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Design & calculation of radiation retaining wall thickness cobalt-60 source of brachytherapy at radiotherapy unit Dr. Kariadi Hospital Semarang

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ABSTRACT

To improve radiotherapy services, Dr. Kariadi hospital Semarang plans to install a new Brakhiterapi machine using Co-60 sources. The radiotherapy room that was built was previously used for Brachytherapy using the Ir-192 source. In accordance with nuclear regulations in force in Indonesia, the Co-60 brachytherapy machine must be installed in a radiotherapy room that has obtained a new construction permit from the Nuclear Energy Supervisory Agency (Bapeten), considering that the radioactive source to be used is different from the previous radioactive source, activity and energy. The calculation document for radiation retaining wall thickness is compiled as one of the requirements to obtain construction approval from the Nuclear Energy Supervisory Agency.

Keywords: Radiotherapy, brachytherapy, Co-60 sources, the calculation for radiation wall thickness

INTRODUCTION

Radiation protection is a system for controlling radiation hazards by using radiation protection equipment and following radiation protection regulations that have been standardized1. Possible radiation hazards are caused by irradiation of the external body (external), if the radiation source is outside the body and maybe the radiation hazard is caused by irradiation of the inner body (internal), if the radiation source is in the body [1,2,3].

Biological Effects of Adverse Radiation are grouped into 3, namely the non-stockastic somatic effect which usually causes redness of the skin, the somatic stockastic effect which is for example cancer of leukemia and the genetic stochastic effect that can be inherited in the next generation. Non-stochastic effects occur when the dose received exceeds the prescribed threshold dose. The price of this threshold dose is not the same for everyone and depends on the conditions of irradiation [2,3].

If the reception of the dose above the threshold dose the effect will be even more severe if the dose received is higher. Usually it will arise immediately (less than 1 year after irradiation). The occurrence of a Stochastic effect follows a probabilitic relationship in the sense that if a group of people receives a higher dose there will be a greater likelihood of certain Stochastic effects. This effect (in somatic terms) will be experienced by several people in this group randomly. In this case the genetic frequency of an abnormality in the next generation is higher when the dose received by the group is higher [2,3].

For this reason, the Government issued regulations aimed at reducing these adverse factors, in the form of Government Regulation No. 11, 12, 13 of 1975, while the implementation provisions were issued through the Decree of the Director General of BATAN no. 24 / DJ / II / 1983. In it the scope is explained as follows: Provisions for occupational safety are intended as a guide for those who work with ionizing radiation sources in the fields of health, industry, education, research and so on. The provisions contained in this manual contain the basics of radiation protection, including regulating: Allowable radiation dose limit values, Work requirements with radiation sources and Work procedures that must be adhered to and carried out by everyone who works with radiation sources [4]. By using a dosage limitation system for body irradiation (both external and internal radiation) the possibility of radiation risk can be ignored. This is the job of a Radiation Protection Officer by following the Radiation Protection Regulations and using sophisticated protective equipment can save radiation workers and society in general.

The procedure commonly used to prevent and control radiation hazards is to eliminate radiation hazards, isolate radiation hazards from humans and isolate humans from radiation hazards. The application of the three radiation protection principles is carried out by the Radiation Protection Officer1, 4,5. The main principle is clear by obeying and implementing radiation protection regulations, secondly by designing the workplace and using radiation protection equipment and adequate radiation retention so that work and environment conditions are safe and secure and the third requires constant monitoring and supervision of radiation workers. environment using individual monitoring tools, environmental monitoring and surveymeter [5,6].

Given that besides the benefits of external and internal radiation which is ionizing radiation, it is potential to cause radiation hazards, while technically it is impossible to eliminate the source, the danger of radiation from external and internal radiation to the officer or the environment can be controlled with three basic rules of radiation protection, namely reducing radiation time. Seek distance from the radiation source as far as possible and use a radiation barrier [5,6].

A radiotherapy operator who has to work for a certain amount of time (according to the required dose calculation) which is relatively long and at a distance that is relatively close to the source of the only way to control radiation hazards is to install a radiation barrier between the source and the operator. There are two types of radiation retention to the source and barrier of radiation for the environment, namely the walls of the radiotherapy machine [4,5,8].

Calculation of barrier planning, anchoring is divided into two types, namely primary and secondary anchors. Primary deterrents provide protection against use rays, which are rays that come directly from the radiation source, while the secondary barrier provides protection against leaky radiation and scattered radiation7. As for the brachytherapy chamber, we consider all retaining walls as primary anchors, because the radiation source from brachytherapy is not collimated.

To improve radiotherapy services, Dr. Kariadi hospital Semarang plans to install a new Brakhiterapi machine using Co-60 sources. The radiotherapy room that was built was previously used for Brachytherapy using the Ir-192 source. In accordance with nuclear regulations in force in Indonesia, the Co-60 brachytherapy aircraft must be installed in a radiotherapy room that has obtained a new construction permit from the Nuclear Energy Supervisory Agency (Bapeten), considering that the radioactive source to be used is different from the previous radioactive source, activity and energy

MATERIALS AND METHOD

In this study the calculation parameters we use are:

- Radioactive source : Co-60
- Energy : 1.33 Mev
- Source activity : 2.5 Ci
- Reference air kerma rate : 308 µgym2/gbqh
- Number of patients : 35 patiens/week
- Duration of treatment : 0.25 hours/patient
- Control area : 0.2 msv/week
- Uncontrol area : 0.01 msv/week (According to PERKA BAPETEN No. 3 of 2013)
- T Factor : 1 (NCRP 151)

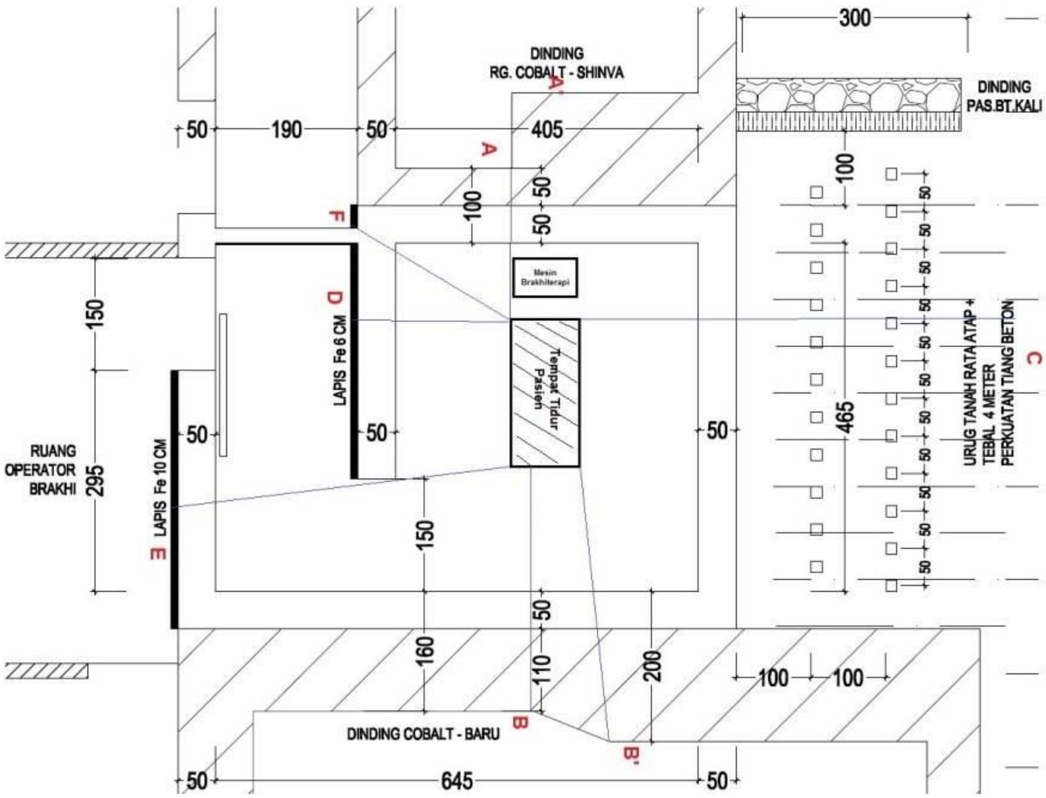

Fig 1. Site Plan of the Brakhiterapi Co-60 Room

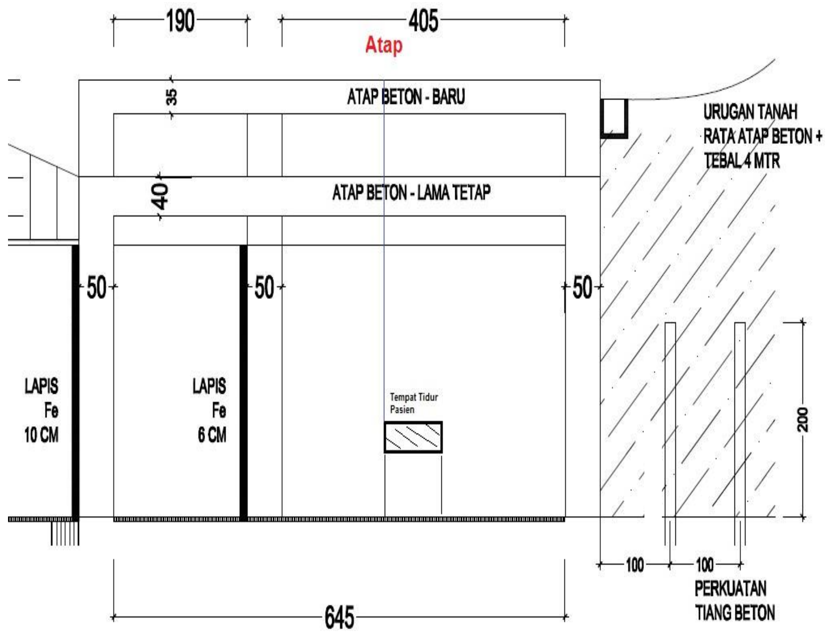

Fig 2. Room Brchytherapy Co-60 space roof plan

Assume the layout of the patient's bed during treatment so that the bed area is likely to position the source as shown in Figure 1.

Distance of Protection Point against source (d)

- A : 2 m
- A' : 3 m
- A' : 3.25 m
- B : 3.65 m
- C : 6 m
- D : 2 m
- E : 4.5 m
- Roof : 3.5 m

Radiation retaining material

	TVL (cm)	TVLe(cm)
Concrete	21.8	21.8
Iron (Fe)	7.1	7.1
Lead (Pb)	4.1	4.1

Workload (W)

Workload is calculated by equation [8]

$$W = T_{AKR}\ x\ A\ x\ t\ x\ n$$

W = brachytherapy / week workload

T_{AKR} = reference rate kerma Cobalt-60 source

A = source ativity

t = duration of treatment/patient

n = number of patients/week

By substituting the value of each of the variables available above into the equation, it is found that the workload of the brachytherapy is **245.25 mGym^2 / week.**

RESULTS AND DISCUSSION

Calculation of Radiation Restraint Thickness

The equation used in calculating the radiation retaining thickness is as follows 8:

$$B = Pd^{2}/WT$$
$$n = \log 10(1/B)$$
$$X = TVL_1 + [n-1] * TVL_e$$

- B = Barrier transmission factor
- P = Dosage limits allowed
- d = Source distance to protection point
- W = Work load brakhiterapy machine
- T = Space placement factor
- n = Number of radiation retaining TVLs
- TVL = Tenth value layer
- X = The radiation retaining thickness at the protection point

By substituting the values of each of the variables available above into the equation above, the wall thickness (X) will be obtained. The results of the calculation of each wall can be summarized in the table as follows:

Table 1. Calculation of brachytherapy chamber wall thickness

Point	area type	P (mSv/week)	T	d(m)	B	n	X
A	uncontrol	0.01	1	2	$1.63x10^{-4}$	3.79	82.6
A'	uncontrol	0.01	1	3	$3.67x10^{-4}$	3.44	74.9
B	uncontrol	0.01	1	3.25	$4.31x10^{-4}$	3.37	73.4
B'	uncontrol	0.01	1	3.65	$5.43x10^{-4}$	3.27	71.2
C	uncontrol	0.01	1	6	$1.47x10^{-3}$	2.83	61.8
D	control	0.2	1	2.06	$3.46x10^{-3}$	2.46	53.6
E	control	0.2	1	4.5	$1.65x10^{-2}$	1.78	38.9
F	control	0.2	1	2.4	$4.7x10^{-3}$	2.33	50.8
Roof	uncontrol	0.01	1	3.5	$5x10^{-4}$	3.30	72

Comparison of brachytherapic chamber wall thickness calculated with actual thickness according to bluebrint is in the following table:

Table 2. Comparisson of brachytherapy chamber wall thickness from the calculated thickness is actually in accordance with bluebrint

Wall	X according to the blue print (cm Concrete)	X calculation (cm Concrete)
A	100	82.6
A’	200	74.9
B	160	73.4
B’	200	71.2
C	50 cm concrete + 400 cm soil	61.8
D	50 cm concrete + 6 cm Fe	53.6
E	50 cm concrete + 10 cm Fe	39.9
F	50 cm concrete + 6 cm Fe	50.8
Roof	75	72

Door Thickness Calculation

In determining the thickness of the door required for a brachytherapy aircraft installation, the dose rate at the labyrinth entry point must be determined in advance. The radiation dose at that point is the accumulation of primary source radiation through the patient and the labyrinthine wall and scattering radiation along the labyrinth wall.

For primary radiation through the patient and the labyrinthine wall, the radiation dose rate can be calculated by the equation [8].

$$D_{\square} = 0.81 \, x \, P$$

D_p = Primary radiation dose rates due to patient attenuation and labyrinthine walls

P = The dose rate allowed after radiation through the wall

D $_{0,81}$ = Attenuation factor of brachytherapy patients (Table 21 SRS 47)

By substituting the values of each of the variables available above into the equation above, the value of **Dp = 0.162 mSv / week** is obtained.

As for scattering radiation along the labyrinth wall, it is obtained using equations [8]:

$$Dw = (W * 0.81 \, / \, d_1{}^2) x (\alpha_0 A_0 \alpha_1 A_1 \, / d_2{}^2)$$

- W = 245.25 $mGym^2$/week
- α_0 = 1.26 x 10^{-2} (Table 6 SRS 47)
- A_0 = 8.4 m^2
- α_1 = 7.79 x 10^{-3} (Table 6 SRS 47)
- A_1 = 6.3 m2
- d1 = 5.7 m
- d2 = 6.3 m

By substituting the values of the above variables to the above equation the value is obtained:

$$Dw = 0.000131 \, mSv/week$$

So the total dose rate at the labyrinth entry point is [8] :

$$\boldsymbol{D}_{\square o \square} = D_{\square} + D_{\square}$$

$$\boldsymbol{D}_{\square o \square} = 0.16 + 0.000131 = 0.1 \text{ mSv/minggu}$$

Behind the door is designed as an uncontrolled area with **P = 0.01 mSv / week**. The thickness of the door needed can be determined based on the equation [8]:

$$\textbf{Thick door} = -\log(P/D_{\square o \square}) * TVL$$

$$\textbf{Thick door} = -\log(0.01/0.16) * TVL$$

$$\textbf{Thick door} = 1.27 * TVL$$

TVL Pb for scattering Co-60 radiation files is 6.5 mmPb (SRS 47 Table 23). So the thickness of Pb needed for the door is **8.26 mmPb**.

The thickness of the door to be built is **8.5 mmPb.**

Calculation of dose rate

Calculation of dose rate is done to determine the rate of weekly dose (P) outside the wall in the actual wall thickness assuming concrete density 2.35 gr / cm^3., And the dose limit for uncontrolled space is 0.01 mSv / week and for controlled space 0.2 mSv /Sunday. Based on the above equations, and entering the actual thickness value of the wall thickness to be built, dose estimates that will pass from each wall will be obtained as shown in the following table:

Table 3. The dose rate after passing through each wall and the dosage limit values allowed

Wall	Wall Thickness (cm)	Actual Conditions	P (mSv/week)	NBD (mSv/week)
A	82.6	100		$1x10^{-2}$
A'	74.9	200	$1.82x10^{-8}1.59x10^{-3}$	$1x10^{-2}$
B	73.4	160	$1.06x10^{-6}$	$1x10^{-2}$
B'	71.2	200	$1.23x10^{-8}$	$1x10^{-2}$
C	61.8	50 cm concrete + 400 cm soil	$1.95x10^{-14}$	$1x10^{-2}$
D	53.6	50 cm concrete + 6 cm Fe	$4.2x10^{-2}$	$2x10^{-1}$
E	38.9	50 cm concrete + 10 cm Fe	$2.41x10^{-3}$	$2x10^{-1}$
F	50.8	50 cm concrete + 6 cm Fe	$3.09x10^{-2}$	$2x10^{-1}$
Roof	72	75	$7.26x10^{-3}$	$1x10^{-2}$

CONCLUSIONS

Shielding types that can be used for fixed installations are concrete and some are added with iron. The exposure dose rate in the observation area or outside the walls of the brakhitarapi aircraft room does not exceed the maximum dose limit set. The thickness of the retaining wall in the brachytherapy plane space of the Cobalt-60 source has met the minimum limit of retaining wall thickness in theory or literature.

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