

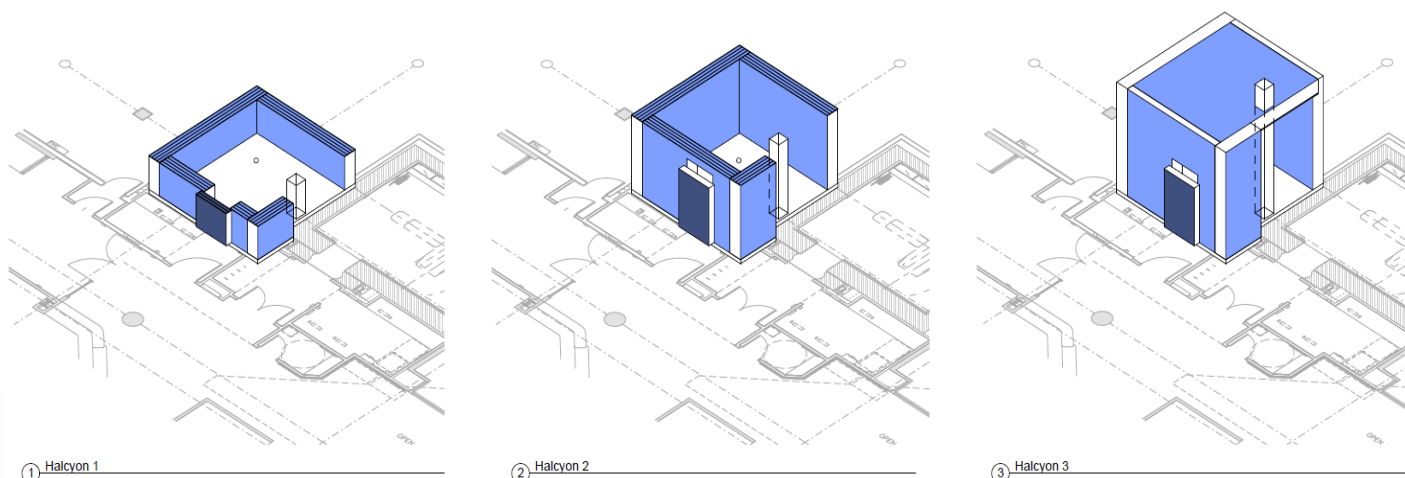


Mississauga Halton Central West Regional Cancer Program

Ontario Health (Cancer Care Ontario)

ONTARIO, CANADA

(Veritas Project ID: XX-XXX-4614)



SCOPE:

- **Room 1:** Direct Entry LINAC bunker, with Varian Halcyon (6 MV FFF)
- **Room 2:** Direct Entry LINAC bunker, with Varian Halcyon (6 MV FFF)
- **Room 3:** Direct Entry LINAC bunker, with Varian Halcyon (6 MV FFF)
- **Room 4:** Orthovoltage X-ray Imaging, with XSTRAHL 200 / 30 mA max beam current.

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A. SCOPE AND FRAMEWORK OF THE PROJECT

This project shall be realized by deploying the optimal Veritas Shielding solution(s) that meet the customer's requirements and needs while fully respecting the international and local radioprotection regulations and laws.

1. The Regulatory Framework

The following calculations were prepared for the radiation protection requirements for the new linear accelerator room being designed for Jefferson Health - Cherry Hill - New Jersey. The purpose of these calculations is to inform the client and their representatives of shielding parameters that have been used as the basis of the quotation and client's purchase order. The client should review all parameters and conditions to ensure that they comply with all codes pertaining to radiation health safety.

It is the client's responsibility to review the proposed recommendations in their entirety to ensure that the proper shielding parameters have been used for the specific site. Information such as design exposure level, workload, etc. are generally taken from NCRP 151 recommendations, where other information has not been previously supplied by the client or their representatives. The client should review the shielding parameters and calculations for compliance with regulating agencies and with the client's preferences.

The client is responsible for ensuring that the shielding parameters have been reviewed and agreed by all relevant parties. It will be assumed that the parameters are correct unless Veritas is notified in writing within 30 days of the date of this report.

2. The shielding Scope of the project

The shielding scope for this project includes:

- **Room 1:** single linac design
 - Houses a Varian Halcyon 6 MV FFF
 - Beam Energies & maximum dose rates: 6 MV FFF at dose rate of 800 MU/min.
- **Room 2:** single linac design
 - Houses a Varian Halcyon 6 MV FFF
 - Beam Energies & maximum dose rates: 6 MV FFF at dose rate of 800 MU/min.
- **Room 3:** single linac design
 - Houses a Varian Halcyon 6 MV FFF
 - Beam Energies & maximum dose rates: 6 MV FFF at dose rate of 800 MU/min.
- **Room 4:** Orthovoltage x-ray Imaging
 - Houses a XSTRAHL 200 / 30 mA max beam current
 - Beam Energies & maximum dose rates: 200 KV/30mA max beam current /1 minute Pulse duration

3. The Veritas Material

The shielding design is based on the use of VeriShield®, a proprietary high-density modular material manufactured by Veritas Medical Solutions. VeriShield barriers consist of interlocking modules (see Fig. 1). The dimensions are 5" × 5" × 10" (127mm × 127mm × 254mm) or 2.5" × 5" × 10" (63mm × 127mm × 254mm). Two types of VeriShield material are used in this design, VHD (220 lb./cf, 3.52g/cc) and VUHD (300 lb./cf, 4.80g/cc). The VeriShield thicknesses used in this report have been rounded up

to the nearest 2.5" (63mm) thickness increment. Other shielding materials are used as needed. The Verishield' TVL values for primary and secondary photons radiation and for neutron leakage in material are given by its manufacturer reference [3]. Table 1 shows a summary of the Verishield radiation shielding properties in comparison to concrete with a standard density (147 lb./cf, 2.35g/cc).

Primary Photons TVLS in inches				Secondary Photons TVLS in inches			
Energy	VHD	VUHD	Concrete	Energy	VHD	VUHD	Concrete
6MV	9	6.5	13.5	6MV	7.4	5.3	11
10MV	10.2	7.4	15.3	10MV	8	5.8	12
15MV	11.4	8.2	17.5	15MV	8.7	6.3	13

Table 1: Comparison of TVLs values for Verishield blocks with concrete.

B. THE PHYSICS AND SHIELDING CALCULATION METHODOLOGY

The shielding design calculations are performed according to the methodology described in NCRP report 151 [1]. The relevant formulas are listed below on page 6. All mega-voltage energies referred to in this report follow the BJR-11 convention unless otherwise noted.

If the permissible doses, workloads, distances, beam use and occupancy factors implemented in calculation working examples in NCRP report 151 [1] differ from those established for use in this facility, the shielding calculations will need to be revised.

1. Permissible Doses

The weekly permissible dose equivalent (P), shown as TADR (time averaged dose rate) in $\mu\text{Sv/wk}$ is based on NCRP 151 recommendations, where the P values are defined for non-controlled and controlled areas. The permissible doses used in the shielding design are summarized in Table 2.

Area type	Permissible weekly limit of dose equivalent in ($\mu\text{Sv/wk}$)
Controlled areas	100
Public areas	20

Table 2: Permissible Doses used in calculation

2. Workload

The primary workload (W) is the weekly absorbed dose at 1m from the target. Its value is calculated on the base of anticipated number of patients per week and the absorbed dose delivered per patient. The leakage workload (WL) is calculated using the anticipated number of patients per week, the absorbed dose per patient and modulation factors for each treatment type (CRT, IMRT, VMAT). The modulation factors account for the higher levels of leakage radiation resulting from various treatment procedures. The workloads are calculated on the base of information supplied by the client; full details are given in the Calculations section.

3. Use factors

Unless otherwise stated, beam use factors $U=0.25$ are used for primary barriers and $U=1$ for secondary barriers, see the calculation section for details

4. Occupancy factors

If the client does not provide specific occupancy factors for the shielded points of interest (survey points), the values suggested for survey point location in NCRP 151 [1, Table B.1] are used. For details see the Calculations section.

5. Distances and Survey Points

C1, C2, C3, L1, L2 are survey points for the ceiling, P1 - P12 indicate survey points for the walls and D for the doors. For calculation purposes it is assumed that all survey measurements are to be taken at 30.5 mm (1 ft.) off the face of the shielding barrier. Primary distances (d_{pri}) are taken from the target (in machine head) to the survey point. This includes a 1 m target-to-isocenter distance. Secondary distances (d_{sec}) are taken from isocenter to the survey point. For the HDR rooms, the survey points are typically indicated by letters P1, P4, P7, P10, C1 and D. Additional survey points are added as necessary depending on occupancies around the room. All survey points and their pertinent distances as well as the barriers' thicknesses for the respective treatment rooms are shown on the attached drawings and on the shielding summary tables at the end of this report.

6. Calculation points based on plans and Drawings

The calculations are based on distances and layout information contained in the plan and section drawings attached at the end of this report. For each barrier, the survey points are located 30.5 mm (1 ft) off its face of the. Walls survey points P1-P12 are spaced (clockwise from above) at 30° intervals with P1 located behind the machine. The ceiling survey points C1, C2, C3 are spaced at directions 0° , 30° and 45° , respectively. Similarly, L1 and L2 are spaced at directions 30° and 45° .

The shielding barrier attenuation for specified survey point relates to the area around this point which is encased by the angle $\pm 15^\circ$ on both sides of the line drawn from the linac isocenter to survey point. The barrier parameters are designed for shielding requirements related to the most demanding conditions in this area.

7. Calculation Methodology

The calculations that are used to arrive at the shielding design, take into consideration the input parameters (workload, permissible dose levels, occupancy factors etc.), site specific conditions (space constraints, existing materials etc.) and cost. The shielding design presented in this report shows that the barriers proposed are adequate and provide required attenuation of both photon and neutron radiation for the set-up. The detailed calculations, including all the steps as performed by Veritas for this project are reported in Annex I attached to this report.

C. CALCULATION INPUTS: DESIGN, MACHINE SPECS AND CLINICAL USE

1. Machine and Beam Parameters

The shielding scope for this project includes:

- **Room 1:** Varian, HALCYON
 - Beam Energies & maximum dose rates: 6 MV FFF at 800 MU/min.
 - Intended clinical use: 80 Pts per day treated as follow: 80 pts (6 MVFFF) treated with IMRT&VMAT to maximum dose of 8Gy/fx.
 - The treatment room dimensions are as follow:

Room Dimensions	Feet	Inches	Meters
Primary-to-primary (external)	23	5.75	7.16
Front-to-back (external)	26	1	7.95
Height to underside of shielding	10	8.25	3.26
Isocenter to back primary (P4)	12	10.75	3.93
Isocenter to back wall (external)	12	0	3.66
Isocenter height	3	4.75	1.04
Target to isocenter			1.00

- **Room 2:** Varian, HALCYON
 - Beam Energies & maximum dose rates: 6 MV FFF at 800 MU/min.
 - Intended clinical use: 80 Pts per day treated as follow: 80 pts (6 MVFFF) treated with IMRT&VMAT to maximum dose of 8Gy/fx.
 - The treatment room dimensions are as:

Room Dimensions	Feet	Inches	Meters
Primary-to-primary (external)	21	3.25	6.48
Front-to-back (external)	25	3.125	7.70
Height to underside of shielding (Halcyon)	10	8.25	3.26
Isocenter to back primary (P4)	10	7.625	3.24
Isocenter to back wall (Halcyon) /external	10	0	3.05
Isocenter height (Halcyon)	3	4.75	1.04

- **Room 3:** Varian, HALCYON
 - Beam Energies & maximum dose rates: 6 MV FFF at 800 MU/min.
 - Intended clinical use: 80 Pts per day treated as follow: 80 pts (6 MVFFF) treated with IMRT&VMAT to maximum dose of 8Gy/fx.
 - The treatment room dimensions are as:

Room Dimensions	Feet	Inches	Meters
Room width (external)	22	2.875	6.78
Room length (external)	25	6.125	7.78
Height to underside of shielding	10	8.25	3.26
Isocenter to back primary (P4)	10	3.438	3.14
Isocenter to back wall (external)	9	0	2.74
Isocenter height	3	4.75	1.04

- **Room 4:** Orthovoltage x-ray Imaging
 - Houses a XSTRAHL 200 / 30 mA max beam current
 - Beam Energies & maximum dose rates: 200 KV/30mA max beam-current /1 minute Pulse duration
 - Intended Clinical Use: **16 patients per day or equivalent to 10000 mA-minute/Week with beam current set to 20 mA.**
 - The treatment room dimensions are as:

Room Dimensions	Feet	Inches	Meters
Room width (external)	20	0	6.10
Room length (external)	13	5	4.09
Height to underside of shielding	11	0	3.35
Isocenter to nearest Wall	3	3	0.99
Isocenter height	3	3.375	1.00

2. Rooms Designs

Figures below show the actual design of the treatment rooms with the dimensions of the rooms and the distances to the various survey points. All treatment room are direct entry with the Isocenter height above the floor is set as specified by the vendor of every specific linac.

LINAC Bunkers: Room1:

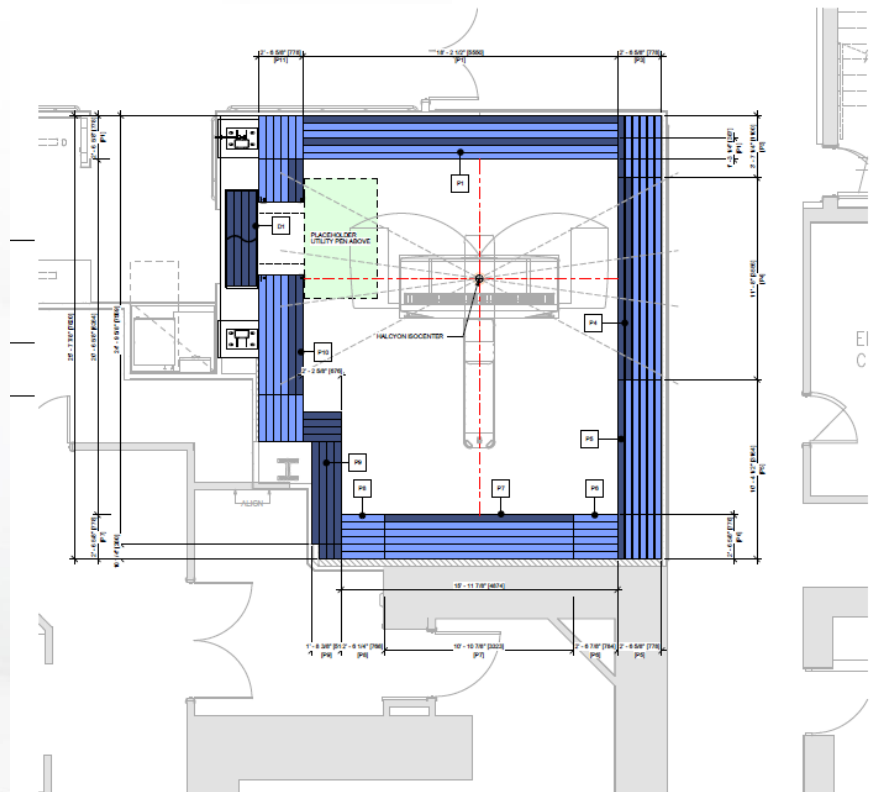


Figure 1: Layout of a horizontal section of the treatment rooms, room1 on the right and room 2 on the left.

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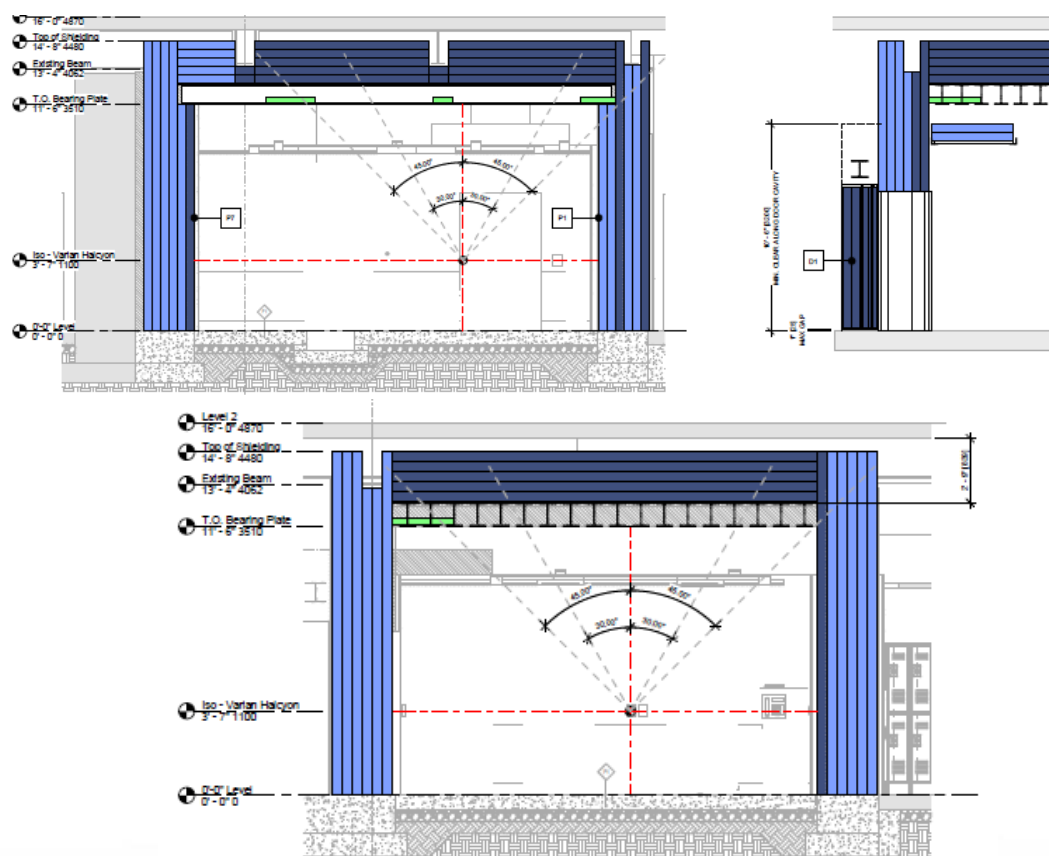


Figure 2a: Layout of a vertical sections along the primary barriers of the treatment rooms (room 1 on right, room2 on Left)

LINAC Bunkers: Room 2:

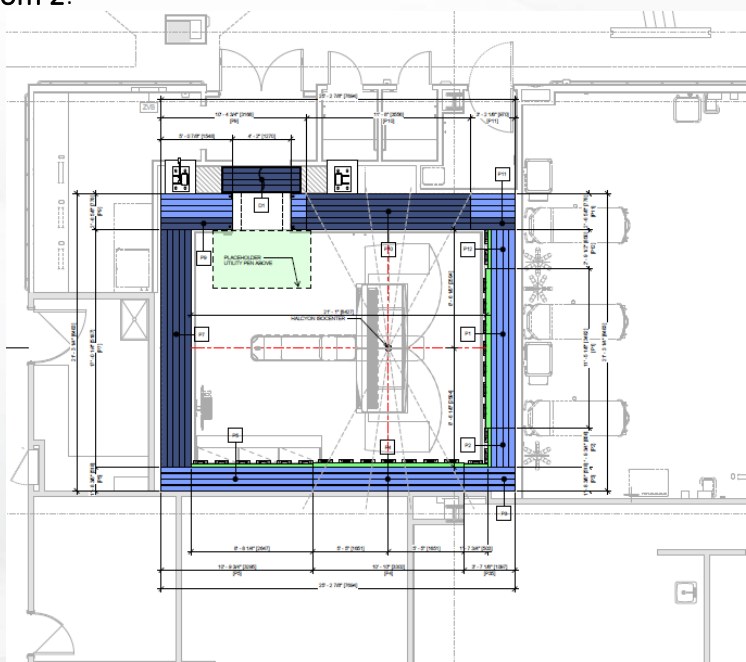


Figure 2b: Layout of a vertical sections showing utility penetration of the treatment rooms (room 1 on right, room2 on Left)

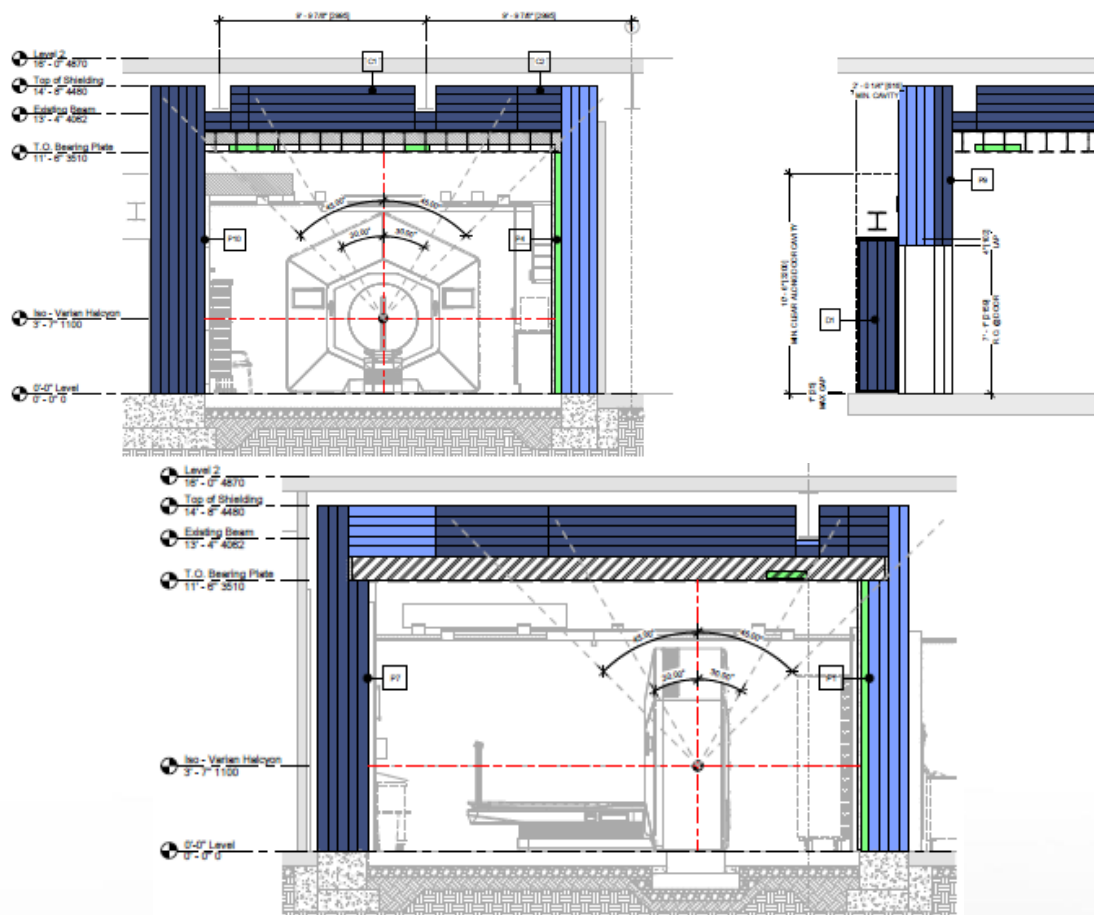


Figure 2c: Layout of a vertical sections showing doors of the treatment rooms (room 1 on right, room2 on Left)
LINAC Bunkers: Room 3:

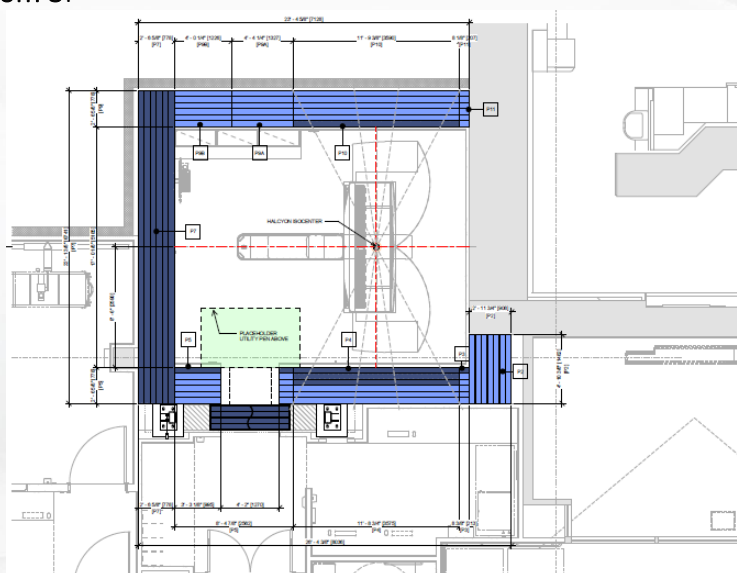


Figure 2b: Layout of a vertical sections showing utility penetration of the treatment rooms (room 1 on right, room2 on Left)

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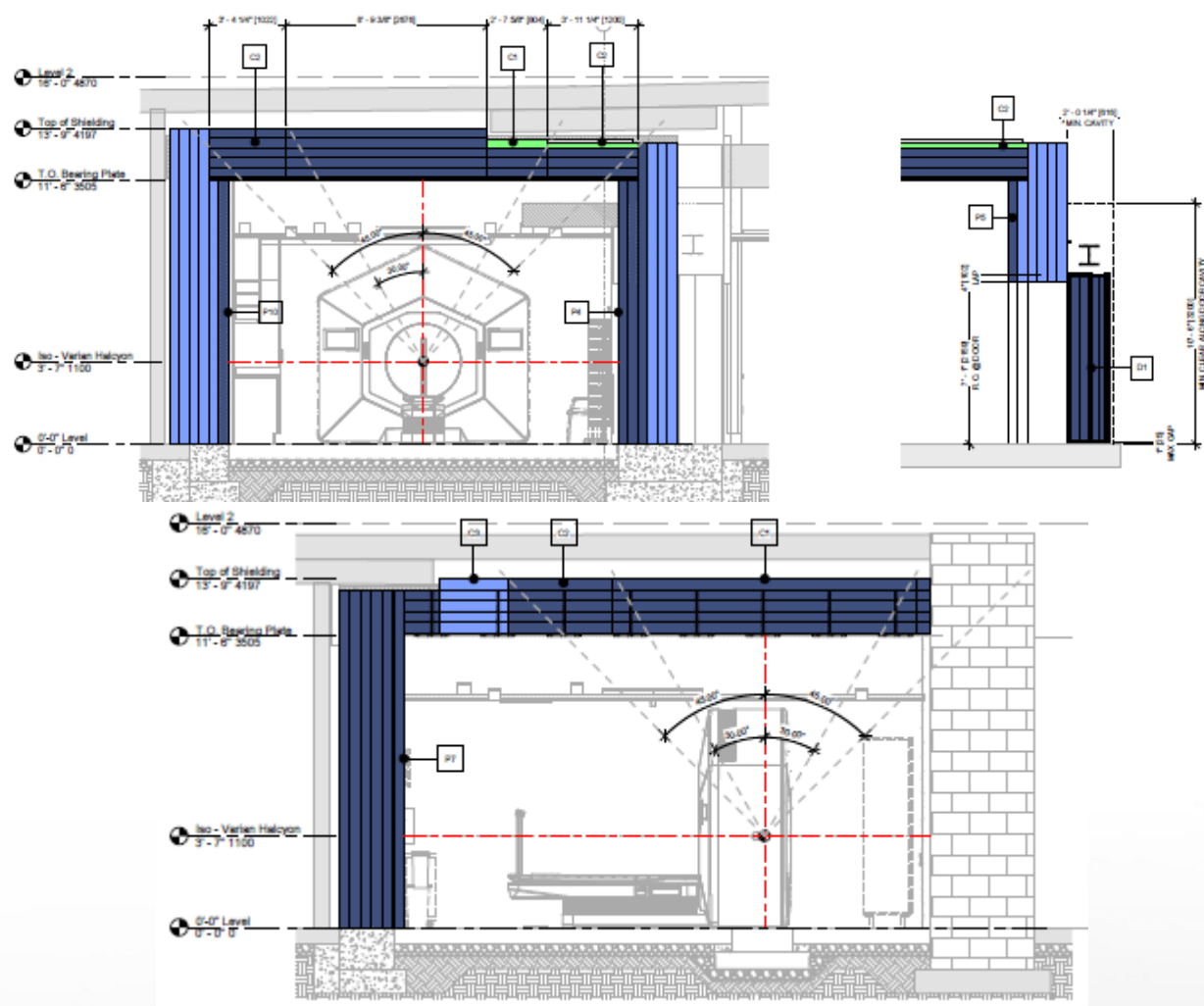


Figure 2c: Layout of a vertical sections showing doors of the treatment rooms (room 1 on right, room2 on Left)

Orthovoltage Radiography Bunker: Room4

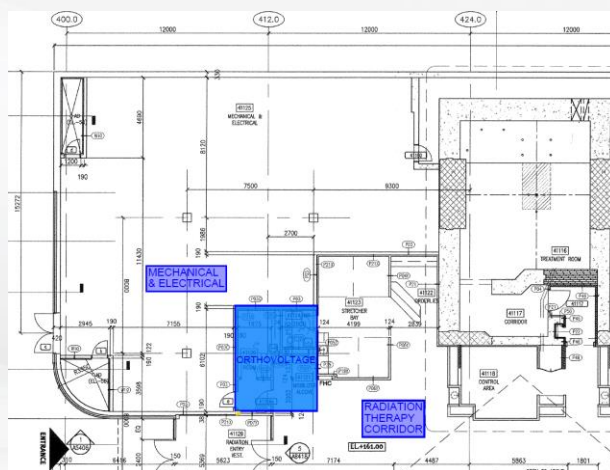


Figure 3: Layout showing a horizontal section of the HDR treatment room,

C. CALCULATIONS RESULTS

1. Room 1 (Halcyon)

a. Workloads:

All workloads are calculated at the isocenter which is 1 meter from the radiation (X-ray) source. The formulas used in this calculation shown in the Annex 1:

Workload Breakdown	6 MV FFF	TOTAL
Primary Workload (cGy/wk)	340000.00	340000.00
Leakage Workload (cGy/wk) at 1 meter from Target	1620.00	1620.00
Neutron Workload (cSv/wk)	0.00	0.00
QA / Service/R&D Workload (cGy/wk)	20000	20000

b. TVLs, Barriers Thickness and expected TADR, and AH-IDR

The table hereafter summarizes the calculations results of the thicknesses of the various barriers in TVLs and in Verishield modules as specified. Equivalent thicknesses in standard concrete (2.35 g/cm³) are also given for reference.

Survey Points	Description	Distance to Survey point (meter)	Permissible TADR (μSv/wk)	Permissible IDR (μSv/hr)	Occupancy Factor T	Use Factor U	Total TVLs needed	VERITAS shielding in V250 / V300 / STEEL / LEADL (inch)	Expected Total weekly TADR (μSv/wk)	Expected maximum IDR (μSv/hr)	Expected In-Any-One-Hour IAH (μSv/hr)
P12	Plan-North Wall / Corridor	4.52	1	10	0.2	1	5.98	15 / 15	0.30	0.03	0.03
P1	Plan-North Wall / Corridor	3.96	1	10	0.2	1	6.09	30	0.53	0.07	0.05
P2	Plan-North Wall / Corridor	4.52	1	10	0.2	1	5.98	15 / 15	0.30	0.03	0.03
P3	Plan-East Wall / Electrical room	3.84	1	10	0.1	1	5.88	30	0.07	0.01	0.01
P4	Plan-East Wall / Electrical room	4.23	1	10	0.1	1	5.73	10 / 20	0.57	0.14	0.10
P5	Plan-East Wall/ Electrical room	4.84	1	10	0.1	1	5.67	20 / 10	0.35	0.05	0.06
P6	Plan-South Wall / HDR room	5.26	20	10	0.5	1	4.94	30	2.65	0.12	0.09
P7	Plan-South Wall/ HDR room	4.59	20	10	0.5	1	5.36	10 / 20	4.85	0.12	0.08
P8	Plan-South Wall/ HDR control room	5.26	20	10	1	1	5.25	25 / 5	3.13	0.07	0.05
P9	Plan-West Wall / Control Room	4.34	20	10	1	1	5.47	25 / 5	7.33	0.10	0.13
P10	Plan-West Wall / Control Room	3.53	20	10	1	1	5.59	5 / 25	5.31	0.13	0.09
P11	Plan-West Wall / Control Room	4.34	20	10	1	1	5.47	25 / 5	7.33	0.10	0.13
C1	Ceiling / low occupancy	3.17	1	10	0.025	1	5.38	0.5 / 25	0.62	0.63	0.43
C2	Ceiling / low occupancy	3.51	1	10	0.025	1	5.29	0.5 / 25	0.09	0.09	0.06
C3	Ceiling / low occupancy	4.09	1	10	0.025	1	5.16	0.5 / 25	0.09	0.09	0.06
L1	Ceiling / low occupancy	3.51	1	10	0.025	1	5.35	0.5 / 25	0.16	0.09	0.11
L2	Ceiling / low occupancy	5.28	1	10	0.025	1	4.94	0.5 / 20	0.33	0.25	0.23
D	Door	6.20	20	10	0.125	1	4.20	0.25/20/0.25	5.34	0.81	0.75

Required Shielding UNDER EXISTING STEEL BEAMS IN CEILING

Barrier	Needed shielding in V300, LEAD, Steel	TADR (usv/week)	IDR (usv/hr)	AH-IDR (usv/hr)
C1	0.5/15/4	0.32	0.32	0.22
C2	0.5/15/2.5	0.38	0.38	0.27
C3	0.5/15/1	0.30	0.31	0.21
L1	0.5/15/2.5	0.68	0.38	0.48
L2	0.5/15/0.5	0.58	0.43	0.41

2. Room 2 (Halcyon)

a. Workloads:

The workload below is similar for both machines (TrueBeam and Ethos) regardless on which one is installed. All workloads are calculated at the isocenter which is 1 meter from the radiation (X-ray) source. The formulas used in this calculation shown in the Annex 1:

Workload Breakdown	6 MV FFF	TOTAL
Primary Workload (cGy/wk)	340000.00	340000.00
Leakage Workload (cGy/wk) at 1 meter from Target	1620.00	1620.00
Neutron Workload (cSv/wk)	0.00	0.00
QA / Service/R&D Workload (cGy/wk)	20000	20000

b. TVLs, Barriers Thickness and expected TADR, and AH-IDR

The table hereafter summarizes the calculations results of the thicknesses of the various barriers in TVLs and in Verishield modules as specified. Equivalent thicknesses in standard concrete (2.35 g/cm³) are also given for reference.

Survey Points	Description	Distance to Survey point (meter)	Permissible TADR (μSv/wk)	Permissible IDR (μSv/hr)	Occupancy Factor T	Use Factor U	Total TVLs needed	VERITAS shielding in V250 / V300 / STEEL / LEAD (inch)	Expected Total weekly TADR (μSv/wk)	Expected maximum IDR (μSv/hr)	Expected In-Any-One-Hour IAH (μSv/hr)
P12	Plan-East Wall / Reception area	3.82	1	10	0.5	1	6.52	20 / 3	0.39	0.02	0.02
P1	Plan-East Wall / Reception area	3.35	1	10	0.5	1	6.64	20 / 4	0.85	0.04	0.04
P2	Plan-East Wall/ Reception area	3.82	1	10	0.5	1	6.52	20 / 3	0.39	0.02	0.02
P3	Plan-South Wall / CT sim Room	4.04	20	10	0.5	1	5.23	20 / 3	0.56	0.02	0.02
P4	Plan- South Wall / Tx Planning Room	3.54	1	10	0.5	1	6.59	20 / 4	0.76	0.04	0.04
P5	Plan- South Wall / office space	4.04	1	10	0.5	1	6.53	20 / 3	0.56	0.02	0.02
P6	Plan-West Wall / Mechanical room	5.67	1	10	0.05	1	5.18	15 / 10	0.59	0.26	0.26
P7	Plan- West Wall / Control room	4.95	20	10	1	1	5.30	25	14.8	0.37	0.37
P8	Plan- West Wall / Control room	5.67	20	10	1	1	5.18	15 / 10	11.7	0.26	0.26

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P9	Plan-North Wall / Corridor	4.27	1	10	0.2	1	6.09	20 / 10	0.89	0.06	0.06
P10	Plan- North Wall / Restroom	3.54	1	10	0.2	1	6.19	30	0.66	0.08	0.08
P11	Plan- North Wall/ Restroom	4.27	1	10	0.2	1	6.09	20 / 10	0.89	0.06	0.06
C1	Ceiling / low occupancy	3.03	1	10	0.025	1	5.42	0.5 / 25	0.62	0.63	0.43
C2	Ceiling / low occupancy	3.37	1	10	0.025	1	5.33	0.5 / 25	0.09	0.09	0.06
C3	Ceiling / low occupancy	3.95	1	10	0.025	1	5.19	0.5 / 25	0.09	0.09	0.06
L1	Ceiling / low occupancy	3.37	1	10	0.025	1	5.39	0.5 / 25	0.16	0.09	0.11
L2	Ceiling / low occupancy	5.25	1	10	0.025	1	4.94	0.5 / 20	0.33	0.25	0.23
D	Door	6.48	20	10	0.125	1	5.06	0.25/20/0.25	5.34	0.81	0.75

Required Shielding UNDER EXISTING STEEL BEAMS IN CEILING

Barrier	Needed shielding in V300, LEAD, Steel	TADR (usv/week)	IDR (usv/hr)	AH-IDR (usv/hr)
C1	0.5/15/4	0.32	0.32	0.22
C2	0.5/15/2.5	0.38	0.38	0.27
C3	0.5/15/1	0.30	0.31	0.21
L1	0.5/15/2.5	0.68	0.38	0.48
L2	0.5/15/0.5	0.58	0.43	0.41

1. Room 3 (Halcyon)

a. Workloads:

The workload below is similar for both machines (TrueBeam and Ethos) regardless on which one is installed. All workloads are calculated at the isocenter which is 1 meter from the radiation (X-ray) source. The formulas used in this calculation shown in the Annex 1:

Workload Breakdown	6 MV FFF	TOTAL
Primary Workload (cGy/wk)	340000.00	340000.00
Leakage Workload (cGy/wk) at 1 meter from Target	1620.00	1620.00
Neutron Workload (cSv/wk)	0.00	0.00
QA / Service/R&D Workload (cGy/wk)	20000	20000

b. TVLs, Barriers Thickness and expected TADR, and AH-IDR

The table hereafter summarizes the calculations results of the thicknesses of the various barriers in TVLs and in Verishield modules as specified. Equivalent thicknesses in standard concrete (2.35 g/cm³) are also given for reference.

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Survey Points	Description	Distance to Survey point (meter)	Permissible TADR (μSv/wk)	Permissible IDR (μSv/hr)	Occupancy Factor T	Use Factor U	Total TVLs needed	VERITAS shielding in V250 / V300 / LEAD (inch)	Expected Total weekly TADR (μSv/wk)	Expected maximum IDR (μSv/hr)	Expected In-Any-One-Hour IAH (μSv/hr)
P12	Plan-East Wall / Control Room	3.47	20	10	1	1	5.61	25	6.40	0.14	0.11
P1	Plan-East Wall / Adjacent Vault	3.04	20	10	0.5	1	5.42	5**	7.98	0.40	0.28
P2	Plan-East Wall/ Adjacent Vault	3.47	20	10	0.5	1	5.31	0**	8.23	0.36	0.29
P3	Plan-South Wall / Control Room	3.92	20	10	1	1	5.56	25 / 5	8.98	0.12	0.16
P4	Plan- South Wall / Control Room	3.44	20	10	1	1	5.61	15 / 15	13.73	0.35	0.24
P5	Plan- South Wall / Control Area	3.92	20	10	0.125	1	4.65	25 / 5	1.12	0.12	0.16
P6	Plan-West Wall / Waiting room	6.11	1	10	0.5	1	6.11	25 / 1	0.24	0.01	0.01
P7	Plan- West Wall / Waiting room	5.33	1	10	0.5	1	6.23	25 / 1.5	0.94	0.05	0.03
P8	Plan- West Wall / Outdoor space	6.11	1	10	0.025	1	4.81	20 / 5	0.42	0.37	0.29
P9	Plan-North Wall / Outdoor space	4.96	1	10	0.025	1	5.05	20 / 1	0.35	0.20	0.25
P10	Plan- North Wall / Outdoor space	3.94	1	10	0.025	1	5.19	20 / 2	0.40	0.41	0.28
P11	Plan- North Wall/ Outdoor space	4.96	1	10	0.025	1	5.05	20 / 1	0.35	0.20	0.25
C1	Ceiling / low occupancy	3.03	1	10	0.025	1	5.42	0.5 / 25	0.62	0.63	0.43
C2	Ceiling / low occupancy	3.37	1	10	0.025	1	5.33	0.5 / 25	0.09	0.09	0.06
C3	Ceiling / low occupancy	3.95	1	10	0.025	1	5.19	0.5 / 25	0.09	0.09	0.06
L1	Ceiling / low occupancy	3.37	1	10	0.025	1	5.39	0.5 / 25	0.16	0.09	0.11
L2	Ceiling / low occupancy	5.25	1	10	0.025	1	4.94	0.5 / 20	0.33	0.25	0.23
D	Door	6.92	20	10	0.125	1	4.10	0.25/20/0.25	5.34	0.81	0.75

Required Shielding UNDER EXISTING STEEL BEAMS IN CEILING

Barrier	Needed shielding in V300, LEAD, Steel	TADR (usv/week)	IDR (usv/hr)	AH-IDR (usv/hr)
C1	0.5/15/4	0.32	0.32	0.22
C2	0.5/15/2.5	0.38	0.38	0.27
C3	0.5/15/1	0.30	0.31	0.21
L1	0.5/15/2.5	0.68	0.38	0.48
L2	0.5/15/0.5	0.58	0.43	0.41

2. Room 3 (ORTHOVOLTAGE RADIOGRAPHY)

a. Workloads:

o Workloads:

16 patients per day: equivalent to 10000 mA-minute/Week with beam current set to 20 mA.

1. Energy Transmission:

INPUT:

Target Material:

X-Ray Energy [keV]:

Target length [mm]:

Pressure (only gases) [atm]:

RESULTS:

Attenuation [%]: 100.0000

Transmission [%]: 0.0000

Interaction Probability [%]:

Photoabsorption: 1.3699

Compton Scattering: 96.5264

Rayleigh Scattering: 2.1036

Nuclear Field Pair Production: 0.0000

Electron Field Pair Production: 0.0000

Interaction Coefficient [cm²/g]:

Photoabsorption: 0.0018

Compton Scattering: 0.1238

Rayleigh Scattering: 0.0027

Nuclear Field Pair Production: 0.0000

Electron Field Pair Production: 0.0000

Total Attenuation: 0.1282

illustration of the minimum thickness of concrete that will fully ATTENUATE an orthovoltage X-ray 200 kVp beam

2. Calculation of Necessary Thickness of Primary Barrier:

In order to achieve the dose limit of 5 mSv/year and assuming the machine is installed in the middle of the room with source to primary wall is 2 meters.

Primary Barrier

Area:

Maximum voltage: kV

Maximum current: mA

Maximum time used weekly: min

Occupancy: %

Usage factor: %

Distance to the source: m

Primary barrier thickness (concrete): cm

October 23rd, 2025

CONCLUSION:

Based on the Energy transmission Test and the shielding calculation, one concludes that 73 cm (28.74") of regular concrete, which is equivalent to: **18.7" (build 20") of VeriShield V220** will be sufficient to shield the XSTRAHL 200 / 30 mA x-ray tube at 2 meters from the source so to not exceed an annual dose limit of 0.055mSv/year while operating at the workload of 10000 min/week at 20 mA.