Application Note 1-AN-52020-6

APPLICATION NOTE

RTI Electronics AB, Sweden **Revision A, December 2007**

Measurements of Scattered Radiation
A Radiation Protection Application

This application note contains a practical example of measurements of scattered radiation required for radiation protection. It contains an interpretation of the NCRP report No. 147 "Structural shielding design for medical X-ray facilities" and a description of how the measurements can be performed with the Piranha and Dose Probe or Barracuda together with the EMM-BiasW electrometer and R100B.

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1. INTRODUCTION

The small dose detectors R100B (for Barracuda) and the Piranha Dose Probe are very suitable when it comes to measuring scattered radiation. They are very durable and are easy to setup. The high sensitivity the leaded back protecting the detector from register backscatter and the minimal energy dependence are other features that make them optimal for these type of measurements. Since they are solid state detectors they do not need any bias voltage or correction for pressure and temperature.

The NCRP report no. 147 contains recommendation and technical information related to the design and installation of structural shielding for facilities that use X-rays for diagnostic imaging. This application note presents a practical interpretation of the report and an example of how your Barracuda or Piranha can be used to measure the required quantities.

The measurements in this document are also according to directions of the swedish radiation institute SSI (SSI FS 2005:6) that was created based on a new law regarding radiation shielding.

2. THE NCRP REPORT No. 147

The report contains recommendations of shielding that are necessary to follow in order to meet the currently accepted standards of radiation protection but it also contains advisory recommendations. The requirements for different types of X-ray facilities are described.

To be able to compute the shielding requirements the report introduces a couple of concepts such as *Distance to the Occupied Area* and *Occupancy Factors*. An occupancy factor (T) for an area is defined as the average fraction of time that the maximally exposed individual is present while the X-ray beam is on. The occupancy factors for different locations are given in the report.

The report also contains instrumentation recommendations for performing radiation protection surveys, see appendix D in the NCRP report. The report recommends a ionization chamber because of its flat energy response and air-kerma-rate independence. However, our dose detectors for Barracuda and Piranha also meet these requirements in the radiographic range, see figure 1. The dose sensitivity is 100 pGy (55µC/Gy).[1] Appendix has a graph showing the energy dependence in the whole range of 50-150 keV.

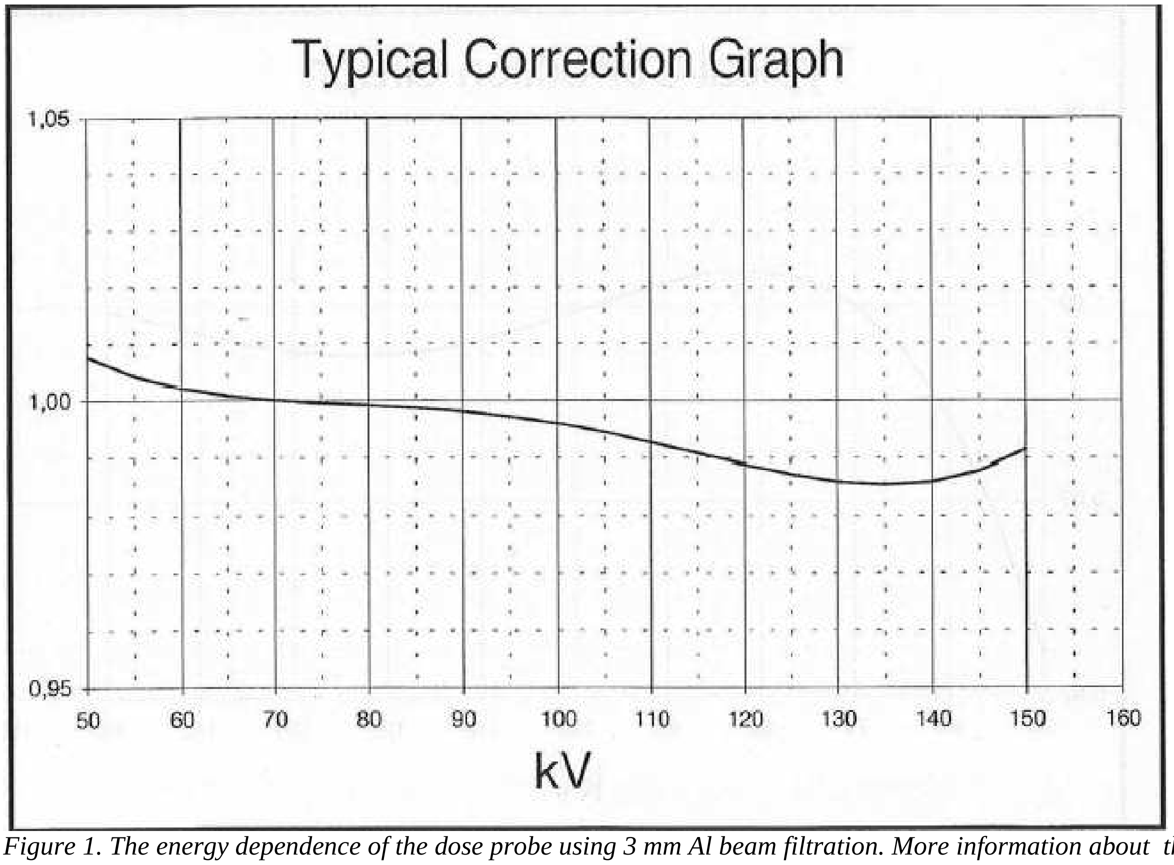


Figure 1. The energy dependence of the dose probe using 3 mm Al beam filtration. More information about the energy dependence of the dose detector can be found in two other application notes, see the reference list. The application notes can be found on our website.

[1] In this application we have not measured after the barrier but such measurements would be no problem. The high sensitivity and the lack of energy dependence make the detectors ideal for measuring both before and after the barrier. The graph in figure 1shows that detectors are suitable for detection of high energetic photon radiation.

3. THE CALCULATIONS

In this example the measurements and calculations are made on a colon suite. We want to determine the minimum barrier thickness required in order to shield the room properly. The occupancy factors according to the NCRP report is in table 1. The calculations are made in a Excel worksheet.

Occupancy factors (T)

Source: NCRP Report no.147

1	Offices, reception, laboratories, pharmacies or other work areas fully occupies by an individual, attended waiting rooms, children's indoor play areas, adjacent X-ray rooms, nurse stations, X-ray control rooms
0.5	Examination and treatment rooms
0.2	Corridors, patient rooms, employee lounges, staff rest rooms
0.125	Corridor doors
0.05	Unattended waiting rooms, public toilets, outside areas with seating, unattended vending areas, storage rooms, patient holding areas
0.025	Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), attics, stairways, unattended elevators, janitor's closet

Table 1. Occupancy factors (NCRP Report 147, page 31)

The occupancy factors in table 1 are used in a schematic overview of the room that are shown in figure 2.

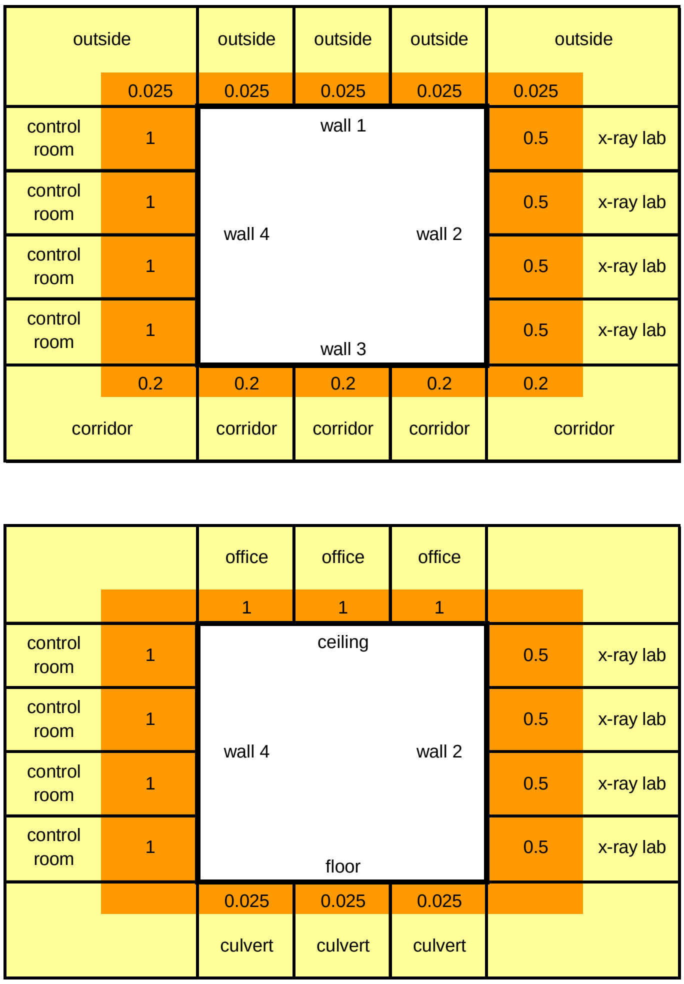


Figure 2. Schematic picture over the examination room.

As shown in the example below (figure 3), the measured dose per year (1), the reference distance inside the room (2) and the distance to the adjacent room (3) are required input parameters for the calculations.

The calculations:		***Example***
1. Measured dose (mSv/year)		*6.25*
2. At a distance of X (m)		*4*
3. In a adjacent room at the distance Y (m)		*4*
4. The unshielded dose is (mSv), according to the square law D = measured dose*(X/Y)^2		*6.25*
		corridor
5. The adjacent room has the occupancy factor T		*0.2*
6. Which means that the allowed yearly dose in the room is (mSv/year) 0,1/T		*0.5*
7. The shielding requirement is given by the transmission (allowed yearly dose for the room)/(unshielded yearly dose for the room)		*0.080*
translated into building material is		
a	mm lead =	*0.32*
b	cm concrete =	*2.87*
c	cm plaster =	*8.90*

Figure 3. Calculation of the shielding requirement.

The unshielded dose (4) is calculated from the input data and the allowed yearly dose (6) is calculated from the occupancy factor. The required shielding translated into building material is then calculated according equation A.2 found on page 117 in the NCRP report. The data for calculating the thickness of different types of building material is found on page 147, table C.1).

We have made the assumption that the X-ray source is a point source. If the field is large and the distance to the detector is small, it may be better to use the equation for extended source instead, i.e. in point 4, change to D = measured dose*(X/Y).

4. THE MEASUREMENTS

4.1 The setup

The measurements were performed on a colon suite at a hospital (Södra Älvsborgs Sjukhus) in Sweden. The Piranha and the external dose probe were used with a (the Piranha and the PC were connected through Bluetooth) running the oRTIgo software. The Barracuda together with the electrometer EMM-BiasW and dose detector R100B could also have been used. The two systems have the same specifications in this type of measurements.

Figure 4. The measurement setup.

The dose probe were placed at a reference distance at the different positions in the room, see figure 4. Four PMMA blocks (each was 5 mm thick) were used to simulate a patient. It is important to angle the active detector area of the dose probe towards the source of radiation since it has lead on the backside and has lower response when radiation comes from an angle.

For each position, that corresponded to the walls in the schematic room overview (figure 2), the dose and the KAP value were measured simultaneously. The generator was set to 74 kV and 1.1 mA and the Real-Time Meter in the oRTIgo software were used to be able to collect the data simultaneously into an Excel work sheet. “Timed” measuring mode was used to be able to start the measurement before the radiation comes on. The sensitivity was set on “high”. For more information about these parameters, see the Barracuda reference manual.

4.2 The result

The measured dose in µGy was directly translated into mSv and the quantity mSv per KAP was calculated, see table 2. Wall 2 (figure 2) could not be measured at a proper distance because the X-ray machine was mounted there and we measured the diagonal value instead.

	Distance to phantom (m)	*KAP (mGycm2)*	*Time (ms)*	*Dose (µGy)*	*mSv per KAP*
Wall 1:	1.7	480	5282	0.444	0.000000925
Wall 2:					
Wall 3:	1	362	5298	0.562	0.000001551
diagonal 3-4	1.7	412	5291	0.347	0.000000841
Wall 4:	1	410	5304	1.196	0.000002918
diagonal 1-4	1.65	414	5283	0.455	0.000001099
diagonal 2-3	1.13	404	5281	0.701	0.000001735

Table 2. The first step; calculation of mSv/KAP.

We have assumed this lab was used in approximately 570 colon examinations per year and a total KAP/year of 29070 Gycm^2 which gives a mean dose of approximately 51 Gycm^2 per examination. By doing this we can estimate, based on the above measurements, the dose/year at each measuring position, see table 3.

mean KAP value (colon) (Gycm2)	*# examinations*	*total KAP / year*	*mSv per year*	
51	570	29070	27	**Wall 1:**
				Wall 2:
51	570	29070	45	**Wall 3:**
51	570	29070	24	diagonal 3-4
51	570	29070	85	**Wall 4:**
51	570	29070	32	diagonal 1-4
51	570	29070	50	diagonal 2-3

Table 3. The second step; calculation of mSv/year.

The dose was not measured for ceiling and floor. The highest measured values have been used at those position. Ceiling and floor is seldom an issue at hospitals since they have a layer of 30 cm concrete. The yellow column containing mSv per year is moved into the Excel sheet in figure 4.

The calculations were then performed according to the example in figure 3, see figure 4.

The dose rate has been measured with the Piranha dose probe	Grey cells are calculated					
The calculations:	**WALL 1**	**WALL 2**	**WALL 3**	**WALL 4**	**FLOOR**	**CEILING**
Measured dose (mSv/year), see tab 0	27	50	45	85	85	85
at a distance of X (m)	1.7	1.7	1	1	1	1
In a adjacent room at the distance Y (m)	5	3	3	2.5	2	2
the unshielded dose is (mSv), according to the square law D = measured dose*(X/Y)^2	3.11	16.06	5.00	13.60	21.25	21.25
The adjacent room has the occupancy factor T (see tab occupancy factors)	0.025	0.5	0.2	1	0.025	1
which means that the allowed yearly dose in the room is (mSv/year) 0,1/T	4.0	0.2	0.5	0.1	4.0	0.1
The shielding requirement is given by the transmission (allowed yearly dose for the room)/(unshielded yearly dose for the room)	1.00	0.01	0.10	0.01	0.19	0.00
translated into building material is						
mm lead =	0.00	0.85	0.28	1.04	0.17	1.21
cm concrete =	0.00	6.43	2.52	7.62	1.63	8.66
cm plaster =	0.00	20.51	7.72	24.13	4.77	27.25
Number of plaster slices of 12 mm	*0.0*	*17.1*	*6.4*	*20.1*	*4.0*	*22.7*

Figure 4. Calculation of the shielding requirement.

If the transmission is larger then 1 (as for Wall 1 in figure 2) no extra shielding is required.

5. CONCLUSIONS

After the measurements a report could be created, see the example below.

Room 2050

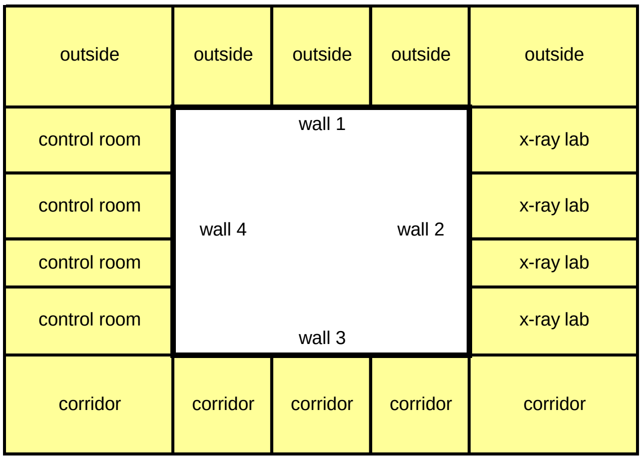
Department Röntgen, SÄS Borås

Room description Colon lab

The room is approved for using X-ray equipment of the type:
Fluoroscopy examinations with image intensifier

The room is approved for activity of the type:
The room is built with at least 2 mm lead equvivalence in all walls, ceiling and floor.
and is therefore approved for fluoroscopy of the trunk up to approximately
1200 examinations/year.
(corresponds to a colon examination)

During the investigation the activity in the surrounding rooms were the following:



Signature Date

Figure 5. Example of a report.

6. REFERENCES

1. NCRP REPORT No. 147; Structural Shielding Design for Medical X-ray Imaging Facilities.
2. SSI FS 2005:6; Statens strålskyddsinstituts föreskrifter och allmänna råd om strålskärmning av lokaler för diagnostik eller terapi med joniserande strålning.
3. Markus Håkansson, Medical Physicist at Södra Älvsborgs Sjukhus.
4. Application Note No. 03-017/01, Typical energy correction for R25 and R100 when measuring with Cu filtration.
5. Application Note No. 03-010/01, Energy correction factors for the R100 Solid State Detector.

7. APPENDIX

7.1 The angular dependence

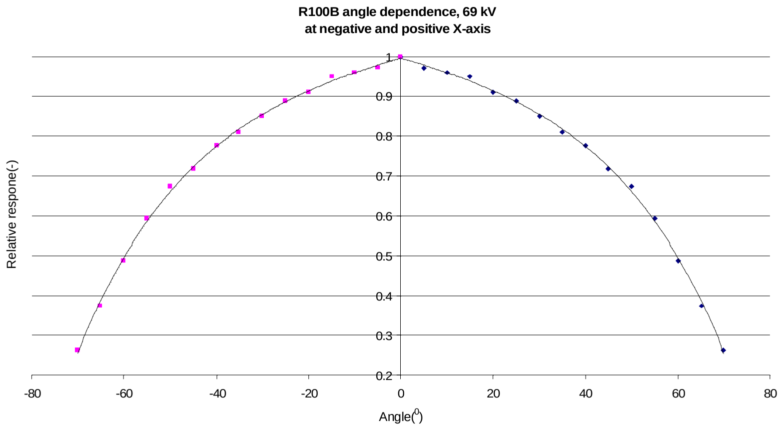


Figure 6. The normalized ratio of the R100B dose value as a function of the R100B angle, using the radiography tube (W/3 mm Al).

7.2 The energy dependence

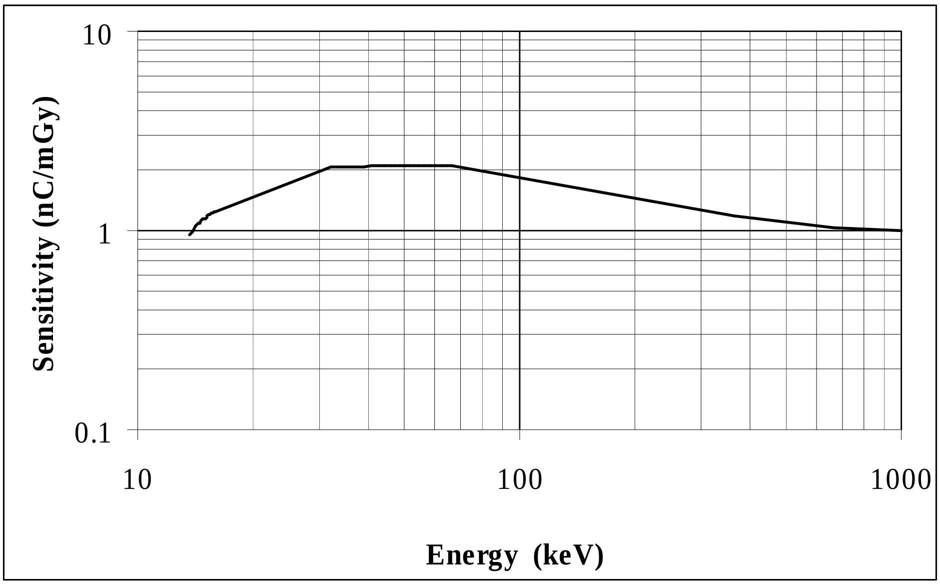


Figure 6. The energy dependence of the dose probe. The values are normalized to 1 at 1MeV.