Environmental Radiation Measurements

Considerations for:
Diagnostic Radiology,
Nuclear Medicine and,
Radiation Oncology

M. S. Towsley, M.S., DABR
Minneapolis Radiation Oncology
Regions Hospital – St. Paul MN

Recognition

I will take this opportunity to recognize and thank the following people's contributions to this presentation.

- Frank Zink, Ph D
- Bruce Gerbi, Ph D
- Susanne Quarfoth Yerich, MS
- Patrick J. Silgen, MS

Objectives

Part 1	Part 2
• Documentation Radiation Source • Survey Objectives • Radiation Detectors • Techniques	• Project Flow • Sources of Derailment • Case Studies

Radiation Survey Objectives

- Shielding Design and Environmental Measurements are Part of a Radiation Safety Program.
- Meet DOH, NRC, ALARA Regulations.
- Shielding Integrity.

Documentation

20 February 2006

Name

Radiology Manager
Medical Center
2450 Riverside Avenue
Minneapolis, MN 55454

What and When

Dear Radiology Manager,

On January 23, 2006, I visited _____Medical Center Riverside Avenue Minneapolis, MN to perform a shielding integrity survey in Radiology Room 1 M-271 Installation. A survey was performed on walls surrounding this room.

Conclusion:

Conclusion up front

All tests on room M-271 showed that the radiation protection was at a safe level as designed. The room was design to a level of protection that conformed to the Minnesota DOH protection levels as stated in the shielding design report.

Documentation

(continued)

Materials and Procedure:

Documentation of instrument used and calibration

A pressurized Ionization type survey meter was used to measure the radiation levels. The survey meter was calibrated on 3/05. The x-ray tube was used as the radiation source. All measurements are in mR/hr (milliroentgens per hour). The source was placed in the usual position at the level of the patient (i.e. table top) for typical exams and aimed at a bucket of water as a scattering medium. Measurements were made at each of the walls as labeled in the diagram below.

Data

Documentation of procedure

The following drawings contain the data collected during my visit. Measurements below are the peak mR/hr's detected along the indicated wall. Actual data measurements are as follows:

Documentation

(continued)

Data Documentation

Survey Data

Wall	Area	Radiation Type	Table Top	Chest Stand	kVp	mAs	Exposure Time (s)	Exposure Rate mR/hr
A-B	Control	Scatter		x	121	100	2.5	0.027
A-B	Control	Scatter	x		90	100	3.5	0.071
B-C	Hallwy/ Xray Rm	Scatter	x		121	100	2.5	0.007
C-D-E	Toilet	Scatter	x		121	100	2.5	0.007
E-F	Corridor	Scatter	x		121	100	2.5	0.035
E-F	Corridor	Primary		x	121	100	2.5	0.017
F-G	Hallway	Scatter	x		90	100	3.5	59
F-G	Hallway	Primary	x		90	100	3.5	129
F-G	Hallway	Scatter		x	121	100	2.5	3
F-G	Hallway	Scatter		x	121	100	2.5	185

Documentation

(continued)

Room Use for Specific Walls

The following assumptions were made for the workload in this room.

kVp	Technique X-Table Hip mAs	PA Chest mAs	Lat Chest mAs	X-Table Hip Procedures per Week	PA Chest Procedures per Week	Lat Chest Procedures per Week
121		12	30		50	50
90	350			6		

Documentation

(continued)

Analysis

The resulting expected maximum exposure would be:

Wall	Area	Radiation Type	Exposure mR/mAs	Hip Exposure per Week mR	Chest Exposure per Week mR	Total Exposure per Week mR
A-B	Control	Scatter	1.88E-07		0.00	
A-B	Control	Scatter	6.90E-07	0.00		0.00
B-C	Hallwy/ Xray Rm	Scatter	4.86E-08	0.00		0.00
C-D-E	Toilet	Scatter	4.86E-08	0.00		0.00
E-F	Corridor	Scatter	2.43E-07	0.00		
E-F	Corridor	Primary	1.18E-07		0.00	0.00
F-G	Hallway	Scatter	5.74E-04	1.20		
F-G	Hallway	Primary	1.25E-03	2.63		
F-G	Hallway	Scatter	2.08E-05		0.04	
F-G	Hallway	Scatter	1.28E-03		2.70	6.58

Documentation

Analysis

(continued)

The control room and walls A through F receive little measurable radiation. The doors labeled A-F can expect at most about 7 mR/week. Other radiographs are expected to add very little to this area. Because this area is a hallway, any person in the area would be expected to receive 1/16th of this, or about 0.5 mR/week.

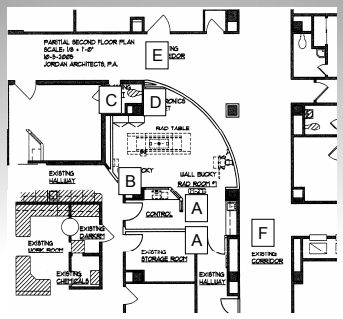
This is below the Minnesota State DOH protection ALARA level of 10 mR/week.

It has been a pleasure working with you and being able to supply this service. If there is any question about this report or anything else I can help with please call me at ((Area Code) Telephone Number)

Sincerely,

Mark Towsley, M.S., DABR
Certified Diagnostic Medical Physicist

Documentation



Included Diagram with Labels

Radiation Sources Diagnostic Radiology

- X-Ray Tube
  - Chest Room, CT, Radiographic Room
- Flouroscopy
  - Flouroscopy Room, Portable C-arm
- Tc-99m Source

Radiation Sources
Diagnostic Radiology

X-Ray Tube

Survey Data

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E-F	Corridor	Scatter	x		121	100	2.5	0.035
E-F	Corridor	Primary		x	121	100	2.5	0.017
F-G	Hallway	Scatter	x		90	100	3.5	59
F-G	Hallway	Primary	x		90	100	3.5	129
F-G	Hallway	Scatter		x	121	100	2.5	3
F-G	Hallway	Scatter		x	121	100	2.5	185

Radiation Sources
Diagnostic Radiology

Tc-99

Location	Reading Inside room mR/hr	Reading Outside room mR/hr	Normalized Reading Inside room mR/hr/mCi	Normalized Reading Outside room mR/hr/mCi	Calculated Transmission Tc-99m	Calculated Transmission 120 kVp
Wall A-B	0.075	0.005	0.00201	0.00002	1.0%	0.1%
Wall B-C	0.088	0.012	0.00237	0.00016	6.9%	0.9%
Wall C-D	0.055	0.008	0.00144	0.00008	5.6%	0.7%
Wall D-E	0.077	0.02	0.00206	0.00033	15.8%	2.0%
Door A-E	0.095	0.021	0.00257	0.00035	13.4%	1.7%

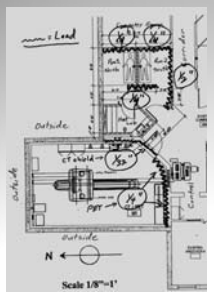
Calculated Transmission of lead at 120 kVp is the ratio of μ for Tc-99m to effective energy of a 120 kVp spectrum ≈ 40 keV

Source: 10 mCi of Tc-99m used
Detector: Pressurized Ion Chamber

Radiation Sources
Nuclear Medicine

- Tc-99m
- F-18
- Or other source for a dedicated room

Radiation Sources
Nuclear Medicine



Net Rdg (mR/hr)	Location
0	Control console
0	entrance to scanner room (door closed)
0.18	entrance to scanner room (door open)
0	Floor outside scanner room (door closed)
0.14	Entrance to uptake room 4 feet above floor (door closed)
0.13	Entrance to uptake room @ floor (door closed)
0.03	Corridor outside uptake room 4 feet above floor
0.1	Max reading corridor outside of uptake room 4 feet above floor
0.1	Area outside of uptake room and scanner room (5 feet from each door)
0.03	Downstairs storage room @ end of hallway (6 feet above floor)
0.18	Downstairs Radiologist breakroom (5 feet above floor)
0.08	Max reading corridor outside Radiologist conference room (4 feet above floor)
0.1	Max reading downstairs utility room
0.23	Max reading in computer room

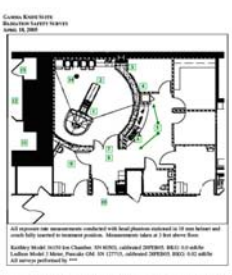
Compliments of Pat Silgen MS
Methodist Hospital, Mpls MN

Radiation Sources
Radiation Oncology

- Gamma Knife Co-6o Source
- Linear Accelerator

Radiation Sources
Radiation Oncology

Gamma Knife



#	Location	mR/hr
1	Edge of couch	600
2	Foot of couch	47
3	Office	0.15
4	Office	0.10
5	Control console - work position	BKG
6	Control console – knee holes	BKG
7	Treatment room doors @ 12"	0.05
8	Treatment room doors @ 36"	0.03
9	Exam/Recovery	BKG
10	Corridor	BKG
11	LINAC treatment room	BKG
12	LINAC treatment room	BKG
13	LINAC treatment room	BKG
14	*2nd floor above treatment room	BKG

Compliments of B. Gerbi, Ph. D.
University of Minnesota

Radiation Sources
Radiation Oncology

Linac

Radiation Room Survey for Elekta Precise Room 1

Hospital Name
Address
City, State

A radiation survey on the Elekta Precise Accelerator Room 1 was performed to assure the shielding design integrity. This survey was performed on 9 February 2004.

Accelerator: Elekta Precise Duel energy 6, 10 MV photons
Survey instrument: Inovision 451P uR meter Calibrated March 2003
Setup conditions: 10 MV photons.
30x30 field size 30 cm attenuating material for scatter for scatter
Dose rate 450 cGy/min.

Results:
See Table

Radiation Sources
Radiation Oncology

Linac

Sample Calculations:
Elekta dose rate of 4.5 Gy/hr
Workload of 500 Gy/wk
Beam on Time per week = $\frac{500\ \text{Gy/wk}}{4.5\ \text{Gy/min}} = 111\ \text{min/wk}$

Assume occupancy of 1
Use factor of 100% for scatter
Exposure to personnel at Elekta Precise control area

$$\text{Exposure} = \frac{530\ \text{uR/hr} * 10^{-5}\ \text{mSv/uR} * 111\ \text{min/wk} * 1 * 1}{60\ \text{hr/min}} = 9.8 \times 10^{-3}\ \text{mSv/wk}$$

Allowable limit: Occupational exposure = 0.1 mSv/wk
General public exposure = 0.02 mSv/wk

Radiation Sources
Radiation Oncology

Location	Gantry Orientation	Radiation Type	Radiation Area	Reading uR/hr	mSv/hr	Workload Gy/wk	Dose Rate Gy/min	Occupancy factor	Use factor	Exposure mSv/wk	Limit mSv/wk	Results
30x30 Field Size Control	Coll=0 Down (0)	30 cm Scatter	Attenuating Controlled	Material 530	0.00530	500	4.5	1	1	0.0098	0.1	Pass
Outside Secondary	Lat (270)	Secondary	Uncontrolled	1000	0.01	500	4.5	.0625	1	0.001	0.02	Pass
30x30 Field Size Outside Primary	Coll=45 Lat (270)	no Primary	Attenuating Uncontrolled	Material 29000	0.29	500	4.5	0.0625	0.25	0.0084	0.02	Pass

Example of using a survey meter in the rate mode

Radiation Sources
Radiation Oncology

Environmental Exposure Report

Date Placed Monitors: 9/12/2006 Date Removed Monitors: 12/7/2006
Beam on Time hrs

Placement of Radiation Monitors	mSv/ 3 Months readings	mSv per week
Outside Secondary	0.13	0.011
Outside Primary	0.18	0.015

Example of integrated dosimeter using a OSL Badges

Radiation Sources
Radiation Oncology

Environmental Exposure Report

Placement of Radiation Monitors	Measured: mSv per week using OSL badges	Occupancy Factor	Adjusted: mSv per week using OSL badges	mSv per week using ion rate meter
Outside Secondary	0.011	0.0625	0.0007	0.001
Outside Primary	0.015	0.0625	0.0009	0.008

Comparing Integrated dose measurements from OSL badges and a survey meter in the rate mode

Radiation Detectors

- Consideration for Choice of Detectors
  - Objective
  - Practical
  - Detector Function
  - Detector Type
  - Energy Response
  - Response Time
  - Handling Background Readings

Radiation Detectors

- Consideration for Choice of Detectors
  - Objective
    - Shielding integrity
    - Designed protection limits
    - Federal/State/Local protection limits

Radiation Detectors

- Consideration for Choice of Detectors
  - Practical
    - Readily available
    - Satisfies and meets the needs regulations
    - Demonstrates reproducibility
    - Demonstrates accuracy
    - Demonstrates linearity

Radiation Detectors

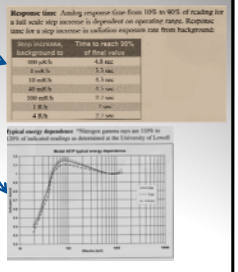
- Consideration for Choice of Detectors
  - Detector Function
    - Rate Meter
    - Integrating

Radiation Detectors

- Consideration for Choice of Detectors
  - Detector Type
    - GM
    - Ion Chamber/Pressurized Ion Chamber
    - Thermoluminescent Dosimeter (TLD)
    - Optical Stimulated Luminescent Dosimeter(OSL)

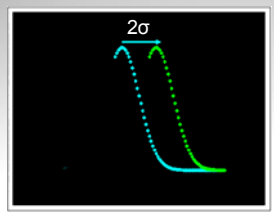
Radiation Detectors

- Consideration for Choice of Detectors
  - Response Time
  - Energy Response



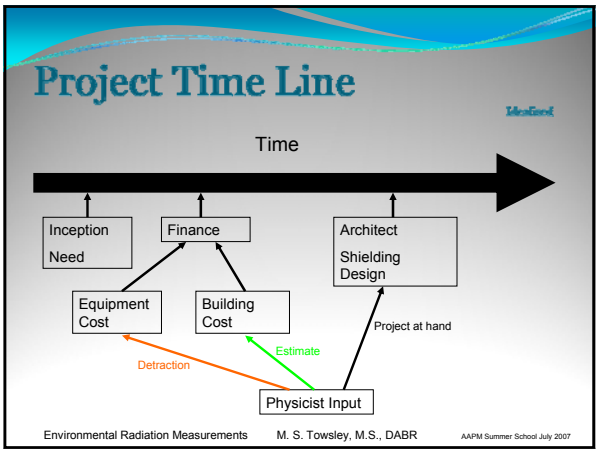
Radiation Detectors

- Consideration for Choice of Detectors
  - Handling Background Readings



For low level radiation measurements you can assume a poisson distribution where the SD = mean.

Therefore in order to be statistically significant to the 95% level, the readings must be 2 SD apart.


Project Time Line
Time
Inception
Need
Finance
Architect
Shielding
Design
Equipment
Cost
Building
Cost
Project at hand
Estimate
Detraction
Physicist Input
Environmental Radiation Measurements
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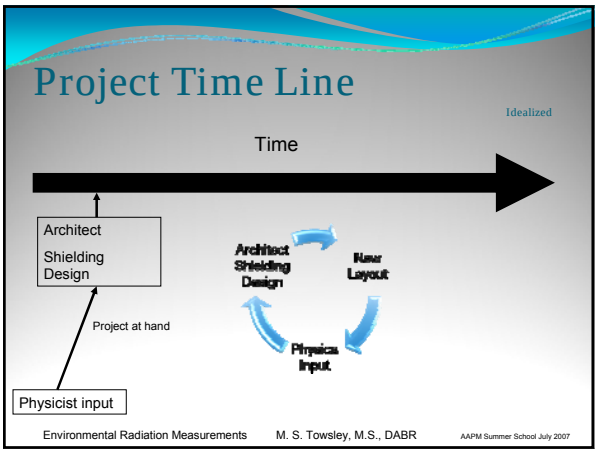
AAPM Summer School July 2007


Project Time Line
Idealized
Time
Architect
Shielding
Design
Project at hand
Physicist input
Environmental Radiation Measurements
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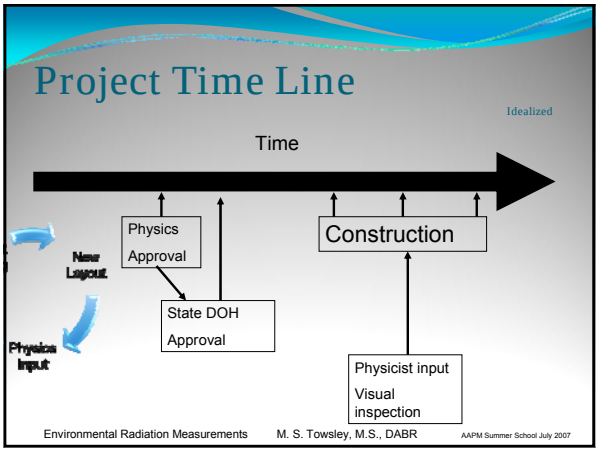
Project Time Line
Idealized
Time
Physics
Approval
Construction
State DOH
Approval
Physicist input
Visual
inspection
Environmental Radiation Measurements
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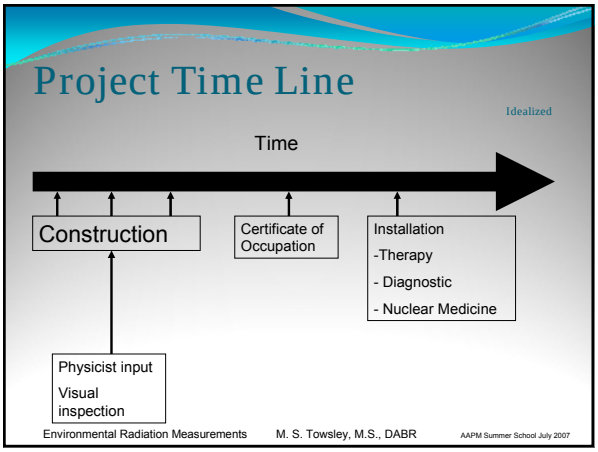
Project Time Line
Idealized
Time
Construction
Certificate of
Occupation
Installation
-Therapy
- Diagnostic
- Nuclear Medicine
Physicist input
Visual
inspection
Environmental Radiation Measurements
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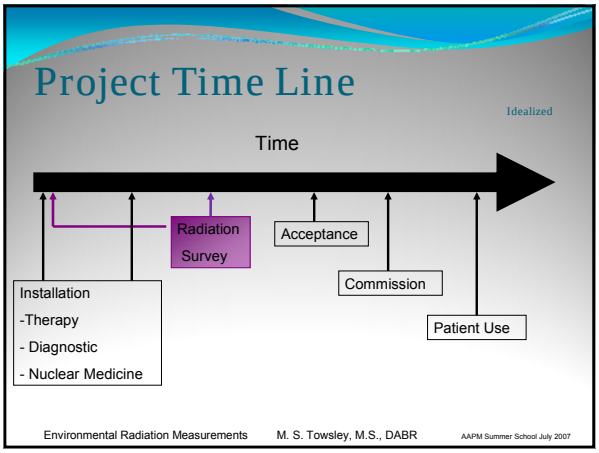
Project Time Line
Idealized
Time
Radiation
Survey
Acceptance
Commission
Patient Use
Installation
-Therapy
- Diagnostic
- Nuclear Medicine
Environmental Radiation Measurements
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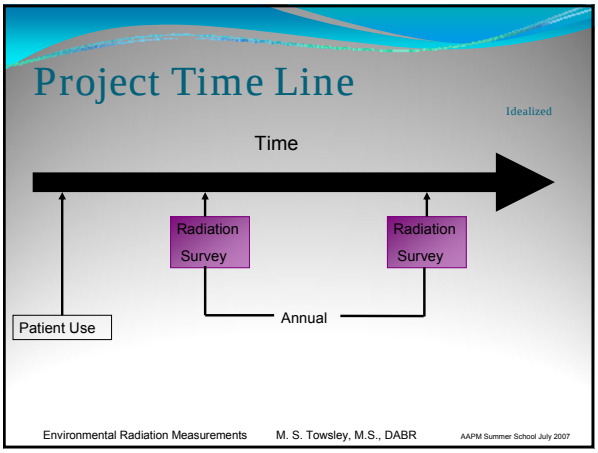
Project Time Line
Idealized
Time
Radiation
Survey
Radiation
Survey
Annual
Patient Use
Environmental Radiation Measurements
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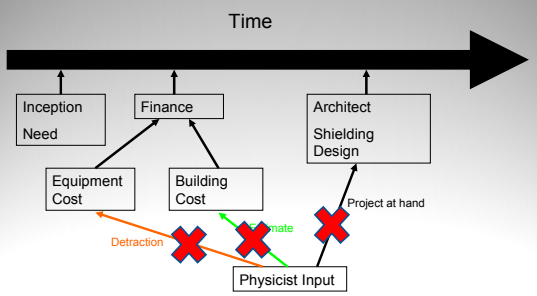
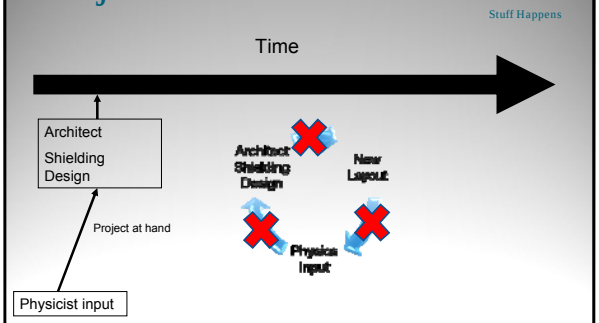
What Really Happens

- Where do things break down.
- Stuff Happens.

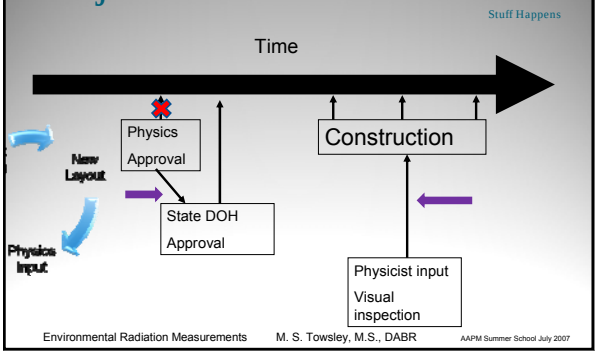
Project Time Line



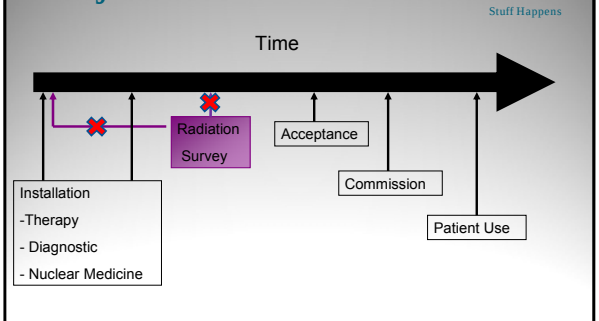
Project Time Line



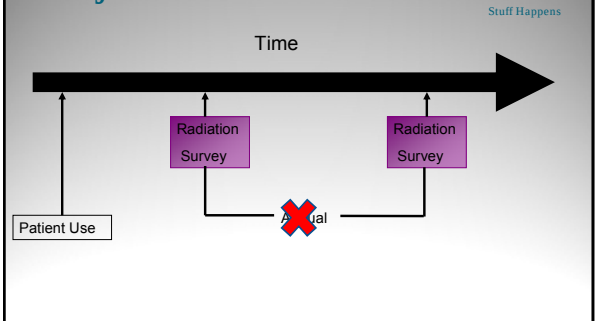
Project Time Line



Project Time Line

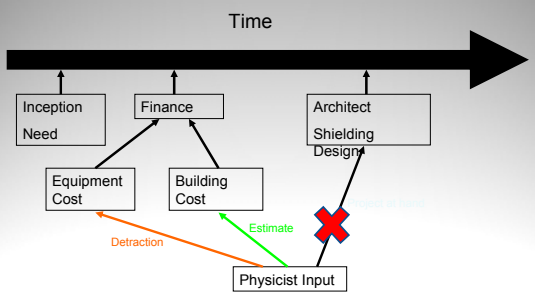


Project Time Line



Examples

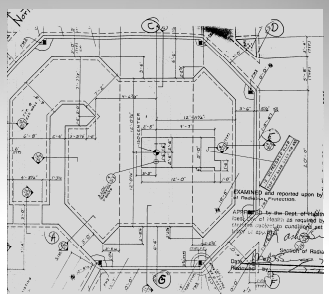
Project Time Line



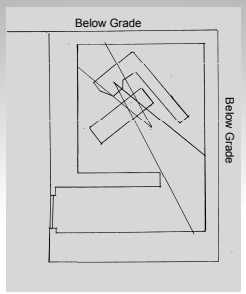
Over Shielded Design

Both the primary walls and the ceiling contain 6'6" of concrete.

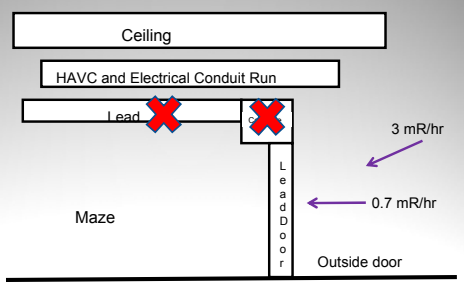
Since 1992, adjacent occupancy around and above has been zero.



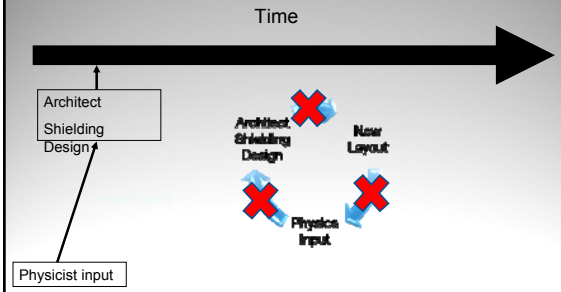
Poor Design



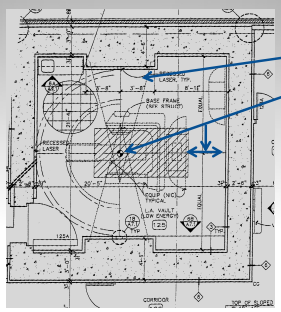
Poor Design



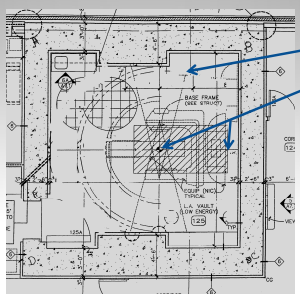
Project Time Line



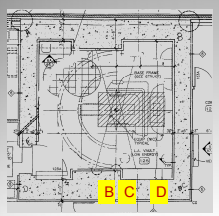
Iterative Process



Iterative Process



Iterative Process

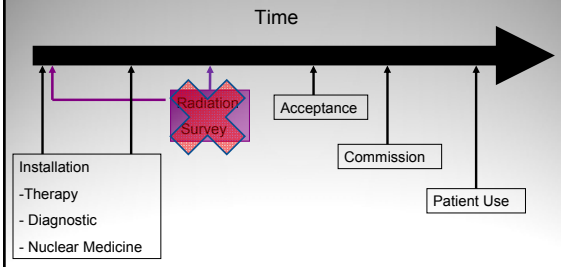


Monitoring Period: 5 Jan 07 – 6 April 07
Low Energy machine 6x photons only
Total Beam on Time: 7.83 hrs
Total Isocenter Dose: 93,960 cGy
Average # patients: 8 patients per day
Integrating Dosimeter: Luxel Badge
Survey Meter: Inovision 451 P

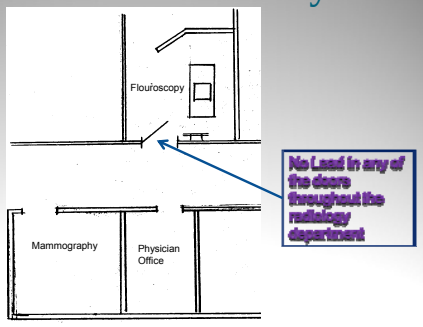
Location	Integrated Exposure (mSv)	Occupancy Factor	Calculated Weekly Exposure (mSv/wk)	Measured Dose Rate (mSv/hr)	Use Factor	Calculated Weekly Exposure (mSv/wk)
B	0.35	0.0625	0.0017	0.10	0.25	0.012
C	0.22	0.0625	0.0011	2.9	0.25	0.35
D	0.11	0.0625	0.0005	Bkgnd	0.25	Bkgnd

Project Time Line

Examples

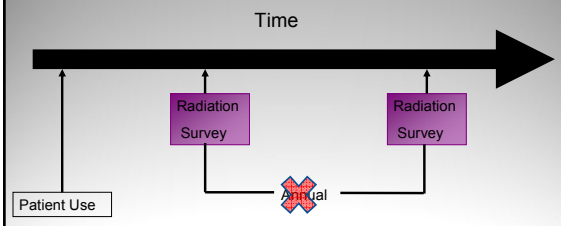


Missed Radiation Survey



Project Time Line

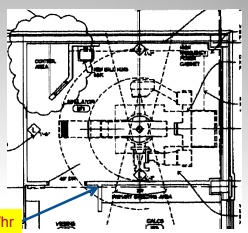
Examples



Time Changes All

This department opened n 1999. In 2007 the unit was replaced and a radiation survey was performed.

A construction worker was able to look down from the top of the wall and see the over time the lead seam had separated.



Compliments of Susanne Quarfoth Yerich, MS

Environmental Survey Type

- Surveys using a dose rate meter will readily identify areas of peak dose rates and alert you to potential problems. These measurements tend to be quit sensitive at low radiation levels. However, they do not represent the inherent use factor.
- Surveys using long term integrating dosimeters contain the use factors but are limited to placement and sensitivity in low radiation levels.

Environmental Radiation Measurements Conclusion

- Be Involved.
- Have a goal and state it in the report.
- Select the dosimeter and radiation source to match that goal.