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The Effect of the Irradiation Geometry on the Image Quality Obtained by Gamma Transmission Method

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Abstract

The effect of the irradiation and counting geometry on the image quality obtained by gamma transmission method has been investigated. As the object for imaging, an absorber was made out using aluminium and lead plates with the dimensions of 40 mm., 20 mm., 4mm. framed with Plexiglas. The absorber has been irradiated with the 662 keV gamma rays of Cs-137, which were collimated in different apertures. A 4.44 cm.x5.87 cm. NaI(Tl) crystal was used to detect the gamma rays transmitted through absorber. The beam intensity distributions were measured for different collimator and beam width. The measurements have been repeated for the different source-to-detector distances to accommodate the beam intensity.

Özet

Gamma transmisyon yöntemiyle elde edilen görüntü kalitesine ışınlama ve sayım geometrisinin etkisi incelendi. Görüntülenecek obje olarak pleksiglas çerçeveli 40 mm.x20 mm.x4mm. boyutlarında alüminyum ve kurşun levhalar kullanılarak bir soğurucu oluşturuldu. Soğurucu, farklı genişliklerde kolime edilmiş Cs-137'nin 662 keV'lik gamma ışın demetleriyle ışınlandı. Soğurucudan geçen gamma ışınlarını saymak için 4.44 cm.x5.87 cm.lik NaI(Tl) kristali kullanıldı. Farklı kolimatör ve demet genişliği için, demet-şiddet dağılımları ölçüldü. Demet şiddetini uygun hale getirmek için ölçümler, farklı kaynak-detektör uzaklıklarında tekrar edildi.

Key words: *Irradiation Geometry, Image Quality, Gamma Transmission Method.*

I. Introduction

While the determination the level of the radioactivity in an organ and/or tissue provides important information, it is more useful to know how the radioactivity is distributed through that organ or tissue. Therefore the imaging, or producing the distribution of the radioactivity is already most important aspect of nuclear medicine. In 1976, approximately 80% of all in-vivo clinical studies in nuclear medicine were involved the imaging processes[1,3,4].

In clinical applications, the image of an object such as an organ or tissue is obtained using either the transmitted or emitted radiation formed as a result of irradiation process. However, some important problems, which effect on the image quality can arise due to inconvenient irradiation and counting geometries. Therefore, we have decided to investigate the effect of both irradiation and counting geometries on the image quality obtained by gamma transmission method, by using the beam intensity distributions.

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II. Experimental

For this purpose, an experimental set up has been installed containing a cylindrical source chamber and a collimator both made from lead, an absorber, and counting system (Figure 1).

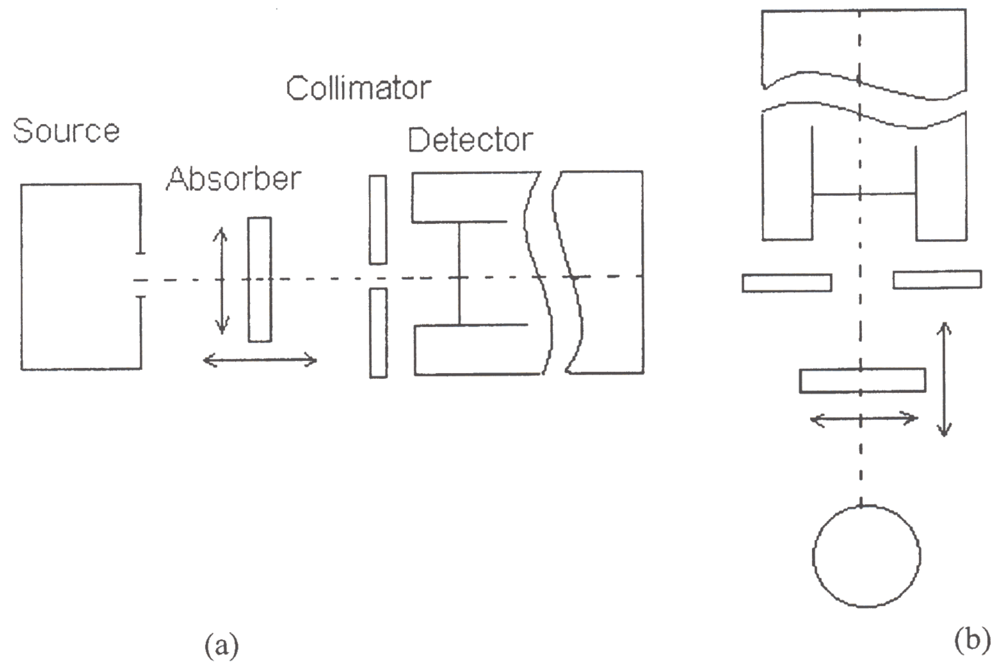

Figure 1: The cross-sectional view of the experimental set up. (a) Side view, (b) Top view.

A multipurpose source chamber was designed in such a way, so that it contains two concentric lead cylinders located in each other. The inner cylinder with 20mm. diameter and 30 mm. high was fixed on a holder. A hole with 10mm. diameter was bored on its lateral surface, in order to obtain a horizontal beam. The outer cylinder however could rotate around their co-axis, having a 40mm. diameter and 80 mm. high. Four holes with different diameters of 2.5 mm., 5 mm., 7.5 mm. and 10 mm. were bored so that the width of the collimated beam can be changed in stepwise. In this way, we were able to obtain collimated beams in four different apertures according to the irradiation conditions. The total wall thickness of the both cylinders was enough to effect also as a shield for safety.

The monoenergetic gamma rays of 662 keV emitted after beta decay of Cs-137, which has a half-life of 30.17 y., so that the intensity of gamma rays remains approximately constant during irradiation process[5,7]. The source chamber and absorber both fixed on two holders separately could be moved on a brass rail horizontally in the direction perpendicular to the detector and absorber surfaces. In this way, we were able to adjust both the source-absorber and absorber-detector distances. On the other hand, we were able to move the absorber put in a Plexiglas frame horizontally in such a way, so that the both absorber and detector surfaces remain parallel. This gives us the possibility to adjust the position of the absorber against the source and detector. In order to minimize the scattered photons, a second matching collimator put close to detector.

III. Results

The gamma spectra have been obtained and analysed at the Canberra S-100 data acquisition and analysing system following a 4.44cm.x 5.87 cm. NaI(Tl) detector(Figure 2) [2]. The system was calibrated energetically by using the gamma rays of Cs-137 and Co-60 sources.

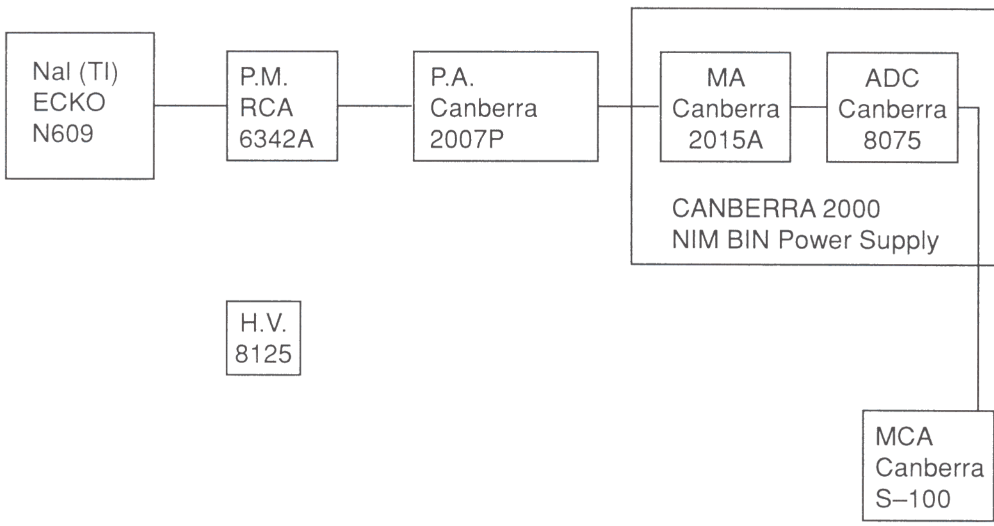

Figure 2: The block diagram of the data acquisition and analysing system.

In order to achieve a reasonable conclusion on the image quality obtained, the intensity distributions have been measured depending on the position of absorber for different combinations of beam width(f) and collimator width(d). The results for a counting time of t =1000 s. are shown in figures 3-(a,b,c,d,e,f).

It can be concluded from these figures, that the maximum intensity behind the absorber has been obtained for the detector collimator width of 2 mm at the position, at which the aluminium and lead plates are joined so that they forms together the absorber. On the other hand, the resolution and efficiency of the collimator affected by means of its length and width strongly. Therefore, the collimator width must have a critical value to decrease the penumbra. Consequently, an image with relatively high quality can be obtained by using an external source.

We have also investigated the effects of the source-to-absorber distance on the intensity distribution for different combinations of the collimator and beam widths, keeping the absorber at a fixed position (Figure 4-a,b,c,d). It can be seen from these figures, that the intensity varies rapidly for large collimator widths for the source-to-detector distances smaller than 70 mm. But the collimator resolution, which affects the sharpness (or detail) of the image directly, becomes poorer as the source-to-detector distance increases (Figure 4-c). However, the collimator width must be large enough to obtain reasonable collimator efficiency.

IV. Discussion

A model has been designed and made to use as an object for imaging process including two extremely different absorbing materials, that is aluminium and lead being a great difference between their absorption coefficients for gamma rays. The main reason to choose such a model for object was to observe the change of the intensity distinctly.

In order to investigate the dependence of the intensity to the detector collimator distance, a single channel collimator has been used. But, this was caused to diminish the geometric efficiency of the collimator. The other failure in this work was arised from the fixed length of collimator. Therefore, we could not investigate the effect of the collimator length on the resolution and efficiency; both effect the intensity distribution strongly[6].

We have also not studied the energy dependence of the image quality, because we have used mono-energetic gamma rays.

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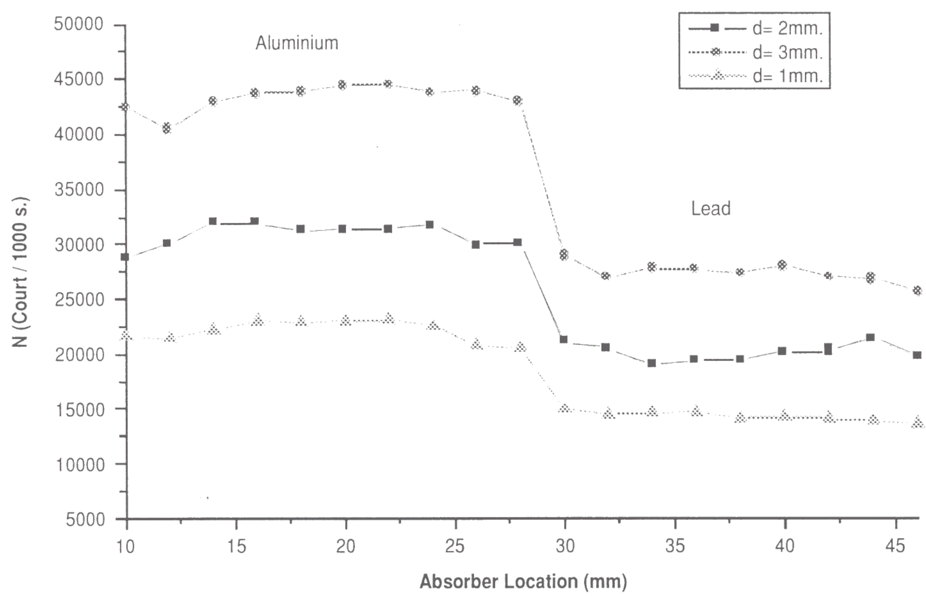

Figure 3-a: The transmitted intensity distributions depending on the absorber location for a constant source-to absorber distance of 20 mm.; f = 10 mm.

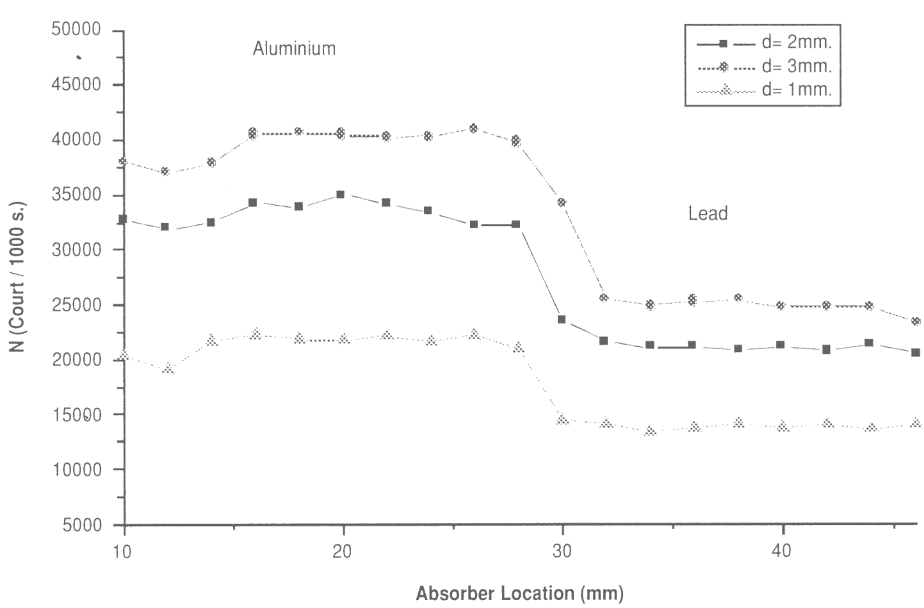

Figure 3-b: f = 7.5 mm.

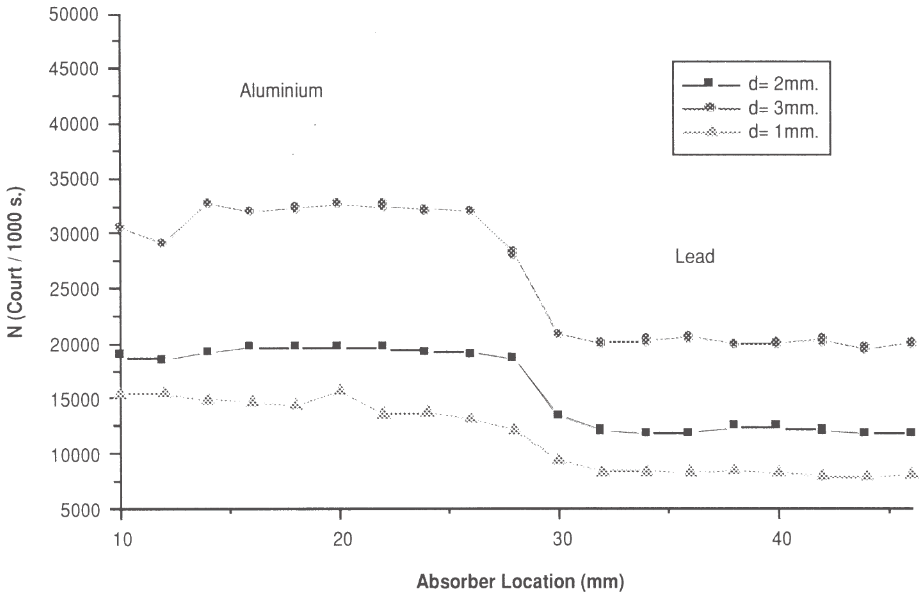

Figure 3-c: $\phi = 5$ mm.

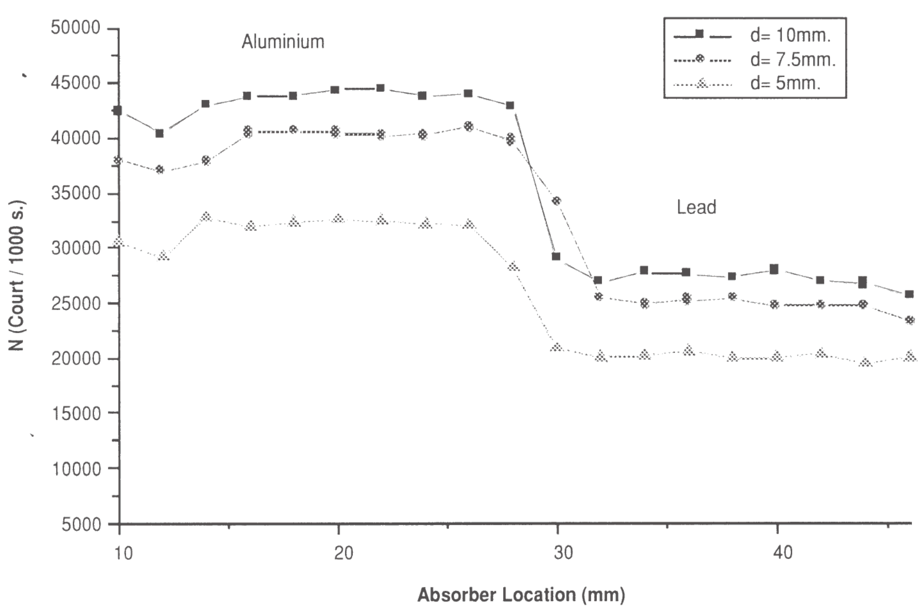

Figure 3-d: The transmitted intensity distributions depending on the absorber location for a constant source-to absorber distance of 20 mm.; d = 3 mm

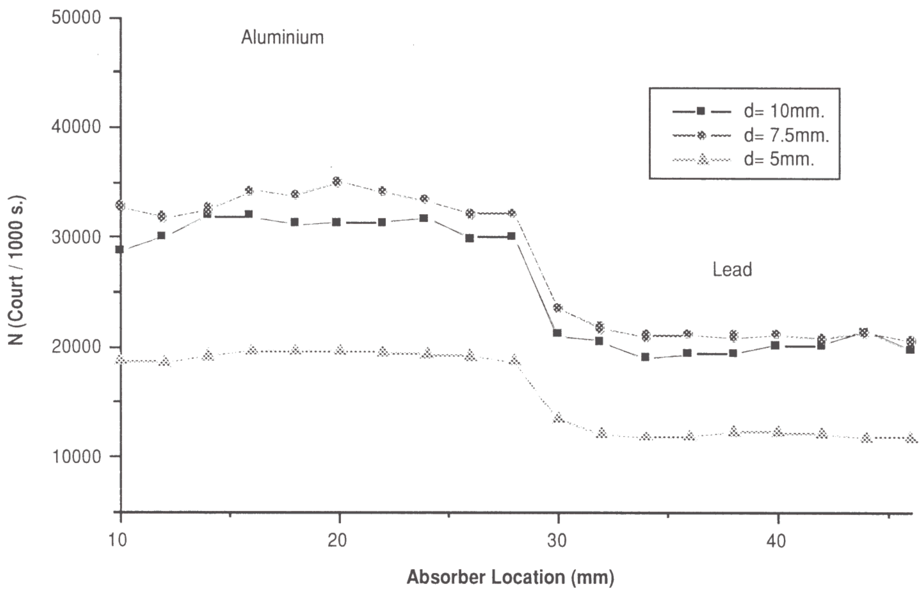

Figure 3-e: d = 2 mm.

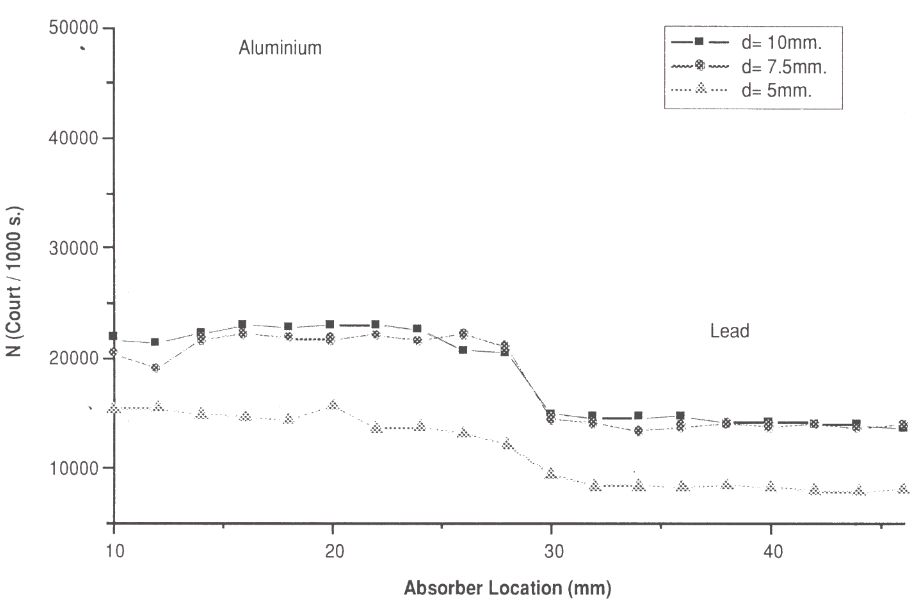

Figure 3-f: d = 1 mm.

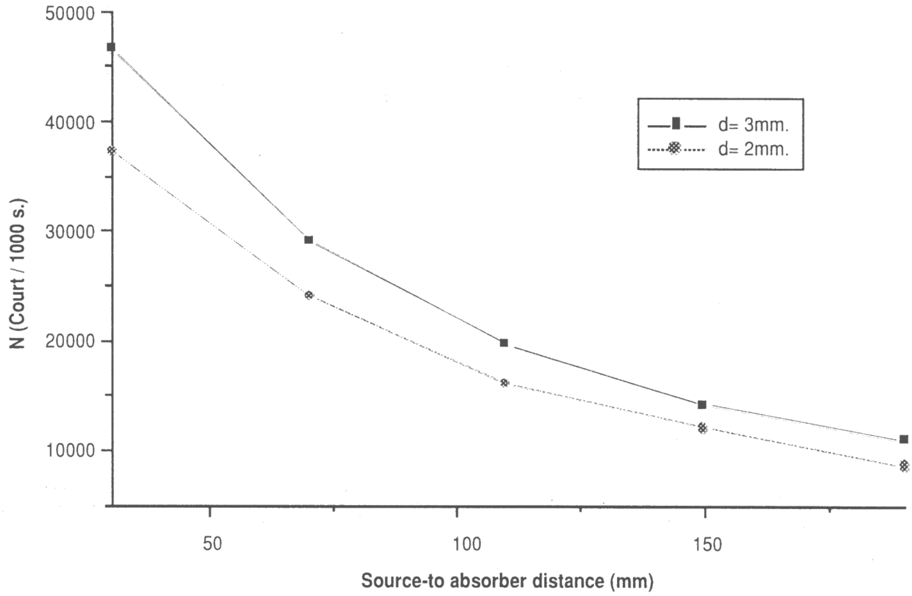

Figure 4-a: The transmitted intensity distributions depending on source-to-absorber distance for a fixed position of the absorber parallel to the detector surface; ϕ = 10 mm.

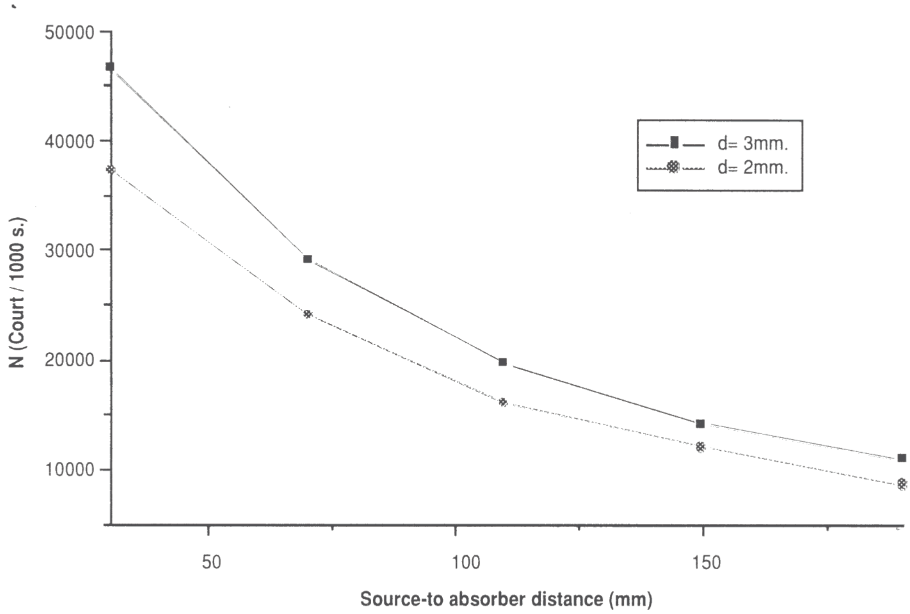

Figure 4-b: ϕ = 7.5 mm.

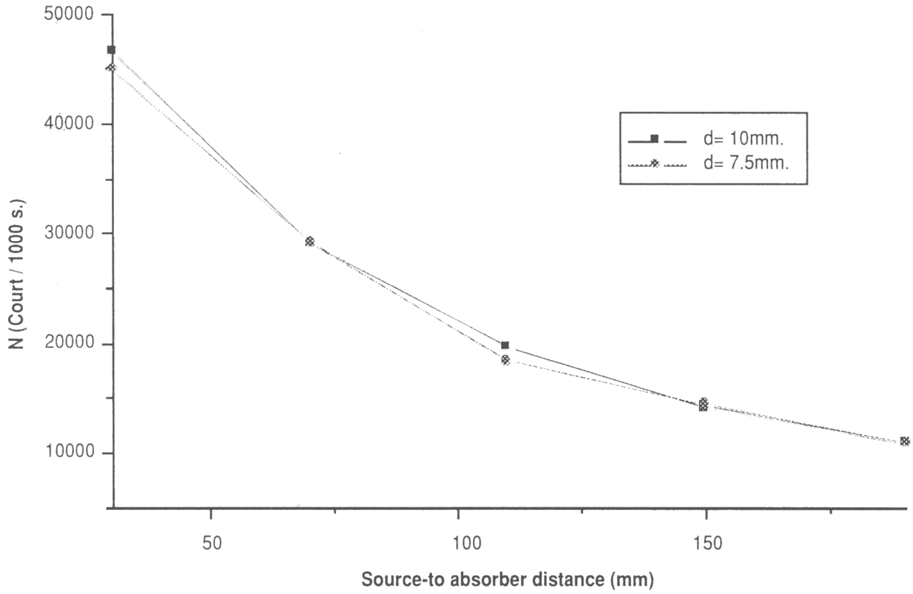

Figure 4-c: The transmitted intensity distributions depending on source-to-absorber distance for a fixed position of the absorber parallel to the detector surface; d=3 mm.

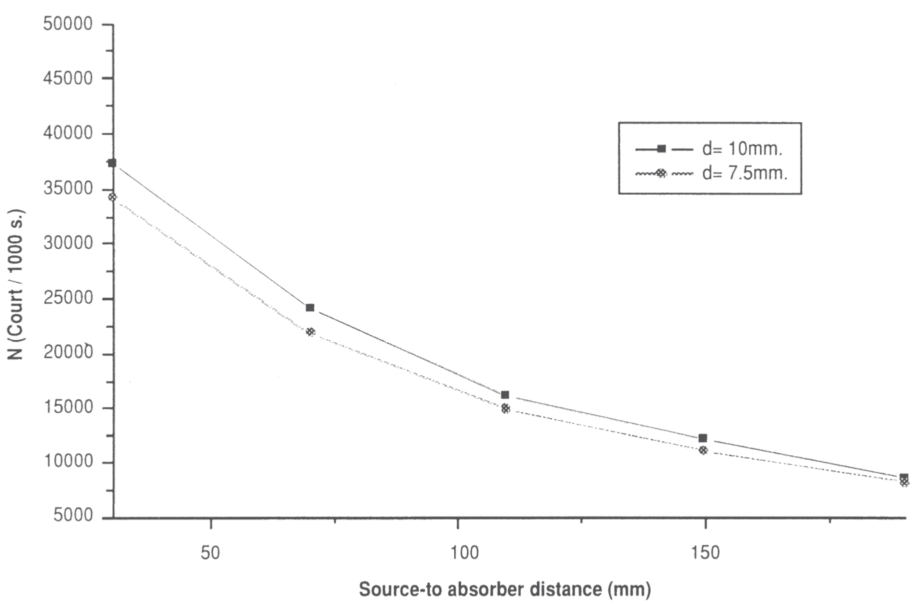

Figure 4-d: d=2 mm