5. Discussion:

The buildup factor values calculated from coincidence spectra are in general lower than those registered by direct spectra. As shown in Tables (2) and (3) this decrease ranges between (3.4% - 8.3%) of the values of direct spectra for the different values of reinforcement with Pb. Even in the case without reinforcing (i.e 0% Pb) the difference is comparable 4.8% .In ref.[6] that used the same coincidence spectrometer, the B values measured by coincidence technique for a single material (Pb sheets) had decreased by(4.6% - 32%) over the whole thicknesses measured (0.2-1.8 cm).These values reflect the good preparing of electronics of the system. Of course, the B values from coincidence were near to 1, which reflects that the coincidence spectrometer registers mainly the unscattered transmitted beam. The reduction of the coincidence B values from the direct measurement values for the other two reinforcing materials were as follows:

For Cu 30% was 11.7%., for Cu 30% f was 2.5% , for Fe 30% was 53% and for Fe 30% f it was 5.9% i.e. the use of sheet reinforcing gave higher reduction than the use of fiber reinforcing for the used materials. Again, the use of coincidence technique reduces the measured B values significantly.

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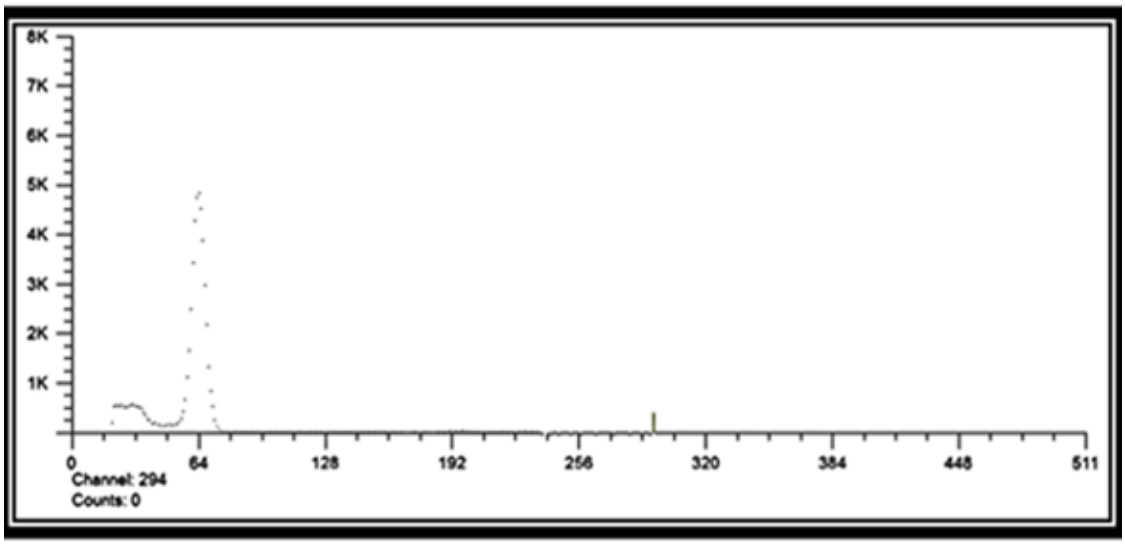

Fig. (4): coincidence spectrum of Na -22

Table (3): B values of coincidence spectra for UP reinforced with different Pb concentrations

Pb Con.%	0	10	20	30	40	50
Build-Up factor	1.17	1.13	1.12	1.10	1.09	1.21

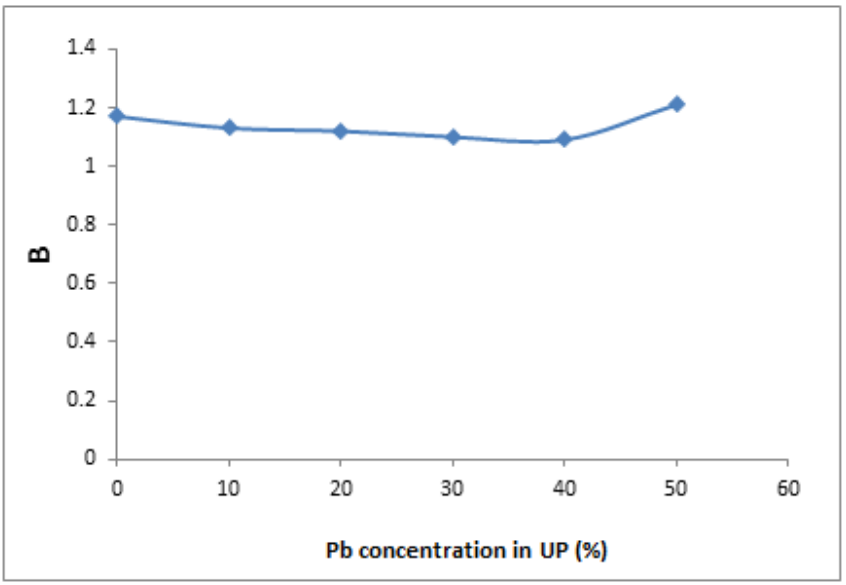

Fig. (5): Relation between B and Pb concentrations for coincidence measurements.

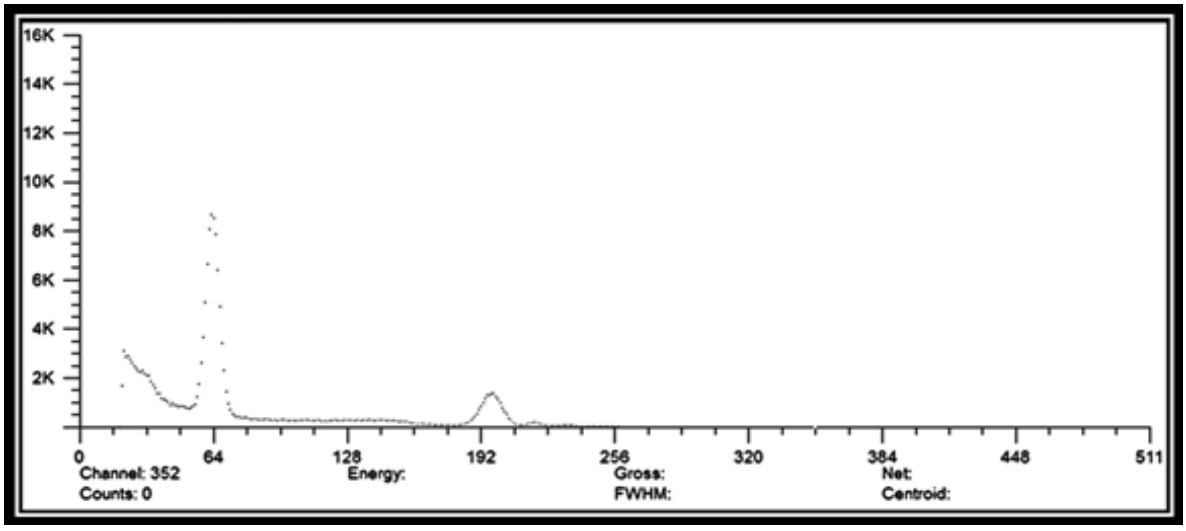

Fig. (2) Direct spectrum of Na-22 Source

Table (2): B values for the data of table (1).

Con.%	UP100	Pb10	Pb20	Pb30	Pb40	Pb50
Build-up factor	1.23	1.17	1.17	1.20	1.18	1.28

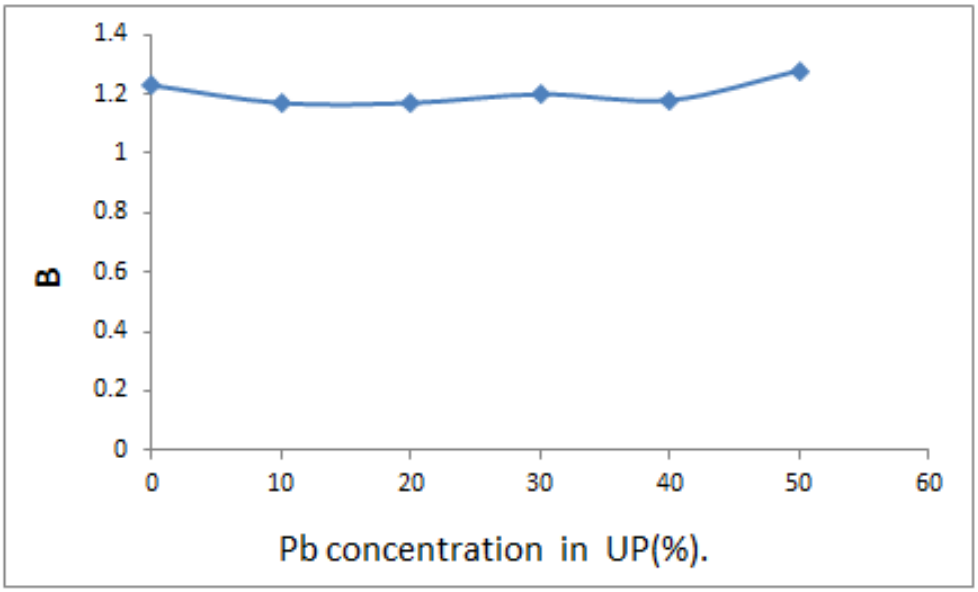

Fig. (3): Relation between B and Pb concentrations for direct measurement.

4-Measurements and Results:

A - Build-up factor measurements for UP reinforced with lead:

i- UP material sheets reinforced with different concentrations of lead i.e. 10%,20%,30%,40% and 50% and without reinforcing (0%) are used in direct measurements both with and without collimator. The data are presented in Table (1).Fig. (2) shows a typical Na-22 spectrum obtained.

The build –up factor is calculated for the samples of different concentrations, and the values are presented in Table (2).Fig. (3) shows the relation between B values and concentrations.

ii- For the same blocks and concentrations mentioned in (i) above, the coincidence spectra are measured for the 0.511 MeV gate. A typical coincidence spectrum is shown in Fig. (4). The B values are calculated and presented in Table (3), and the data are plotted as shown in Fig. (5).

B- Build-up factor measurements of UP reinforced with Cu sheets (Cu 30%) and Cu fibers (Cu 30% f):

i- With the same procedure mentioned in A above the direct spectra are measured and the B value calculated for the (Cu 30%) case was 1.19 and for the (Cu30% f) case it was 1.17.

ii - The build-up factor values are also calculated for the coincidence spectra. The B values for the cases (Cu 30%) and (Cu 30% f) were 1.056 and 1.142 respectively.

C- Build-up factor measurements for UP reinforced with Fe sheets (Fe 30%) and Fe fibers (Fe 30% f):-

i- For direct spectra measurement, the B values calculated for the (Fe 30%) and (Fe 30% f) cases were 2.466 and 1.18 respectively.

ii- For coincidence measurements, the B Values calculated for the cases (Fe 30%) and (Fe 30% f) were 1.142 and 1.119 respectively.

Table (1): Data of direct spectra for UP reinforced with different Pb concentrations

Spectrum	Con.%	Centroid (ch)	FWHM (ch)	NPA Count/s
DS UC	Pb10	63.46	8.54	66063
DS CO	Pb10	63.8	8.82	12419
DS UC	Pb20	63.57	8.67	63249
DS CO	Pb20	63.99	8.96	11805
DS UC	Pb30	63.55	8.7	63273
DS CO	Pb30	63.82	9.04	11533
DS UC	Pb40	63.65	8.63	60548
DS CO	Pb40	64.14	9.11	11199
DS UC	Pb50	63.6	8.63	56076
DS CO	Pb50	63.98	9.16	9611
DS UC	UP100	63.69	8.63	65671
DS CO	UP100	64.04	8.98	11682

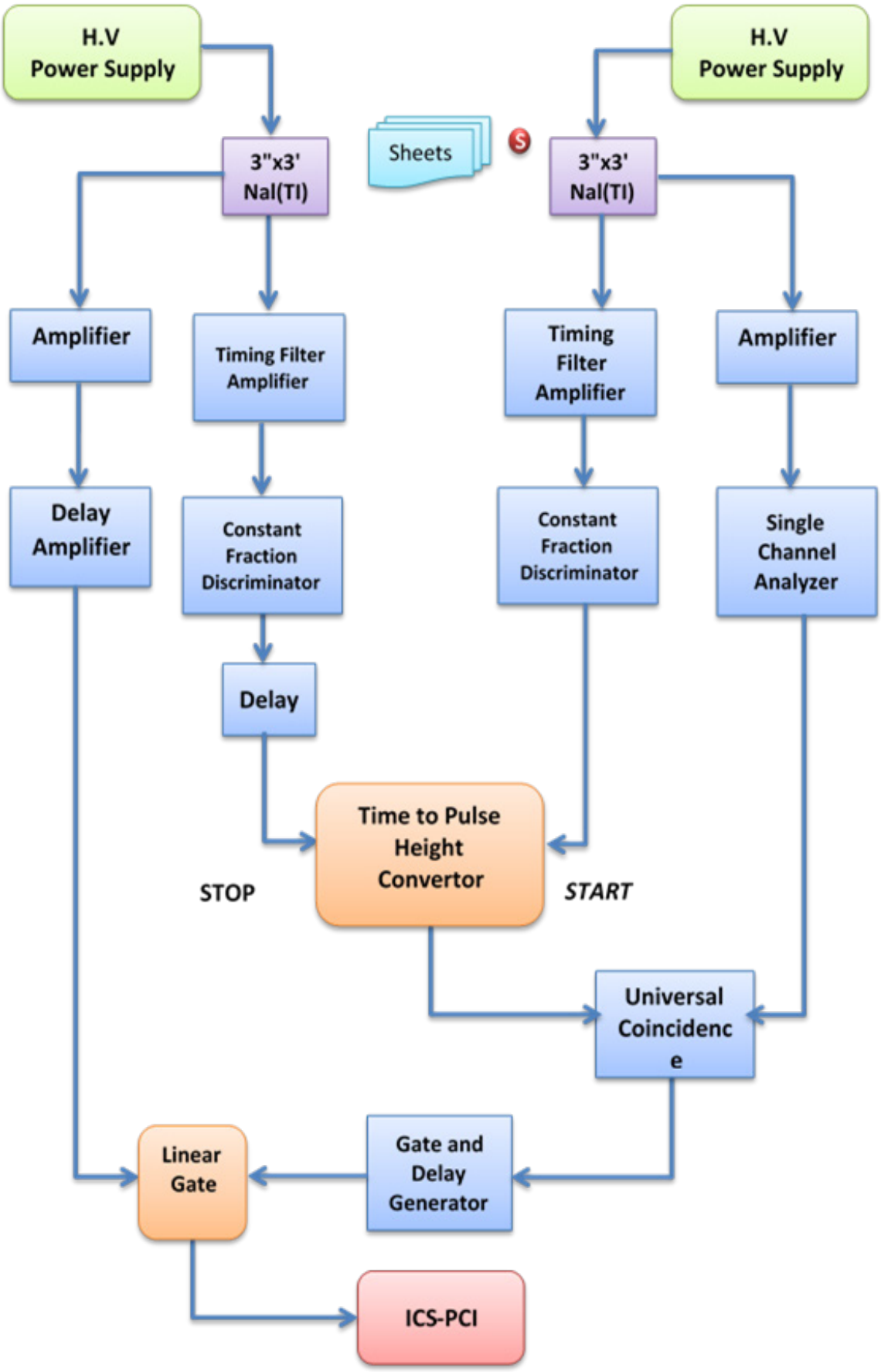

Fig. (1): The gamma-gamma coincidence spectrometer

where Iu.n and $I_{0.n}$ are the intensities of the transmitted (narrow) and the incident (narrow) beams respectively.

For a broad beam (bad geometry), eq.(1) may be written as:

$$I_{t.b} = B\, I_{0.b}\, \exp(-\mu x) \qquad (4)$$

where $I_{t.b}$ and $I_{0.b}$ are the intensities of the total transmitted beam (broad), and total incident beam (broad) respectively.

From eqs.(3) and (4) we can write:

$$B = \frac{I_{t.b}/I_{0.b}}{I_{u.n}/I_{0.n}} \qquad (5)$$

3-Experimental

A-Apparatus:

The gamma-gamma coincidence spectrometer used in this study is diagrammed in Fig.(1) with the details are given in many references [4-6]. Two 3»X 3» NaI (TI) detectors and Na-22 point source with o.4 μCi activity are used. The two detectors are facing each other at 180° angle and the source is kept between . Measurements are carried on using a lead collimator with 1 cm diameter and 5 cm length. Measurements are made for both cases with and without using the collimator. A gate is selected (at 0.511 MeV energy) in one of the detector branches, and the other branch allows the whole spectrum pulses to pass, and in this latter branch the measured material sheets are allocated. Both direct and coincidence spectra are measured for each thickness case.

B- Materials:

The principal material used in the present work for build-up factor measurements is unsaturated polyester (UP).This material is reinforced with the following additives:

i- Lead with percentages 10%,20%,30%,40%and 50%.

ii- 30% Cu sheets and 30% Cu fibers.

iii- 30% Fe sheets and 30% Fe fibers.

The samples for each of the above mentioned materials are prepared in blocks with 10x10 cm^2 dimensions and 1cm thickness.

1- Introduction

The commonly used relation of gamma– rays attenuation in materials, i.e., the Lambert equation requires the beam to be collimated and monoenergetic. However, and in many cases the beams are broad, and this needed to make intensity corrections through what is called build-up factor corrections. A large number of researches were carried on concerning build-up factor both theoretically and experimentally with different sources and materials [1-3].

From the results of these studies and others that were principally based on direct measurements, there seems a need for using another technique in measurements that differs from direct methods. The inspection of the transmitted beam shows that this consists of a part that penetrates the matter without being scattered and a scattered part. The scattered γ -rays may suffer further side interactions in the attenuating material before being recorded by the detector. From these interactions two important mechanisms can occur, i.e, Compton scattering and pair production. These are regarded as the main causes of the building-up of intensity of the recorded beam [2].

Recently a number of researches were carried on that used coincidence technique as tool for further insight in measurement [4-6]. Measurement of build-up factor by the coincidence method showed that the values obtained at different thickness were generally lower than those registered by the direct method [6].

In the present work we use the coincidence technique in measuring the build-up factor for unsaturated polyester composite material that may be suitable for shielding purposes. This material was reinforced separately with Pb, Cu and Fe components. The measurements were concentrated upon the difference between direct and coincidence spectra recorded.

2- Theory

A gamma beam passing through a material may be attenuated and the beam intensity I after traversing a thickness x is given by the relation

$$I = I_0 \, e^{(-\mu x)} \qquad (1)$$

where I0 is the incident beam intensity and μ is the attenuation coefficient.

However, the use of eq. (1) requires the beam to be narrow, parallel and monoenergetic, besides the thickness of the attenuating material is little.

When the incident beam is broad and not parallel and the shield thickness is large, eq.(1) will not be suitable for application because of the appearance of beam build up [2]. The build-up factor is defined as the total beam intensity (scattered and not scattered) divided by the unscattered beam intensity Iu through the beam penetration in the shield. The build-up factor originates principally from two mechanisms of photon interaction, namely Compton scattering and pair production.

The build-up factor is given as:

$$B = \frac{It}{Iu} \qquad (2)$$

For a narrow beam (good geometry),eq. (1) can be written as:

$$I_{u.n} = I_{0.n} \, e^{(-\mu x)} \qquad (3)$$

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BUILD-UP FACTOR MEASUREMENTS OF A COMPOSITE MATERAIL WITH DIFFERENT REINFORCEMENTS BY USING DIRECT AND COINCIDENCE METHODS

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Abstract

The build-up factor B of gamma-rays is measured for an unsaturated polyester (UP) composite material with different reinforcement by using direct and coincidence methods. The coincidence spectrometer consisted of two 3"x3" NaI(TI) detectors with Na-22 source. The B values measured by the coincidence method were generally lower than those obtained by using direct method. The reduction ranged between 3.4%-8.3% for samples reinforced with different Pb (10 -50.%.) ratios. For the reinforcement with 30% Cu (sheets) and 30% Fe (sheets) the reductions were 11.7% and 53% respectively, while for the reinforcement with 30% Cu (fibers) and 30% Fe(fibers) the reductions were 2.5% and 5.9% respectively. The decrease in B values resembles the decrease in attenuation coefficient measured by other investigators using coincidence technique.

Keywords: Coincidence technique, build-up factor, gamma -ray, composite material.

قياسات عامل التراكم لمادة متراكبة بتدعيم مختلف باستعمال الطريقتين المباشرة والتطابقية

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الخلاصة

قيس عامل التراكم B لاشعة كاما لمادة بولي استر غير المشبع (UP) بتدعيم مختلف باستعمال الطريقتين المباشرة والتطابقية.

المطياف التطابقي يتألف من كاشفي (NaI (Tl بحجم 3"*3" مع مصدر Na-22 . ان قيم B المقاسة باستخدام طريقة التطابق كانت عموما اقل من تلك المقاسة بالطريقة المباشرة . ان الانخفاض كان بمدى من 3.4% -8.3% لنماذج مدعمة بنسب مختلفة (10%-50%) من الرصاص . وللتدعيم باستخدام الواح النحاس Cu 30% والواح الحديد Fe 30% كان الأنخفاض 11.7% و53% على التوالي , بينما لحالة التدعيم بألياف النحاس Cu 30% والياف الحديد Fe 30% كان الانخفاض 2.5% و5.9% على التوالي . ان النقصان في قيم B يشابه النقصان في قيم معامل التوهين المقاسة من قبل باحثين اخرين باستعمال تقنية التطابق .

كلمات مفتاحية : تقنية التطابق، عامل التراكم ،اشعة كاما ،مادة متراكبة .