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LEAD EQUIVALENT THICKNESS MEASUREMENT FOR MIXED COMPOSITIONS OF BARIUM PLASTER BLOCK



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Outline

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- Objectives
- Materials & Methods
- Result & Discussion
- Conclusion
- References

Introduction

- Measurement of lead equivalent thickness for ionizing radiation exposure room wall shall be performed as stated in Malaysian Standard MS 838 (2007) & MS 2228(2009).
- Purpose of shielding : To limit radiation exposure to employees and members of the public to an acceptable level.
- The Malaysian Ministry of Health (MOH) has established that the irradiation room must have sufficient shielding thickness

Gamma radiation shielding

- Most materials absorb the energy of gamma rays to some extent.
- The extent of attenuation depends on:- the density of elements, thickness of the shielding material ,the mass per unit area of shielding material & energy of the incident gamma radiation, the atomic number and also activity of radionuclide.
- Hence a thick layer of a lighter material will have the same effect as a thin layer of a denser material.

The attenuation of gamma shielding:-

$$I = I_0 e^{-\mu \rho t} \quad \text{or} \quad I = I_0 e^{-\mu d}$$

I = intensity after shielding
 I_0 = incident intensity
 μ = mass absorption coefficient (cm^2/g)
 d = thickness of absorber (g/cm^2)
 ρ = density of absorber (g/cm^3)
 t = physical thickness of absorber (cm)

Interaction Gamma with Matter:-

- Photoelectric Effect (high Z, , 50 keV)
- Compton Scattering (low Z, 100 keV – 10 MeV)
- Pair Production (low Z, 1.02 MeV)

Shielding Design Materials

- ✓ Interior Wall-Gypsum wall board, lead sheet, steel nail, screw, concrete block, clay brick and etc.
- ✓ Some of them has voids –can be filled with grout, sand or mortar
- ✓ Exterior Wall-Stone, brick, concrete, wood, vinyl and etc
- ✓ Lead lined door or wooden door (calcium silicate)
- ✓ Floor or ceiling – metal-deck-supported Concrete (typical thickness : 4 -20 cm)-standard weight/light weight .
- ✓ The distance (floor & ceiling) - at least 2.1m

Composite materials are becoming increasingly available from shielding manufacturers.

UHPC –Ultra High Performance Concrete

Shielding verification activity for exp. rooms

Objective

To determine the lead equivalent thickness (LET) of samples using Cs-137, Am-241 & Co-60

Materials

- Radioactive Source
- Survey meter (451P-RYR, S/N: 2469)
- Lead (Pb) sheets
- Measuring tape
- Adjustable source holder with container
- PPE

Material-radioactive sources

Source	Half life	Energy (keV)	S/N:	Initial Activity	Date	Activity during measurement
Cs-137	30 yrs	662	1618-35	996 uCi	1 Jun 2013	946 uCi
Am-241	432 yrs	59	5218 lv	200 mCi	N/A	26.5 mCi
Co-60	5.3 yrs	1332 1170	1639-67-3	106.7 uCi	1 Jun 2013	73 uCi

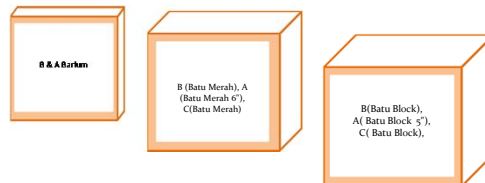
Measurement of sources activity

samples

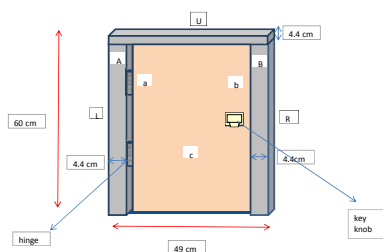
- ❖ 9 samples (barium plaster) from a company to be tested



Sample Blocks:-



Door and Frame:-



B & A Barium :-

- 3cm thickness including back frame
- 0.5 cm thickness of back frame
- 2.5 cm thickness of Barium only
- Surrounding frame thickness is 1.5 cm
- Length x Width of Barium only = 30.5 x 30.5 cm
- Length x Width of Barium including frame = 33.5 x 33.5 cm

B (Batu Merah), A (Batu Merah 6"), C (Batu Merah):-

- 0.5 cm back frame thickness
- 15 cm thickness of concrete
- Surrounding frame adalah 1.5 cm tebal not including back frame
- Length x Width of compositions = 33.5 x 33.5 cm

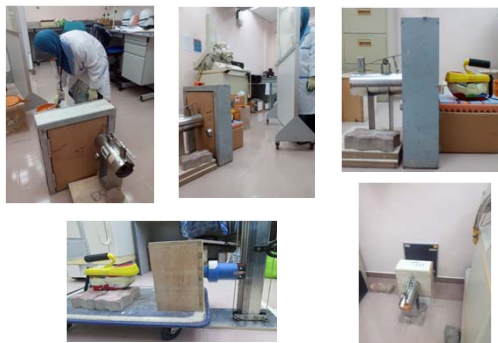
B (Batu Block), A (Batu Block 5"), C (Batu Block):-

- 0.5 cm back frame thickness
- 12.6 cm thickness compositions
- Surrounding frame adalah 1.5 cm tebal not including back frame
- Length x Width of compositions = 33.5 x 33.5 cm

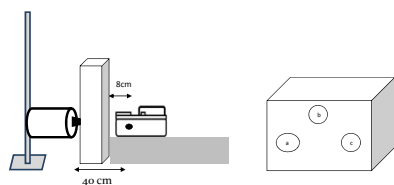
Method

- Build up calibration curve for 3 sources using Pb sheets at SID ~ 40 cm
- Open window size of source casing: various diameter
- Test the samples using the 3 sources
- Analyzed the data obtained
- Determine the lead equivalent thickness using Matlab software based on calibration curve

Experiment Set-up

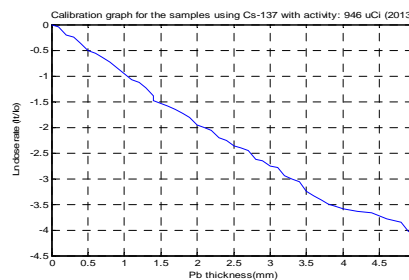


Schematic Diagram of experiment set up

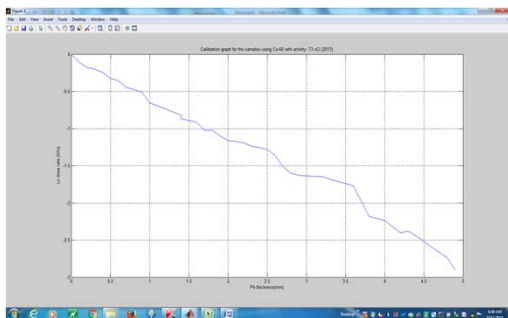


Result & Discussion

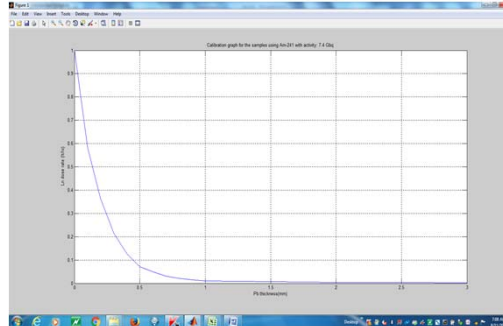
Calibration Graph for Cs-137

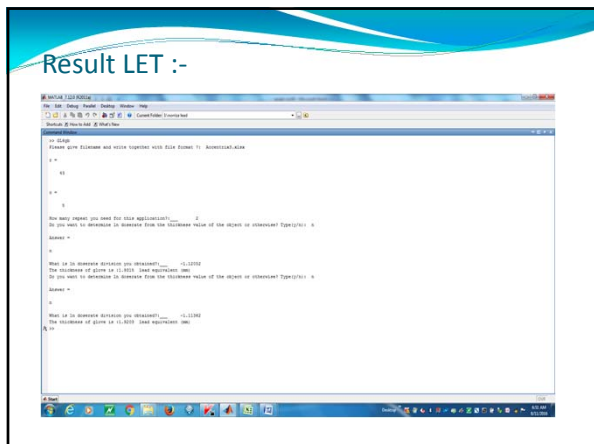


Calibration graph for Co-60:-



Calibration Graph for Am-241:-



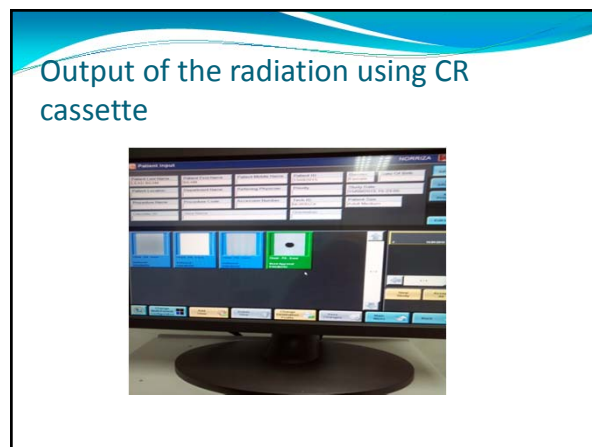


LET for Blocks:-

Physical Thickness (cm)	Radioactive Source	Cs-137	Am-241	Co-60
	Samples	Average Lead Equivalent Thickness, T (mmPb)	Average Lead Equivalent Thickness, T (mmPb)	Average Lead Equivalent Thickness, T (mmPb)
15.0	A (Batu Merah 6")	1.374	>> 2mmPb	1.9315
15.0	B (Batu Merah)	1.370	>> 2mmPb	1.9203
15.0	C (Batu Merah)	1.313	>> 2mmPb	1.697
12.5	A (Batu Block 5")	0.544	>> 2mmPb	0.6763
12.5	B (Batu Block)	0.764	>> 2mmPb	0.9006
12.5	C (Batu Block)	0.725	>> 2mmPb	0.8035
2.5	A (Barium)	0.357	>> 2mmPb	0.4261
2.5	B (Barium)-3cm tebal	0.384	>> 2mmPb	0.4684

LET for Door & Frame:-

Radioactive Source	Cs-137	Am-241	Co-60	
Samples	Average LET (mmPb)	Average LET (mmPb)	Average LET (mmPb)	
Door	a	0.153	0.995	0.293
	b	0.281	1.130	0.305
	C	0.315	1.157	0.416
	Key	0.655	2.324	0.695
Door Frame	U	1.499	1.168	1.883
	R	1.839	1.164	1.911
	L	1.891	1.231	2.145



- ### Based on the result:-
- i. Higher physical thickness will give higher LET
 - ii. The same physical thickness is not give same LET
 - iii. The LET for the samples is higher for Co-60 compare to Cs-137. (Reason Even Co-60 has higher energy, it can penetrate more caused of its activity is lower than Cs-237).
 - iv. No Am-241 radiation passed through the samples cause of low energy and low activity except for the door & its frame.
 - v. The LET side a of door is less compare to b side (hinge-give space), therefore more scattered radiation.

- ### Limitation of the test
- Shield Case for the Am-241(cylinder) is different design with Co-60 (vial) & Cs-137 (vial) cause of different container of source.
 - The beam is a broad beam, scattered radiation contribute the extra reading to detector.
 - The width of frame sample is smaller compare to diameter of collimator window.
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Conclusion

- ❖ The LET of the shielding material is depend on
 - i. Composition of material
 - ii. Energy of source
 - iii. Activity of source
- ❖ Good shielding material should have similar characteristic with Pb.

Future measurement

- Set-up using various activity of same energy
- Protect detector from scattered radiation
- Geometry set up for verification test always use the same geometry set-up during calibration.

References

- MS 838:2007, Code of practice for Radiation Protection-Medical X-ray Diagnosis
- J. C. Courtney *et al.*, "Photon shielding for a positron emission tomography suite," *Health Phys.* **81**, S24-28 2001.
- Madsen, Mark, et al. *AAPM Task Group 108: PET/CT Shielding Requirements*. *Medical Physics* 33, 1 (January 2006): 4-15.

Acknowledgment

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**Thank you for
your attention**