26.4 inches concrete corrected for density $= \frac{26.4}{1.0138} = 26.04$ inches Path length: $\frac{26.04 \text{ in.}}{\cos 15^\circ} = 26.96$ inches or 68.47 cm	$7500 \frac{mR}{hr} \times \frac{1}{(3.43m)^2} = 637.5 \frac{mR}{hr}$ $I_L = 637.5 \frac{mR}{hr} \times e^{-\frac{.693 \times 68.47 cm}{6.2 cm}}$ $I_L = 637.5 \frac{mR}{hr} \times e^{-7.6532}$ $I_L = 637.5 \frac{mR}{hr} \times [4.7453 \times 10^{-4}]$ $I_L = 0.3025 \frac{mR}{hr}$	
		(b) <u>90° Scatter</u> Path Length: 68.47 cm as above. Total Exposure Rate from beam orientation (1) at Point W-3 is: 0.3025 mR/hr + 0.0450 mR/hr 0.348 $\frac{mR}{hr}$	$\frac{7500 \frac{R}{hr} \times 0.0009}{(0.65m)^2 \times (3.43m)^2} = 1,358 \frac{mR}{hr}$ $I_{90° Scatter} = 1,358 \frac{mR}{hr} \times e^{-\frac{.693 \times 68.47 cm}{4.6 cm}}$ $I_{90° Scatter} = 1,358 \frac{mR}{hr} \times e^{-10.3152}$ $I_{90° Scatter} = 1,358 \frac{mR}{hr} \times [3.3127 \times 10^{-5}]$ $I_{90° Scatter} = 0.0450 \frac{mR}{hr}$	0.348 $\frac{mR}{hour}$
W-3(d)	(3)	(d) <u>Leakage (only)</u> Path Length: $\frac{26.04 \text{ in.}}{\cos 20^\circ} = 27.71$ inches or 70.38 cm	$7500 \frac{mR}{hr} \times \frac{1}{(2.67m)^2} = 1,052 \frac{mR}{hr}$ $I_L = 1,052 \frac{mR}{hr} \times e^{-\frac{.693 \times 70.38 cm}{6.2 cm}}$ $I_L = 1,052 \frac{mR}{hr} \times e^{-7.867}$ $I_L = 1,052 \frac{mR}{hr} \times [3.8331 \times 10^{-4}]$ $I_L = 0.4032 \frac{mR}{hr}$	0.403 $\frac{mR}{hr}$
W-3(e)+(f)	(2)	(e) <u>30° Scatter</u> Path Length: $\frac{26.04 \text{ in.}}{\cos 15^\circ} = 26.96$ inches or 68.47 cm	$\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.58m)^2} = 8,310 \frac{mR}{hr}$ $I_{30° Scatter} = 8,310 \frac{mR}{hr} \times e^{-\frac{.693 \times 68.47 cm}{6.1 cm}}$ $I_{30° Scatter} = 8,310 \frac{mR}{hr} \times e^{-7.7786}$ $I_{30° Scatter} = 8,310 \frac{mR}{hr} \times [4.1858 \times 10^{-4}]$ $I_{30 Scatter} = 3.478 \frac{mR}{hr}$	
		(f) <u>Leakage</u> Path Length: $\frac{26.04 \text{ in.}}{\cos 12.5^\circ} = 26.67$ inches or 67.75 cm Total Exposure Rate from beam orientation (2) at Point W-3 is: 3.478 $\frac{mR}{hr}$ 0.217 mR/hr 3.695 mR/hr	$7500 \frac{mR}{hr} \times \frac{1}{(4.22m)^2} = 421 \frac{mR}{hr}$ $I_L = 421 \frac{mR}{hr} \times e^{-\frac{0.693 \times 67.75 cm}{6.2 cm}}$ $I_L = 421 \frac{mR}{hr} \times e^{-7.573}$ $I_L = 421 \frac{mR}{hr} \times [5.143 \times 10^{-4}]$ $I_L = 0.2165 \frac{mR}{hr}$	3.695 $\frac{mR}{hr}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS		EXPOSURE RATE
W-4 (a)+(b)	(1)	(a) Leakage 26.4 inches concrete corrected for density $= \frac{26.4}{1.0138} = 26.04$ inches Path Length: 26.04 inches or 66.14 cm	$7500 \frac{mR}{hr} \times \frac{1}{(3.30m)^2} = 688.7 \frac{mR}{hr}$ $I_L = 688.7 \frac{mR}{hr} \times e^{-\frac{.693 \times 66.14cm}{6.2cm}}$ $I_L = 688.7 \frac{mR}{hr} \times e^{-7.3927}$ $I_L = 688.7 \frac{mR}{hr} \times [6.157 \times 10^{-4}]$ $I_L = 0.424 \frac{mR}{hr}$	
		(b) 90° Scatter Path Length = 66.14 cm as above. Total Exposure Rate from beam orientation (1) at Point W-4 is: $0.424 \frac{mR}{hr}$ + 0.069 mR/hr = $0.493 \frac{mR}{hr}$	$\frac{7500 \frac{R}{hr} \times 0.0009}{(0.65m)^2 \times (3.30m)^2} = 1,467 \frac{mR}{hr}$ $I_{90^\circ scatter} = 1,467 \frac{mR}{hr} \times e^{-\frac{.693 \cdot 66.14cm}{4.6cm}}$ $I_{90^\circ scatter} = 1,467 \frac{mR}{hr} \times e^{-9.9641}$ $I_{90^\circ scatter} = 1,467 \frac{mR}{hr} \times [4.7057 \times 10^{-5}]$ $I_{90^\circ scatter} = 0.069 \frac{mR}{hr}$	$0.493 \frac{mR}{hr}$
W-4 (d)	(3)	(d) Leakage (only) Path Length: 26.04 inches or 66.14 cm	$7500 \frac{mR}{hr} \times \frac{1}{(2.65m)^2} = 1,068 \frac{mR}{hr}$ $I_L = 1,068 \frac{mR}{hr} \times e^{-\frac{.693 \times 66.14cm}{6.2cm}}$ $I_L = 1,068 \frac{mR}{hr} \times e^{-7.3927}$ $I_L = 1,068 \frac{mR}{hr} \times [6.157 \times 10^{-4}]$ $I_L = 0.658 \frac{mR}{hr}$	$0.658 \frac{mR}{hr}$
W-4 (e)+(f)	(2)	(e) 30° Scatter Path Length: 26.04 inches or 66.14 cm	$\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.45m)^2} = 8,948 \frac{mR}{hr}$ $I_{30^\circ scatter} = 8,948 \frac{mR}{hr} \times e^{-\frac{.693 \times 66.14cm}{6.1cm}}$ $I_{30^\circ scatter} = 8,948 \frac{mR}{hr} \times e^{-7.51394}$ $I_{30^\circ scatter} = 8,948 \frac{mR}{hr} \times [5.4542 \times 10^{-4}]$ $I_{30^\circ scatter} = 4.880 \frac{mR}{hr}$	
		(f) Leakage Path Length: 26.04 inches or 66.14 cm Total Exposure Rate from beam orientation (2) at Point W-4 is: $4.880 \frac{mR}{hr}$ + $0.275 \frac{mR}{hr}$ = 5.155 mR/hr	$7500 \frac{mR}{hr} \times \frac{1}{(4.10m)^2} = 446$ mR/hr $I_L = 446 \frac{mR}{hr} \times e^{-\frac{.693 \times 66.14cm}{6.2cm}}$ $I_L = 446 \frac{mR}{hr} \times e^{-7.3927}$ $I_L = 446 \frac{mR}{hr} \times [6.1570 \times 10^{-4}]$ $I_L = 0.275 \frac{mR}{hr}$	$5.155 \frac{mR}{hr}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
W-1(e)+(f)	(2)	(e) 36° Scatter Path Length: 26.4 inches concrete corrected for density $= 26.4\text{ in.} \times \frac{148.52}{147} = 26.673$ inches $\frac{26.673\text{ in.}}{\cos 36°} = 32.97$ inches or 83.74 cm $\frac{7500 \frac{R}{hr} \times 0.005}{(0.65m)^2 \times (4.22m)^2} = 4,984 \frac{mR}{hr}$ $I_{36° scatter} = 4,984 \frac{mR}{hr} \times e^{-\frac{.693 \times 83.74}{6.1 cm}}$ $I_{36° scatter} = 4,984 \frac{mR}{hr} \times e^{-9.513913}$ $I_{36° scatter} : 4,984 \frac{mR}{hr} \times [7.3854 \times 10^{-5}]$ $I_{36° scatter} : 0.368$ mR/hr. (f) Leakage Path Length: $\frac{26.673\text{ inches}}{\cos 30°} = 30.80$ inches or 78.23 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.78)^2} : 328 \frac{mR}{hr}$ $I_L : 328 \frac{mR}{hr} \times e^{-\frac{.693 \times 78.23 cm}{6.2 cm}}$ $I_L : 328 \frac{mR}{hr} \times e^{-8.744}$ $I_L : 328 \frac{mR}{hr} \times [1.594 \times 10^{-4}]$ $I_L : 0.052 \frac{mR}{hr}$ Total Exposure Rate from beam orientation (2) at Point W-1 is: 0.368 mR/hr 0.052 mR/hr 0.420 mR/hr	$0.420 \frac{mR}{hr}$
W-2(e)+(f)	(2)	(e) 30° Scatter Path Length: $\frac{26.673\text{ in.}}{\cos 28°} = 30.21$ in. or 76.73 cm $\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.94m)^2} = 6861 \frac{mR}{hr}$ $I_{30° scatter} = 6,861 \frac{mR}{hr} \times e^{-\frac{.693 \times 76.73 cm}{6.1 cm}}$ $I_{30° scatter} = 6,861 \frac{mR}{hr} \times e^{-8.717}$ $I_{30° scatter} : 6,861 \frac{mR}{hr} \times [1.6377 \times 10^{-4}]$ $I_{30° scatter} = 1.124 \frac{mR}{hr}$ (f) Leakage Path Length: $\frac{26.673\text{ in.}}{\cos 24°} = 29.20$ in or 74.16 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.50m)^2} = 371 \frac{mR}{hr}$ $I_L = 371 \frac{mR}{hr} \times e^{-\frac{.693 \times 74.16}{6.2 cm}}$ $I_L = 371 \frac{mR}{hr} \times e^{-8.2893}$ $I_L : 371 \frac{mR}{hr} \times [2.5119 \times 10^{-4}]$ $I_L : 0.093$ mR/hr Total Exposure Rate from beam orientation (2) at Point W-2 is: 1.124 mR/hr +0.093 mR/hr 1.217 mR/hr.	$1.217 \frac{mR}{hr}$
W-3(e)+(f)	(2)	(e) 30° Scatter Path Length: $\frac{26.673\text{ in}}{\cos 15°} = 27.61$ in. or 70.14 cm $\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.58m)^2} = 8,310 \frac{mR}{hr}$ $I_{30° scatter} = 8,310 \frac{mR}{hr} \times e^{-\frac{.693 \times 70.14 cm}{6.1 cm}}$ $I_{30° scatter} : 8,310 \frac{mR}{hr} \times e^{-7.9684}$ $I_{30° scatter} : 8,310 \frac{mR}{hr} \times [3.4624 \times 10^{-4}]$ $I_{30° scatter} : 2.877$ mR/hr (f) Leakage Path Length: $\frac{26.673\text{ in.}}{\cos 12.5°} = 27.32$ in or 69.39 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.22m)^2} : 421 \frac{mR}{hr}$ $I_L : 421 \frac{mR}{hr} \times e^{-\frac{.693 \times 69.39 cm}{6.2 cm}}$ $I_L : 421 \frac{mR}{hr} \times e^{-7.756}$ $I_L : 421 \frac{mR}{hr} \times [4.2816 \times 10^{-4}]$ $I_L : 0.180$ mR/hr. Total Exposure Rate from beam orientation (2) at Point W-3 is: 2.877 mR/hr +0.180 mR/hr 3.057 mR/hr.	$3.057 \frac{mR}{hr}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
W-4 (e)+(f)	(2)	(e) 30° Scatter Path Length: 26.673 in. or 67.75 cm $\frac{7500 \frac{R}{hr} \times 0.0060}{(0.65m)^2 \times (3.45m^2)} = 8,948 \frac{mR}{hr}$ $I_{30° Scatter} = 8,948 \frac{mR}{hr} \times e^{-\frac{.693 \times 67.75cm}{6.1cm}}$ $I_{30° Scatter} = 8,948 \frac{mR}{hr} \times e^{-7.6968}$ $I_{30° Scatter} = 8,948 \frac{mR}{hr} \times [4.5425 \times 10^{-4}]$ $I_{30° Scatter} = 4.065$ mR/hr (f) Leakage Path Length: 26.673 in. or 67.75 cm $7500 \frac{mR}{hr} \times \frac{1}{(4.10m)^2} = 446$ mR/hr. $I_L = 446 \frac{mR}{hr} \times e^{-\frac{.693 \times 67.75cm}{6.2cm}}$ $I_L = 446 \frac{mR}{hr} \times e^{-7.5727}$ $I_L = 446 \frac{mR}{hr} \times [5.1430 \times 10^{-4}]$ $I_L = 0.229$ mR/hr. Total Exposure Rate from beam orientation (2) at Point W-4 is: 4.065 mR/hr +0.229 mR/hr 4.294 mR/hr	$4.294 \frac{mR}{hr}$
N-1 (c)+(d)	(1)	(c) Leakage Path Length: 20.4 in. ÷ 1.0138 = 20.122 in. or 51.11 cm $7500 \frac{mR}{hr} \times \frac{1}{(3.81m)^2} = 517 \frac{mR}{hr}$ $I_L = 517 \frac{mR}{hr} \times e^{-\frac{.693 \times 51.11cm}{6.2cm}}$ $I_L = 517 \frac{mR}{hr} \times e^{-5.71278}$ $I_L = 517 \frac{mR}{hr} \times [3.3034 \times 10^{-3}]$ $I_L = 1.708 \frac{mR}{hr}$ (d) 90° Scatter Path Length: 20.4 in. ÷ 1.0138 = 20.122 in. or 51.11 cm $\frac{7500 R/hr \times 0.0009}{(0.65m)^2 \times (3.81m)^2} = 1,101 \frac{mR}{hr}$ $I_{90° Scatter} = 1101 \frac{mR}{hr} \times e^{-\frac{.693 \times 51.11cm}{4.6cm}}$ $I_{90° Scatter} = 1,101 \frac{mR}{hr} \times e^{-7.6998}$ $I_{90° Scatter} = 1,101 \frac{mR}{hr} \times [4.529 \times 10^{-4}]$ $I_{90° Scatter} = 0.499$ mR/hr. Total Exposure Rate from beam orientation (1) at Point N-1 is: $1.708 \frac{mR}{hr}$ 0.499 mR/hr. 2.207 mR/hr.	$2.207 \frac{mR}{hr.}$
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
N-1 (c)+(d)	(1)	(c) Leakage Path Length: $20.4 in. \times \frac{148.52}{147} = 20.61$ in. or 52.35 cm. $7500 \frac{mR}{hr} \times \frac{1}{(3.81)^2} = 517 \frac{mR}{hr}$ $I_L = 517 \frac{mR}{hr} \times e^{-\frac{.693 \times 52.35cm}{6.2cm}}$ $I_L = 517 \frac{mR}{hr} \times e^{-5.85138}$ $I_L = 517 \frac{mR}{hr} \times [2.8759 \times 10^{-3}]$ $I_L = 1.487 \frac{mR}{hr}$ (d) 90° Scatter Path Length: $20.4 in \times \frac{148.52}{147} = 20.61$ in or 52.35 cm $\frac{7500 R/hr \times 0.0009}{(0.65m)^2 \times (3.81m)^2} = 1,101 \frac{mR}{hr}$ $I_{90° Scatter} = 1,101 \frac{mR}{hr} \times e^{-\frac{.693 \times 52.35cm}{4.6cm}}$ $I_{90° Scatter} = 1,101 \frac{mR}{hr} \times e^{-7.88664}$ $I_{90° Scatter} = 1,101 \frac{mR}{hr} \times [3.7573 \times 10^{-4}]$ $I_{90° Scatter} = 0.414$ mR/hr Total Exposure Rate from beam orientation (1) at Point N-1 is: 1.487 mR/hr 0.414 mR/hr 1.901 mR/hr	$1.901 \frac{mR}{hr.}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
N-2 (a)+(b)	(1)	(a) <u>Leakage:</u> Path Length: 14.2in. ÷ 1.0138 = 14.007in. or 35.58cm $\frac{35.58cm}{\cos 13°}$ = 36.51cm. or 14.38in. $7500 \frac{mR}{hr} \times \frac{1}{(7.42m)^2} = 136.2 mR/hr$ $I_L = 136.2 \frac{mR}{hr} \times e^{-\frac{.693 \times 36.51cm}{6.2cm}}$ $I_L = 136.2 \frac{mR}{hr} \times e^{-4.0809}$ $I_L = 136.2 \frac{mR}{hr} \times [1.689 \times 10^{-2}]$ $I_L = 2.301 \frac{mR}{hr}$ (b) <u>90° Scatter:</u> Path Length: 36.51cm or 14.38in. $\frac{7500 R/hr \times 0.0009}{(0.65m)^2 \times (7.42m)^2} = 290.2 \frac{mR}{hr}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times e^{-\frac{.693 \times 36.51cm}{4.6cm}}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times e^{-5.500}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times [4.0855 \times 10^{-3}]$ $I_{90° Scatter} = 1.186 \frac{mR}{hr}$ Total Exposure Rate from beam orientation (1) at Point N-2 is: 2.301 mR/hr 1.186 mR/hr 3.487 mR/hr	3.487 mR/hr
		<u>Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³</u>	
N-2 (a)+(b)	(1)	(a) <u>Leakage:</u> Path Length: 14.2in × $\frac{148.52}{147}$ = 14.35in. or 36.44cm. $\frac{36.44cm}{\cos 13°}$ = 37.40cm or 14.72in. $7500 \frac{mR}{hr} \times \frac{1}{(7.42m)^2} = 136.2 \frac{mR}{hr}$ $I_L = 136.2 \frac{mR}{hr} \times e^{-\frac{.693 \times 37.40cm}{6.2cm}}$ $I_L = 136.2 \frac{mR}{hr} \times e^{-4.1804}$ $I_L = 136.2 \frac{mR}{hr} \times [1.5293 \times 10^{-2}]$ $I_L = 2.083$ mR/hr. (b) <u>90° Scatter:</u> Path Length: 37.40cm or 14.72in. $\frac{7500 R/hr \times 0.0009}{(0.65m)^2 \times (7.42m)^2} = 290.2 \frac{mR}{hr}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times e^{-\frac{.693 \times 37.4cm}{4.6cm}}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times e^{-5.634}$ $I_{90° Scatter} = 290.2 \frac{mR}{hr} \times [3.5728 \times 10^{-3}]$ $I_{90° Scatter} = 1.037$ mR/hr. Total Exposure Rate from beam orientation (1) at Point N-2 is: 2.083 mR/hr 1.037 mR/hr 3.12 mR/hr	3.12 mR/hr
N-2 (e)+(f)	(2)	(e) <u>Leakage:</u> Path Length: 14.2in. ÷ 1.0138 = 14.007in or 35.58cm $\frac{35.58cm}{\cos 7°}$ = 35.85cm or 14.11in. $7500 \frac{mR}{hr} \times \frac{1}{(7.32m)^2} = 140 \frac{mR}{hr}$ $I_L = 140 \frac{mR}{hr} \times e^{-\frac{.693 \times 35.85cm}{6.2cm}}$ $I_L = 140 \frac{mR}{hr} \times e^{-4.007}$ $I_L = 140 \frac{mR}{hr} \times [1.8186 \times 10^{-2}]$ $I_L = 2.546$ mR/hr. (f) <u>78° Scatter:</u> Path Length: 14.2in. ÷ 1.0138 = 14.007in or 35.58cm $\frac{35.58cm}{\cos 12°}$ = 36.37cm or 14.32in. $\frac{7500 \frac{R}{hr} \times 0.0014}{(0.65m)^2 \times (7.39m)^2} = 455 \frac{mR}{hr}$ $I_{78° Scatter} = 455 \frac{mR}{hr} \times e^{-\frac{.693 \times 36.37cm}{5.0cm}}$ $I_{78° Scatter} = 455 \frac{mR}{hr} \times e^{-5.041}$ $I_{78° Scatter} = 455 \frac{mR}{hr} \times [6.468 \times 10^{-3}]$ $I_{78° Scatter} = 2.943$ mR/hr. Total Exposure Rate from beam orientation (2) at Point N-2 is: 2.546 mR/hr 2.943 mR/hr 5.489 mR/hr.	5.489 mR/hr

THE RADI IUM COBALT-60 TELETHERAP ROOM

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
N-2 (e)+(f)	(2)	Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³ (e) Leakage: Path Length: $14.2\,in \times \frac{148.52}{147} = 14.35\,in$ or $36.44\,cm$ $\frac{36.44\,cm}{\cos 7^\circ} = 36.71\,cm$ or $14.45\,in.$ $7500\,\frac{mR}{hr} \times \frac{1}{(7.32m)^2} = 140\,\frac{mR}{hr}$ $I_L = 140\,\frac{mR}{hr} \times e^{-\frac{.693 \times 36.71cm}{6.2cm}}$ $I_L = 140\,\frac{mR}{hr} \times e^{-4.1032}$ $I_L = 140\,\frac{mR}{hr} \times [1.6519 \times 10^{-2}]$ $I_L = 2.313\,\frac{mR}{hr}$ (f) 78° Scatter: Path Length: $14.2\,in. \times \frac{148.52}{147} = 14.35\,in.$ or $36.44\,cm$ $\frac{36.44\,cm}{\cos 12^\circ} = 37.25\,cm$ or $14.67\,in.$ $\frac{7500\,\frac{R}{hr} \times 0.0014}{(0.65m)^2 \times (7.39m)^2} = 455\,\frac{mR}{hr}$ $I_{78^\circ Scatter} = 455\,\frac{mR}{hr} \times e^{-\frac{.693 \times 37.25cm}{5.0cm}}$ $I_{78^\circ Scatter} = 455\,\frac{mR}{hr} \times e^{-5.163}$ $I_{78^\circ Scatter} = 455\,\frac{mR}{hr} \times [5.7253 \times 10^{-3}]$ $I_{78^\circ Scatter} = 2.605\,\frac{mR}{hr}$ Total Exposure Rate from beam orientation (2) at Point N-2 is: 2.313 mR/hr. 2.605 mR/hr. 4.918 mR/hr.	$4.918\,\frac{mR}{hr.}$
E-1 (c)+(d)	(3)	(c) Leakage: Path Length: $\frac{22.2in}{1.0138} = 21.898\,in$ or $55.62\,cm$ $\frac{55.62\,cm}{\cos 34^\circ} = 67.09\,cm$ or $26.41\,in.$ $7500\,\frac{mR}{hr} \times \frac{1}{(6.2m)^2} = 195\,\frac{mR}{hr.}$ $I_L = 195\,\frac{mR}{hr} \times e^{-\frac{.693 \times 67.09cm}{6.2cm}}$ $I_L = 195\,\frac{mR}{hr} \times e^{-7.4989}$ $I_L = 195\,\frac{mR}{hr} \times [5.5367 \times 10^{-4}]$ $I_L = 0.108$ mR/hr. (d) 37° Scatter: Path Length: $\frac{22.2in}{1.0138} = 21.898\,in$ or $55.62\,cm$ $\frac{55.62\,cm}{\cos 37^\circ} = 69.64\,cm$ or $27.42\,in.$ $\frac{7500\,\frac{R}{hr} \times 0.0049}{(0.65m)^2 \times (5.66m)^2} = 2{,}715\,\frac{mR}{hr}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times e^{-\frac{.693 \times 69.64cm}{6.05cm}}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times e^{-7.977}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times [3.4328 \times 10^{-4}]$ $I_{37^\circ Scatter} = 0.932$ mR/hr. Total Exposure Rate from beam orientation (3) at Point E-1 is: 0.108 mR/hr. 0.932 mR/hr. 1.04 mR/hr.	$1.04\,\frac{mR}{hr.}$
E-1 (c)+(d)	(3)	Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³ (c) Leakage: Path Length: $22.2\,in. \times \frac{148.52}{147} = 22.43\,in$ or $56.97\,cm.$ $\frac{56.97\,cm}{\cos 34^\circ} = 68.72\,cm$ or $27.05\,in.$ $7500\,\frac{mR}{hr} \times \frac{1}{(6.2)^2} = 195$ mR/hr. $I_L = 195\,\frac{mR}{hr} \times e^{-\frac{.693 \times 68.72cm}{6.2cm}}$ $I_L = 195\,\frac{mR}{hr} \times e^{-7.6811}$ $I_L = 195\,\frac{mR}{hr} \times [4.6145 \times 10^{-4}]$ $I_L = 0.090$ mR/hr. (d) 37° Scatter: Path Length: $22.2\,in \times \frac{148.52}{147} = 22.43\,in.$ or $56.97\,cm$ $\frac{56.97\,cm}{\cos 37^\circ} = 71.33\,cm$ or $28.08\,in.$ $\frac{7500\,\frac{R}{hr} \times 0.0049}{(0.65m)^2 \times (5.66m)^2} = 2{,}715\,\frac{mR}{hr.}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times e^{-\frac{.693 \times 71.33cm}{6.05cm}}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times e^{-8.17053}$ $I_{37^\circ Scatter} = 2{,}715\,\frac{mR}{hr} \times [2.8286 \times 10^{-4}]$ $I_{37^\circ Scatter} = 0.768$ mR/hr. Total Exposure Rate from beam orientation (3) at Point E-1 is: 0.090 mR/hr 0.768 mR/hr 0.858 mR/hr.	$0.858\,\frac{mR}{hr.}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
E-2 (a)+(b)	(1)	(a) Leakage: Path Length: $\frac{22.2 in}{1.0138} = 21.898 in.$ or $55.62 cm$ $\frac{55.62 cm}{\cos 8.5°} = 56.24 cm$ or $22.14 in.$ $7500 \frac{mR}{hr} \times \frac{1}{(4.37m)^2} = 393 \frac{mR}{hr}$ $I_L = 393 \frac{mR}{hr} \times e^{-\frac{.693 \times 56.24 cm}{6.2 cm}}$ $I_L = 393 \frac{mR}{hr} \times e^{-6.2862}$ $I_L = 393 \frac{mR}{hr} \times [1.8618 \times 10^{-3}]$ $I_L = 0.732 \frac{mR}{hr}$ (b) 107° Scatter: Path Length: $\frac{22.2 in}{1.0138} = 21.898 in.$ or $55.62 cm$ $\frac{55.62 cm}{\cos 17°} = 58.16 cm$ or $22.90 in.$ $\frac{7500 \frac{R}{hr} \times 0.0008}{(0.65m)^2 \times (4.52m)^2} = 695 \frac{mR}{hr}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times e^{-\frac{.693 \times 58.16 cm}{4.5 cm}}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times e^{-8.95664}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times [1.2887 \times 10^{-4}]$ $I_{107° Scatter} = 0.0896$ mR/hr Total Exposure Rate from beam orientation (1) at Point E-2 is: 0.732 mR/hr. +0.090 mR/hr. 0.822 mR/hr.	$0.822 \frac{mR}{hr.}$
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
E-2 (a)+(b)	(1)	(a) Leakage: Path Length: $22.2 in. \times \frac{148.52 lbs/ft^3}{147 lbs/ft^3} = 22.43 in$ or $56.97 cm.$ $\frac{56.97 cm}{\cos 8.5°} = 57.60 cm$ or $22.68 in.$ $7500 \frac{mR}{hr} \times \frac{1}{(4.37m)^2} = 393 \frac{mR}{hr.}$ $I_L = 393 \frac{mR}{hr} \times e^{-\frac{.693 \times 57.60 cm}{6.2 cm}}$ $I_L = 393 \frac{mR}{hr} \times e^{-6.43819}$ $I_L = 393 \frac{mR}{hr} \times [1.5992 \times 10^{-3}]$ $I_L = 0.629 \frac{mR}{hr}$ (b) 107° Scatter: Path Length: $22.2 in \times \frac{148.52}{147} = 22.43 in$ or $56.97 cm$ $\frac{56.97 cm}{\cos 17°} = 59.57 cm$ or $23.45 in.$ $\frac{7500 \frac{R}{hr} \times 0.0008}{(0.65m)^2 \times (4.52m)^2} = 695 \frac{mR}{hr}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times e^{-\frac{.693 \times 59.57 cm}{4.5 cm}}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times e^{-9.17378}$ $I_{107° Scatter} = 695 \frac{mR}{hr} \times [1.0372 \times 10^{-4}]$ $I_{107° Scatter} = 0.072$ mR/hr. Total Exposure Rate from beam orientation (1) at Point E-2 is: 0.629 mR/hr +0.072 mR/hr 0.701 mR/hr	$0.701 \frac{mR}{hr.}$
E-2 (e)+(f)	(3)	(e) Leakage: Path Length: $\frac{22.2 in.}{1.0138} = 21.898 in.$ or $55.62 cm$ $\frac{55.62 cm}{\cos 14°} = 57.323 cm$ or $22.57 in.$ $7500 \frac{mR}{hr} \times \frac{1}{(5.28m)^2} = 269 \frac{mR}{hr.}$ $I_L = 269 \frac{mR}{hr} \times e^{-\frac{.693 \times 57.323 cm}{6.2 cm}}$ $I_L = 269 \frac{mR}{hr} \times e^{-6.407232}$ $I_L = 269 \frac{mR}{hr} \times [1.6495 \times 10^{-3}]$ $I_L = 0.4437$ mR/hr. (f) 35° Scatter: Path Length: $\frac{22.2 in.}{1.0138} = 21.898 in.$ or $55.62 cm$ $\frac{55.62 cm}{\cos 18°} = 58.483 cm$ or $23.025 in.$ $\frac{7500 \frac{R}{hr} \times 0.0053}{(0.65m)^2 \times (4.70m)^2} = 4,259 \frac{mR}{hr.}$ $I_{35° Scatter} = 4,259 \frac{mR}{hr} \times e^{-\frac{.693 \times 58.483 cm}{6.07 cm}}$ $I_{35° Scatter} = 4,259 \frac{mR}{hr} \times e^{-6.6768894}$ $I_{35° Scatter} = 4,259 \frac{mR}{hr} \times [1.2596 \times 10^{-3}]$ $I_{35° Scatter} = 5.365 \frac{mR}{hr}$ Total Exposure Rate from beam orientation (3) at Point E-2 is: 0.444 mR/hr +5.365 mR/hr 5.809 mR/hr.	$5.809 \frac{mR}{hr.}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
E-2(e)+(f)	(3)	Concrete Density is 148.52 lbs/ft^3 vice 145 lbs/ft^3 (e) Leakage: Path Length: 22.2 in. $\times \frac{148.52}{147}$ = 22.43 in. or 56.971 cm $\frac{56.971\text{cm}}{\cos 14°}$ = 58.72 cm or 23.12 in. $7500\frac{mR}{hr} \times \frac{1}{(5.28m)^2} = 269\frac{mR}{hr.}$ $I_L: 269\frac{mR}{hr} \times e^{-\frac{.69314 \times 58.72cm}{6.2cm}}$ $I_L: 269\frac{mR}{hr} \times e^{-6.5647727}$ $I_L: 269\frac{mR}{hr} \times [1.4091 \times 10^{-3}]$ $I_L: 0.379\ \frac{mR}{hr.}$ (f) 35° Scatter: Path Length: 22.2 in $\times \frac{148.52}{147}$: 22.43 in or 56.971 cm $\frac{56.971\text{ cm}}{\cos 18°}$ = 59.903 cm or 23.584 in. $\frac{7500\frac{R}{hr} \times 0.0053}{(0.65m)^2 \times (4.70m)^2} : 4,259\frac{mR}{hr.}$ $I_{35° Scatter} = 4,259\frac{mR}{hr} \times e^{-\frac{.69314 \times 59.903}{6.07cm}}$ $I_{35° Scatter} = 4,259\frac{mR}{hr} \times e^{-6.8404586}$ $I_{35° Scatter} = 4,259\frac{mR}{hr} \times [1.0696 \times 10^{-3}]$ $I_{35° Scatter} = 4.555\frac{mR}{hr.}$ Total Exposure Rate from beam orientation (3) at Point E-2 is: 0.379 mR/hr + 4.555 mR/hr 4.934 mR/hr.	$4.934\frac{mR}{hr.}$
S-1(a)+(b)	(1)	(a) Leakage: Path Length: Measured directly from the elevation drawing since both WALL + ROOF are involved. Thickness of concrete ranges from 2 ft 6" to 3 ft. depending on source of leakage or scatter. For all subsequent calculations to this point, we will assume a concrete thickness of 30 in. or 76.2 cm corrected for density to: 29.59 in. or 75.16 cm. $7500\frac{mR}{hr} \times \frac{1}{(3.73m)^2} : 539\frac{mR}{hr.}$ $I_L = 539\frac{mR}{hr} \times e^{-\frac{.693 \times 75.16cm}{6.2cm}}$ $I_L: 539\frac{mR}{hr} \times e^{-8.40095}$ $I_L: 539\frac{mR}{hr} \times [2.2465 \times 10^{-4}]$ $I_L: 0.121$ mR/hr. (b) 127° Scatter: Path Length: 29.59 in. or 75.16 cm. $\frac{7500\frac{R}{hr} \times 0.000653}{(0.65m)^2 \times (4.04m)^2} : 693\frac{mR}{hr.}$ $I_{127° Scatter} : 693\frac{mR}{hr} \times e^{-\frac{.693 \times 75.16cm}{4.4cm}}$ $I_{127° Scatter} : 693\frac{mR}{hr} \times e^{-11.8377}$ $I_{127° Scatter} : 693\frac{mR}{hr} \times [7.2269 \times 10^{-6}]$ $I_{127° Scatter} : 0.005\frac{mR}{hr}$ Total Exposure Rate from beam orientation (1) at Point S-1 is: 0.121 mR/hr + 0.005 mR/hr 0.126 mR/hr.	$0.126\frac{mR}{hr.}$
S-1(a)+(b)	(1)	Concrete Density is 148.52 lbs/ft^3 vice 145 lbs/ft^3 Path Length: [30 in or 76.2 cm] $\times \left(\frac{148.52}{147}\right)$: 30.31 in. or 76.99 cm (a) Leakage $I_L: 539\frac{mR}{hr} \times e^{-\frac{.693 \times 76.99cm}{6.2cm}}$ $I_L: 539\frac{mR}{hr} \times e^{-8.6058951}$ $I_L: 539\frac{mR}{hr} \times [1.8309 \times 10^{-4}]$ $I_L: 0.0987$ mR/hr. (b) 127° Scatter: $I_{127° Scatter} : 693\frac{mR}{hr} \times e^{-\frac{.693 \times 76.99}{4.4cm}}$ $I_{127° Scatter} = 693\frac{mR}{hr.} \times e^{-12.1259}$ $I_{127° Scatter} : 693\frac{mR}{hr} \times [5.4172 \times 10^{-6}]$ $I_{127° Scatter} : 0.0038$ mR/hr. Total Exposure Rate from Beam Orient. (1) to Point S-1 is: 0.0987 mR/hr 0.0038 mR/hr 0.1025 mR/hr.	$0.103\frac{mR}{hr.}$

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
S-1(c)+(d)	(2)	Path Length for both Leakage and 90° Scatter is assumed to be at least 30 inches or 76.2 cm, corrected for density to: 29.59 in or 75.16 cm. (c) Leakage: $7500 \frac{mR}{hr} \times \frac{1}{(4.28m)^2} = 409.4 \frac{mR}{hr.}$ $I_L = 409.4 \frac{mR}{hr} \times e^{-\frac{.693 \times 75.16cm}{6.2cm}}$ $I_L = 409.4 \frac{mR}{hr} \times e^{-8.4009483}$ $I_L = 409.4 \frac{mR}{hr} \times [2.2465 \times 10^{-4}]$ $I_L = 0.092$ mR/hr. (d) 90° Scatter: $\frac{7500 \frac{R}{hr} \times 0.0009}{(0.65m)^2 \times (4.09m)^2} = 955 \frac{mR}{hr.}$ $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times e^{\frac{-.693 \times 75.16cm}{4.6cm}}$ $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times e^{-11.323}$ $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times [1.2091 \times 10^{-5}]$ $I_{90^\circ scatter} = 0.012$ mR/hr Total Exposure Rate from beam orientation (2) at Point S-1 is: 0.092 mR/hr + 0.012 mR/hr = 0.104 mR/hr.	$0.104 \frac{mR}{hr.}$
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
S-1(c)+(d)	(2)	Path Length: [30 in. or 76.2 cm] $\times \left(\frac{148.52}{147}\right)$ = 30.31 in or 76.99 cm (c) Leakage: $I_L = 409.4 \frac{mR}{hr} \times e^{-\frac{.693 \times 76.99cm}{6.2cm}}$ $I_L = 409.4 \frac{mR}{hr} \times e^{-8.6055}$ $I_L = 409.4 \frac{mR}{hr} \times [1.831 \times 10^{-4}]$ $I_L = 0.075$ mR/hr. (d) 90° Scatter: $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times e^{-\frac{.693 \times 76.99}{4.6cm}}$ $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times e^{-11.59871}$ $I_{90^\circ scatter} = 955 \frac{mR}{hr} \times [9.1779 \times 10^{-6}]$ $I_{90^\circ scatter} = 0.009$ mR/hr. Total Exposure Rate From Beam Orient. (2) at Point S-1 is 0.075 mR/hr + 0.009 mR/hr = 0.084 mR/hr.	$0.084 \frac{mR}{hr.}$
C-1(a)	(1)	(a) Leakage: Path Length: 27.0 in. $\times \frac{1}{1.0138}$ = 26.63 in. or 67.65 cm. $7500 \frac{mR}{hr} \times \frac{1}{(2.06m)^2} = 1,767 \frac{mR}{hr}$ $I_L = 1,767 \frac{mR}{hr} \times e^{-\frac{.693 \times 67.65cm}{6.2cm}}$ $I_L = 1,767 \frac{mR}{hr} \times e^{-7.5615241}$ $I_L = 1,767 \frac{mR}{hr} \times [5.2008 \times 10^{-4}]$ $I_L = 0.919$ mR/hr	$0.919 \frac{mR}{hr.}$
		Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³	
C-1(a)	(1)	(a) Leakage: Path Length = [27.0 in or 68.58 cm] $\times \frac{148.52 \, lbs/ft^3}{147 \, lbs/ft^3}$ = 27.28 in. or 69.29 cm $7500 \frac{mR}{hr} \times \frac{1}{(2.06m)^2} = 1767 \frac{mR}{hr.}$ $I_L = 1767 \frac{mR}{hr} \times e^{-\frac{.693 \times 69.29cm}{6.2cm}}$ $I_L = 1767 \frac{mR}{hr} \times e^{-7.7448}$ $I_L = 1767 \frac{mR}{hr} \times [4.3297 \times 10^{-4}]$ $I_L = 0.765 \frac{mR}{hr}$	$0.765 \frac{mR}{hr.}$

VII. Signature of Certifying Official

I hereby certify that the Radiarium has implemented the ALARA Program set forth above.

Richard A Morrison
(Signature)

Richard A. Morrison, M.D.
(Name - print or type)

Director
(Title)

Licensee Address:

Prior to December 15, 1980:	Richard A. Morrison, M.D. 9021 Delmar Shawnee Mission, Kansas 66207
After December 15, 1980 :	Richard A. Morrison, M.D. The Radiarium 17525 Medical Center Parkway Independence, Missouri 64057

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

Annex G - Item No. 18
Emergency Procedures for the Teletherapy Unit

IN THE EVENT OF EQUIPMENT FAILURE
RESULTING IN THE SOURCE REMAINING
"ON", THE OPERATOR SHOULD DO THE
FOLLOWING:

A. If the patient is ambulatory, instruct him to get off the table and leave the room.

B. If the patient is not ambulatory:

1. If the patient can be removed from the room, enter the room and avoiding exposure to the useful beam, pull the treatment table as far away from the useful beam as possible, transfer the patient to a stretcher and remove him from the room.

2. If the patient cannot be removed from the teletherapy room without assistance:

(a) Take the red "T" rod kept at the control panel and enter the treatment room. Insert the "T" rod into hole in front head trim cover and push source drawer to "OFF" position.

(b) Obtain additional assistance in removing the patient from the room.

CAUTION: STAY OUT OF THE DIRECT (USEFUL) BEAM AT ALL TIMES

C. Close the entry door to the treatment room, lock it, and post a sign to guard against unauthorized access.

D. Notify Dr. Richard Morrison for remedial action to be taken.

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DATE: July 15, 1980

THE RADIARIUM COBALT-60 TELETHERAPY ROOM

SHIELDED EXPOSURE RATE CALCULATIONS

WALL-LOC. POINT	BEAM ORIENT.	CALCULATIONS	EXPOSURE RATE
C-1(d)+(e)	(4)	see below (1)	4.862 mR/hr.
C-1(d)+(e)	(4)	see below (2)	4.033 mR/hr.
C-2(a)+(b)	(4)	see below (3)	4.444 mR/hr
C-2(a)+(b)	(4)	see below (4)	3.722 mR/hr.

(1) C-1(d)+(e), Beam Orientation (4)

(d) Leakage:

Path Length: $27.0\text{in.} \times \frac{1}{1.0138} = 26.63\text{in.}$ or 67.65cm

$7500\frac{mR}{hr} \times \frac{1}{(3.61m)^2} = 575.5\frac{mR}{hr.}$

$I_L = 575.5\frac{mR}{hr} \times e^{-\frac{.693 \times 67.65cm}{6.2cm}}$

$I_L = 575.5\frac{mR}{hr} \times e^{-7.5615241}$

$I_L = 575.5\frac{mR}{hr} \times [5.2008 \times 10^{-4}]$

$I_L = 0.299$ mR/hr.

(e) 35° Scatter:

Path Length $= 27.0\text{in.} \times \frac{1}{1.0138} = 26.63\text{in}$ or 67.65cm

$\frac{7500\frac{R}{hr} \times 0.0053}{(0.65m)^2 \times (3.02m)^2} = 10{,}315.6\frac{mR}{hr.}$

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times e^{-\frac{.693 \times 67.65cm}{6.07cm}}$

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times e^{-7.7234678}$

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times [4.4232 \times 10^{-4}]$

$I_{35^\circ Scatter} = 4.563$ mR/hr.

Total Exposure Rate from Beam Orientation (4) at Point C-1 is:
0.299 mR/hr
+4.563 mR/hr.
4.862 mR/hr.

(2) C-1(d)+(e), Beam Orientation (4)

Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³

Path Length $= [27.0\text{in or } 68.58\text{cm}] \times \frac{148.52\ lbs/ft^3}{147\ lbs/ft^3} = 27.28\text{in}$ or 69.29cm.

(d) Leakage:

$I_L = 575.5\frac{mR}{hr} \times e^{-\frac{.693 \times 69.29cm}{6.2}}$

$I_L = 575.5\frac{mR}{hr} \times e^{-7.7448338}$

$I_L = 575.5\frac{mR}{hr} \times [4.3297 \times 10^{-4}]$

$I_L = 0.249\frac{mR}{hr.}$

(e) 35° Scatter:

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times e^{-\frac{.693 \times 69.29}{6.07}}$

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times e^{-7.910713}$

$I_{35^\circ Scatter} = 10{,}315.6\frac{mR}{hr} \times [3.6679 \times 10^{-4}]$

$I_{35^\circ Scatter} = 3.784\frac{mR}{hr.}$

Total Exposure Rate from Beam Orientation (4) at Point C-1 is:
0.249 mR/hr
+3.784 mR/hr
4.033 mR/hr.

(3) C-2(a)+(b), Beam Orientation (4)

(a) Leakage:

Path Length: $20.0\text{in} \times \frac{1}{1.0138} = 19.73\text{in.}$ or 50.11cm

$50.11\text{cm} \times \frac{1}{\cos 35^\circ} = 61.173\text{cm}$ or 24.08in.

$7500\frac{mR}{hr} \times \frac{1}{(4.42m)^2} = 384\frac{mR}{hr}$

$I_L = 384\frac{mR}{hr} \times e^{-\frac{.693 \times 61.173cm}{6.2cm}}$

$I_L = 384\frac{mR}{hr} \times e^{-6.837563}$

$I_L = 384\frac{mR}{hr} \times [1.0727 \times 10^{-3}]$

$I_L = 0.412$ mR/hr.

(b) 35° Scatter:

Path Length: $20.0\text{in} \times \frac{1}{1.0138} = 19.73\text{in}$ or 50.11cm

$50.11\text{cm} \times \frac{1}{\cos 39^\circ} = 64.48\text{cm}$ or $25.38''$

$\frac{0.0053 \times 7500\frac{R}{hr}}{(0.65m)^2 \times (3.85m)^2} = 6{,}347$ mR/hr.

$I_{35^\circ Scatter} = 6{,}347\frac{mR}{hr} \times e^{-\frac{.693 \times 64.48}{6.07cm}}$

$I_{35^\circ Scatter} = 6{,}347\frac{mR}{hr} \times e^{-7.3616}$

$I_{35^\circ Scatter} = 6{,}347 \times [6.3521 \times 10^{-4}]$

$I_{35^\circ Scatter} = 4.032$ mR/hr.

TOTAL EXPOSURE RATE FROM BEAM ORIENTATION (4) TO POINT C-2 IS:
0.412 mR/hr
+4.032 mR/hr
4.444 mR/hr

(4) C-2(a)+(b), Beam Orientation (4)

Concrete Density is 148.52 lbs/ft³ vice 145 lbs/ft³

(a) Leakage:

Path length: $20.0\text{in} \times \frac{148.52}{147} = 20.207\text{in}$ or 51.325cm

$51.325\text{cm} \times \frac{1}{\cos 35^\circ} = 62.656\text{cm}$ or 24.67in.

$I_L = 384\frac{mR}{hr} \times e^{-\frac{.693 \times 62.656cm}{6.2cm}}$

$I_L = 384\frac{mR}{hr} \times e^{-7.0033238}$

$I_L = 384\frac{mR}{hr} \times [9.0885 \times 10^{-4}]$

$I_L = 0.349$ mR/hr.

(b) 35° Scatter:

Path length: $20.0\text{in} \times \frac{148.52}{147} = 20.207\text{in}$ or 51.325cm

$51.325\text{cm} \times \frac{1}{\cos 39^\circ} = 66.043\text{cm}$ or 26.0in.

$I_{35^\circ scatter} = 6{,}347\frac{mR}{hr} \times e^{-\frac{.693 \times 66.043}{6.07}}$

$I_{35^\circ scatter} = 6{,}347\frac{mR}{hr} \times e^{-7.53991}$

$I_{35^\circ scatter} = 6{,}347\ mR/hr \times [5.3139 \times 10^{-4}]$

$I_{35^\circ scatter} = 3.373$ mR/hr.

Total Exposure Rate from Beam Orientation (4) to Point C-2 is:
0.349 mR/hr
3.373 mR/hr.
3.722 mR/hr.

THE RADIARIUM

APPLICATION FOR NUCLEAR REGULATORY COMMISSION TELETHERAPY LICENSE

An F - Item No. 13
Radia..on Safety Program

The Radiarium Program for Maintaining Occupational
Radiation Exposures as low as Reasonably Achievable
(ALARA)

Sections that differ from the model ALARA program have been marked in the margin

Richard A. Morrison, M.D.

July 15, 1980

I. Management Commitment

a. I, the Director of the Radiarium, a radiation therapy facility, am committed to the program described in this paper for keeping exposures (individual and collective) as low as reasonably achievable (ALARA). In accord with this commitment, I hereby describe an administrative organization for radiation safety and will develop the necessary written policy, procedures and instructions to foster the ALARA concept within my institution. The organization will include the Director as onsite Radiation Safety Officer and an offsite consulting medical physicist or health physicist.

b. I will perform a formal annual review of the radiation safety program including ALARA considerations. This shall include reviews of operating procedures and past exposure records, inspections, etc., and consultations with the above mentioned medical physicist or health physicist.

c. Modification to operating and maintenance procedures and to equipment and facilities will be made where they will reduce exposures unless the cost, in my judgement, is considered to be unjustified. I will be able to demonstrate, if necessary, that improvements have been sought, that modifications have been considered, and that they have been implemented

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Annex F - Item No. 13
I. Management Commitment (continued)

where reasonable. Where modifications have been recommended but not implemented, I will be prepared to describe the reasons for not implementing them.

d. In addition to maintaining doses to individuals as far below the limits as is reasonably achievable, the sum of the doses received by all exposed individuals will also be maintained at the lowest practicable level. It would not be desirable, for example, to hold the highest doses to individuals to some fraction of the applicable limit if this involved exposing additional people and significantly increasing the sum of radiation doses received by all involved individuals.

II. Radiation Safety Committee

At the present time, the responsibilities of the radiation safety committee have been assumed by the Director who will carry out the following functions where applicable, until such time as the staff of the Radiarium expands to make the establishment of a radiation safety committee practical. The Director will also function as the radiation safety officer in consultation with a medical physicist or health physicist, until such time as a full-time qualified radiation physicist or health physicist can join the staff.

a. Review of Proposed Users and Uses

1. The RSC will thoroughly review the qualifications of each applicant with respect to the types and quantities of materials and uses for which he has applied to assure that the applicant will be able to take appropriate measures to maintain exposure ALARA.

2. When considering a new use of byproduct material, the RSC will review the efforts of the applicant to maintain exposure ALARA. The user should have systematized procedures to ensure ALARA, and shall have incorporated the use of special equipment such as syringe shields, rubber gloves, etc., in his proposed use.

3. The RSC will ensure that the user justifies his procedures and that dose will be ALARA (individual and collective).

Annex F - Item No. 13
II. Radiation Safety Committee (continued)

b. Delegation of Authority

1. The RSC will delegate authority to the RSO for enforcement of the ALARA concept.

2. The RSC will support the RSO in those instances where it is necessary for the RSO to assert his authority. Where the RSO has been overruled, the committee will record the basis for its action in the minutes of the committee's quarterly meeting.

c. Review of ALARA Program

1. The RSC will encourage all users to review current procedures and develop new procedures as appropriate to implement the ALARA concept.

2. The RSC will perform a quarterly review of occupational radiation exposure with particular attention to instances where Investigational Levels in Table I below are exceeded. The principle purpose of this review is to assess trends in occupational exposure as an index of the ALARA program quality and to decide if action is warranted when Investigational Levels are exceeded.

3. The RSC will evaluate this institution's overall efforts for maintaining exposures ALARA on an annual basis. This review will include the efforts of the RSO, authorized users, and workers as well as those of management.

Annex F is the Radiarium Program for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable (ALARA). This program is based on the Model Program which was enclosed with the NRC letter to all medical licensees and dated June 16, 1980. Since this is an application for a private practice physician to be licensed for use of a Co-60 teletherapy unit, references in the Model Program to a Radiation Safety Committee do not apply. In particular, Section II of the Model Program has been modified in the Radiarium Program for the following reasons:

a. Review of Proposed Users and Uses.
Since the Radiation Safety Committee does not exist in this private practice environment and since the Radiation Safety Officer is also the Director and the only user (for the near future), and since for the

Annex F - Item No. 13
II. Radiation Safety Committee (continued)

purpose of this license the only use will be external beam teletherapy, it is unlikely that paragraphs 1, 2, and 3 of Section IIa could apply.

b. Delegation of Authority.
It is assumed that in the case of a private practice, such as exists here, the authority normally vested with the Radiation Safety Committee will rest with the Radiation Safety Officer, since the RSC does not exist.

c. Review of ALARA Program.
The three items mentioned in this section overlap into the responsibilities of the Radiation Safety Officer, which are outlined in Section III.

The Radiarium Program will be general enough to allow for expansion of staff to include a radiation safety committee.

Personnel Monitoring Devices:
Searle Diagnostics, Inc., Health Physics Services, will provide clip-on film badges for all occupationally exposed personnel to determine "whole body and skin" X-, gamma and beta dose. Badges are changed and reported monthly.

III. Radiation Safety Officer (RSO)
The Director, functioning as the RSO, may request a consulting medical physicist or health physicist to carry out some of the functions listed below.

a. Annual and Quarterly Review

1. Annual review of the Radiation Safety Program. The RSO will perform an annual review of the Radiation Safety Program for adherence to ALARA concepts. Reviews of specific procedures may be conducted on a more frequent basis.

2. Quarterly review of Occupational Exposures. The RSO will review at least quarterly the external radiation exposures of authorized

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III. Radiation Safety Officer (RSO) (continued)

users and workers to determine that their exposures are ALARA in accordance with the provisions of paragraph VI of this program.

3. Quarterly review of records of Radiation Level Surveys. The RSO will review radiation levels in unrestricted and restricted areas to determine that they were at ALARA levels during the previous quarter.

b. Education Responsibilities for an ALARA Program

1. The RSO will schedule briefings and educational sessions to inform workers of ALARA program efforts.

2. The RSO will assure that authorized users, workers, and ancillary personnel who may be exposed to radiation will be instructed in the ALARA philosophy and informed that management, the RSC and the RSO are committed to implementing the ALARA concept.

c. Cooperative Efforts for Development of ALARA Procedures

1. Radiation workers will be given opportunities to participate in formulation of the procedures that they will be required to follow.

2. The RSO will be in close contact with all users and workers in order to develop ALARA procedures for working with radioactive materials.

3. The RSO will establish procedures for receiving and evaluating the suggestions of individual workers for improving health physics practices and encourage the use of those procedures.

d. Reviewing Instances of Deviation from Good ALARA Practices.

The RSO will investigate all known instances of deviation from good ALARA practices; and, if possible, determine the causes. When the cause is known, the RSO will require changes in the program to maintain exposures ALARA.

IV. Authorized Users

a. New Procedures Involving Potential Radiation Exposures

1. The authorized user will consult with, and receive the approval of, the RSO and/or RSC during the planning stage before using radioactive materials for a new procedure.

2. The authorized user will evaluate all procedures before using radioactive materials to ensure that exposures will be kept

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IV. Authorized Users (continued)

ALARA. This may be enhanced through the application of trial runs.

b. Responsibility of the Authorized User to Those He Supervises

1. The authorized user will explain the ALARA concept and his commitment to maintain exposures ALARA to all of those he supervises.

2. The authorized user will ersure that those under his supervision who are subject to occupational radiation exposure are trained and educated in good health physics practices and in maintaining exposures ALARA.

V. Persons Who Receive Occupational Radiation Exposure

a. The worker will be instructed in the ALARA concept and its relationship to his working procedures and work conditions.

b. The worker will know what recourses are available if he feels that ALARA is not being promoted on the job.

VI. Establishment of Investigational Levels in Order to Monitor Individual Occupational External Radiation Exposures.

The Radiarium hereby establishes Investigational Levels for occupational external radiation exposure which, when exceeded, will initiate review or investigation by the Radiation Safety Committee and/or the Radiation Safety Officer. The Investigational Levels that we have adopted are listed in Table 1 below. These levels apply to the exposure of individual workers.

Table 1

	Investigational Levels (mrems per calendar quarter)	
	LEVEL I	LEVEL II
1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	125	375
2. Hands and forearms; feet and ankles	1875	5625

(Deleted skin values)

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VI. Establishment of Investigational Levels ... (continued)

The Radiation Safety Officer will review and record on Form NRC-5, Current Occupational External Radiation Exposures, or an equivalent form (e.g. dosimeter processor's report), results of personnel monitoring, not less than once in any calendar quarter, as is required by 10 CFR 20, 20.401. The following actions will be taken at the Investigational Levels as stated in Table 1.

a. Quarterly exposure of individuals to less than Investigational Level I.

Except when deemed appropriate by the RSO, no further action will be taken in those cases where an individual's exposure is less than Table 1 values for the Investigational Level I.

b. Personnel exposures equal to or greater than Investigational Level I, but less than Investigational Level II.

The RSO will review the exposure of each individual whose quarterly exposures equal or exceed Investigational Level I. He will report the results of his reviews at the first RSC meeting following the quarter when the exposure was recorded. If the exposure does not equal or exceed Investigational Level II, no action related specifically to the exposure is required unless deemed appropriate by the Committee. The Committee will,however, consider each such exposure in comparison with those of others performing similar tasks as an index of ALARA program quality and will record the review in the Committee minutes.

c. Exposure equal to or greater than Investigational Level II.

The RSO will investigate in a timely manner the cause(s) of all personnel exposures equaling or exceeding Investigational Level II

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VI. Establishment of Investigational Levels ... (continued)

and, if warranted, take action. A report of the investigation, actions taken, if any, and a copy of the individual's Form NRC-5 or its equivalent will be presented to the Radiation Safety Committee at the first Radiation Safety Committee meeting following completion of the investigation. The details of these reports will be recorded in the Committee minutes. Committee minutes will be sent to the management of this institution for review. The minutes, containing details of the investigation, will be made available to NRC inspectors for review at the time of the next inspection.

d. Re-establishment of an individual occupational worker's Investigational Level II above that listed in Table 1.

In cases where a worker's or a group of worker's exposures need to exceed Investigational Level II, a new, higher Investigational Level II may be established on the basis that it is consistent with good ALARA practices for that individual or group. Justification for a new Investigational Level II will be documented.

The Radiation Safety Committee will review the justification for, and will approve, all revisions of Investigational Levels II. In such cases, when the exposure equals or exceeds the newly established Investigational Level II, those actions listed in paragraph c above will be followed.

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