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COMPARISON OF GAMMA SOURCES (COBALT AND CESIUM) FOR DENSITY MEASUREMENT OF METALS AND ALLOYS VIA USING TRANSMISSION TECHNIQUE

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Abstract

One of the solutions for density measurement is to make use of gamma-ray transmission technique. We studied by this technique, using by Co-60 and Cs-137. Each source, without materials in geometry, was counted and noted intensities as (I0). All materials were counted and noted intensities as (I). [I/I0] rates were calculated. Now, density of materials could be determined via using Beer-Lambert Equation. Experimental application was performed on industrial metals or metal alloys like lead&copper and steel&brass. Given densities and obtained densities were compared. Differences or deviations for lead, stell copper and brass are -5.07; 0.26; 1.11; -5.73 (Co-60) and 1.07; 3.08; -0.22; 2.34 (Cs-137) consequently. It could be said that, these differences are still in acceptable limits.

Keywords: Co-60/Cs-137, density measurement, metal/alloy, gamma-transmission technique, nuclear applications, nuclear technique

1. Introduction

Since the end of XX century, nuclear techniques are used more frequently for many industrial materials and also applications. The main reason of this status, is applicable for a lot of products without contact, giving detailed information about inside of material, existing in Non-destructive methods, sometimes unprecedented ([1]). Nuclear techniques are especially used for density and thickness measurement, viscosity measurements, material analysis and also corrosion determination ([2]). Especially, there are two types of radiation used for these techniques as X-ray and Gamma ray. X-ray tubes are suitable for stable applications; Gamma sources are convenient for portable applications and also in laboratory, too. In this study, Co-60 (has two gamma peaks: 1.17 and 1.33 MeV) and Cs-137 (has one gamma peak: 0.662 Mev) Distinguished Radionuclides were selected for comparing and the main target is to obtain the

Sensitivity of these sources. Its outstanding specification is to be applicable without any connection to material. That's -superiority- of this technique, too.

2. Theory: Gamma-ray transmission technique, *Density measurement

Whenever gamma-ray interacts to material, energy will be decreases regarding absorbance effect. Attenuation coefficient and absorption are important to understand (LET) linear energy transfer. Some portion of energy will be absorbed by material. Decreasing energy of gamma-ray is seemed as exponential (Eq. 1). Nearby, if gamma-ray doesn't loss whole energy, it will be pass through the material and reach to the detector which represents transmission technique. Regarding this technique, theory and equation details had been referred to book ([3]), too. By transmission technique, it is possible to measure both *density and also thickness. In this study, regarding density measurement; the equation will be given here (Eq. 2). Besides, there are a lot of studies, related gamma ray transmission technique ([4-8]) were referred in literature. In order to analysis this technique, the main focusing is to follow up the intensities which correlated to activity of source, as I0 and I consequently. Another subject is the true geometry of measurement as source and detector would be settled the opposite sides of material. Figure 1 indicates this geometry and Gamma-ray peak was clearly shown in Figure 2 [9].

$$I = I_0 \,[exp\,(-\mu x)] \tag{1}$$

where μ linear absorption coefficient of material, x material thickness [1] and $\mu_m = \mu/\rho$ here, μ_m is mass absorption coefficient [2]. By using the ratio (I/I_0), density calculation could be possible ([10]):

$$\rho = -[(1/(x\mu_m)]\ln[I/I_0] \tag{2}$$

where, ρ is density, x is thickness and μ_m is mass absorption coefficient.

3. Sources, materials and radiation measurement instrument

Gamma-ray sources, alloys and metals, are written here consequently. Co- 60 (its average energy is 1.25 MeV) and Cs-137 (its 662keV peak), Ordinary materials as steel and brass, copper and lead samples are prepared as commonly 0.32 cm thickness. Cobalt and Cesium sources are accessible and distinguished for a lot of applications ([11]). Half lives are 5.27 years and 29 years for Cobalt and Cesium consequently. Sources and materials were shown in Figure 3. In this study, Nucleus brand detector was used. It is Thallium doped: NaI crystal, scintillation detector. Also, Canberra brand analyzer (consist of Electronic circuits and devices) was used to image the peak intensities for each energy level. Instruments were shown in Figure 4.

4. Results

All counts were repeated three times and got the average of them. Standard deviations were also calculated. Relative count rates were obtained by means of measuring the radiation which arrived to detector after passed through the sample material. All these data were given in Table 1. Another table numbered 2 was also shown the obtained densities which were calculated by equation 1. Now it is possible to compare between Obtained Densities and Given Densities by checking values in Table 2. All steps were also applied for another source Cs-137. Relative count rates were written in Table 3 and densities were given in Table 4 ([12]).

There are acceptable differences obtained between the measured densities and given densities of them. In hence, the minimum difference was obtained as 0.26% (up) for steel and the maximum difference was obtained as 5.73% (down) for brass while source was Co-60. Other hand, the minimum difference is obtained as 0.22% (down) for copper and the maximum difference is obtained as 3.08% (up) for steel while source was Cs-137. These differencies are shown in Table 5. Then, schematic diagram was drawn in Figure 5.

5. Comparison and conclusion

Minimum difference was obtained as 0.26% and 1.11% up for steel and copper, near by 5.07% and 5.73% down for lead and brass (source: Co-60). Minimum difference was obtained as 0.22% down for copper, near by 1.07%, 2.34% and 3.08% up for lead, brass and steel respectively (source: Cs-137). Tolerable Differency limits change regarding the subdivisions of industry. For example; these limits are not same for (Aerospace and Nuclear) Industry regarding to for others. Generally, limit is around 10% for normal Manufacturing industry (and nowadays it runs to lower percents). By the way, for Aerospace and Nuclear industry; 10 or 5 percent is unacceptable. In this study, Gamma Transmission Technique is checked one more time and seen that, results as generally; differency is limited to under 6%. In this study, Gamma Transmission Technique was checked one time more and generally as results; differency is limited to under 6% (Source: Co-60; maximum 5.07 and 5.73 for lead and brass). Finally, it could be said that, this method is reliable for material density measurements especially for industrial manufacturings. This study would be also a baseline for related future works, for example; same technique via using different gamma-ray source, and/or analysing by different materials, too. Finally, for Co-60; although lead and brass, it is realized that; this technique is the more sensitive for steel and copper. For Cs-137; this technique is the more sensitive for lead and copper.

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5. Figures

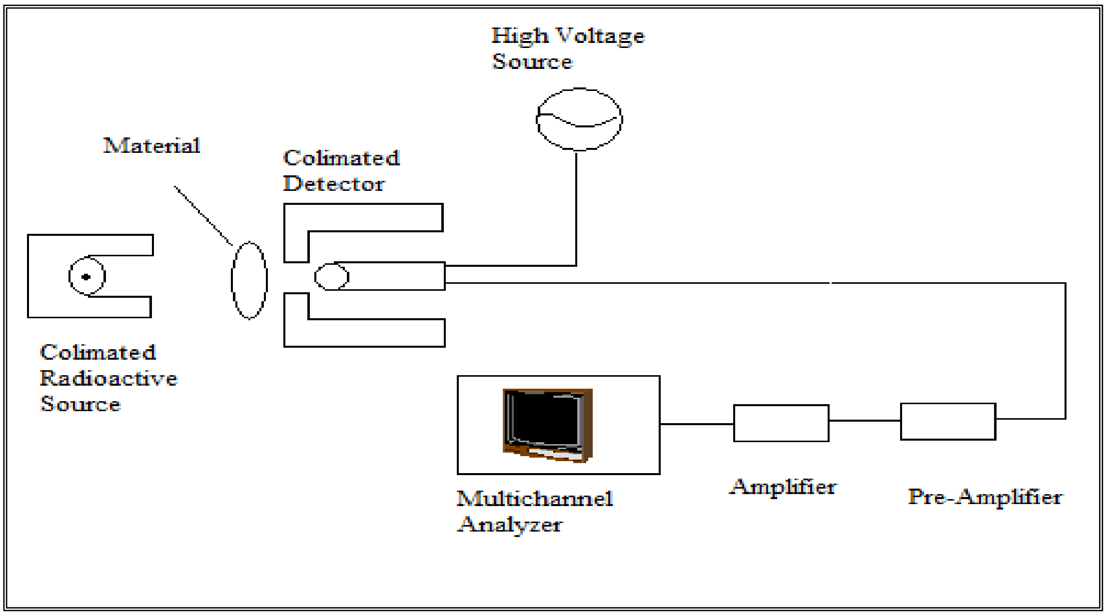

Figure 1. Gamma Transmission Technique Principle Schema

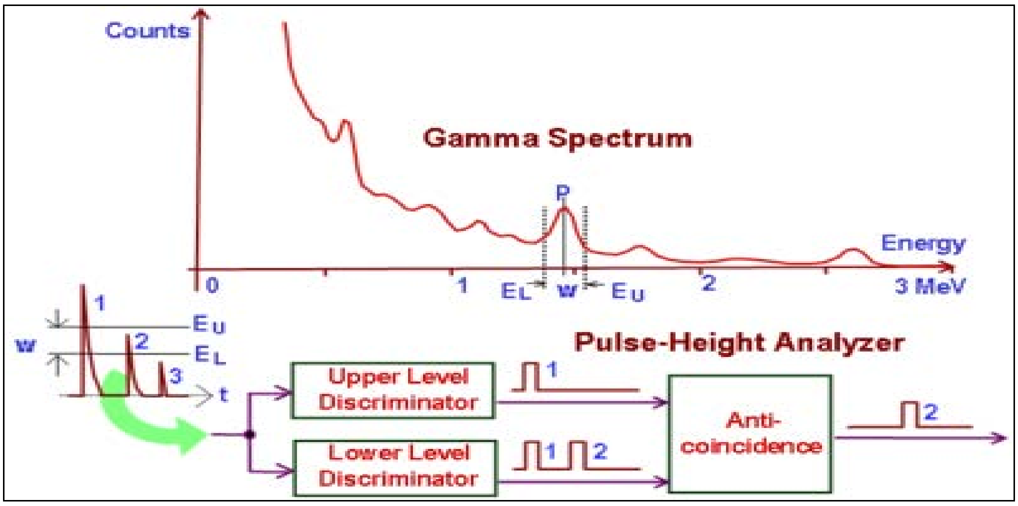

Figure 2. Spectrogram which taken by Scintillation detector system [7].

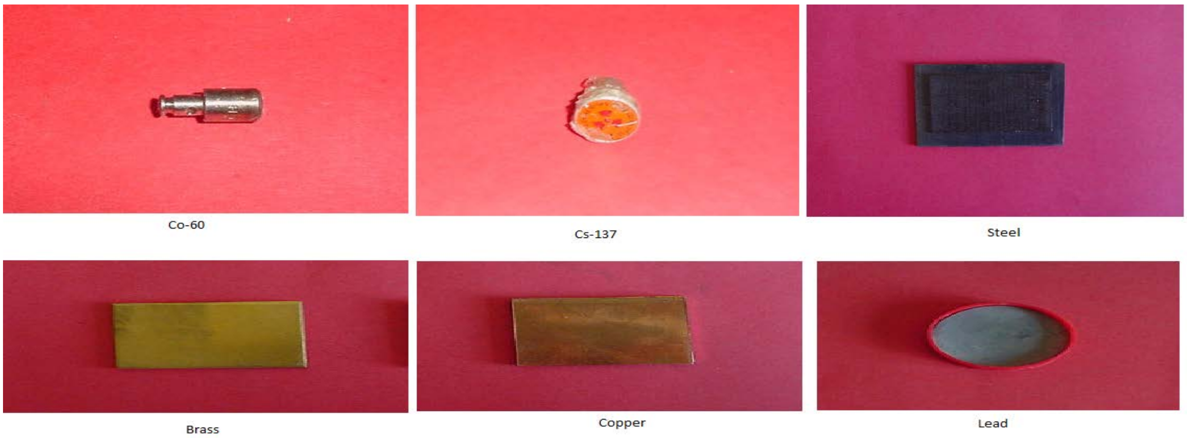

Figure 3. Sources and materials

Figure 4. NaI (TI) Scintillation Detector and Multichannel Analyzer (MCA)

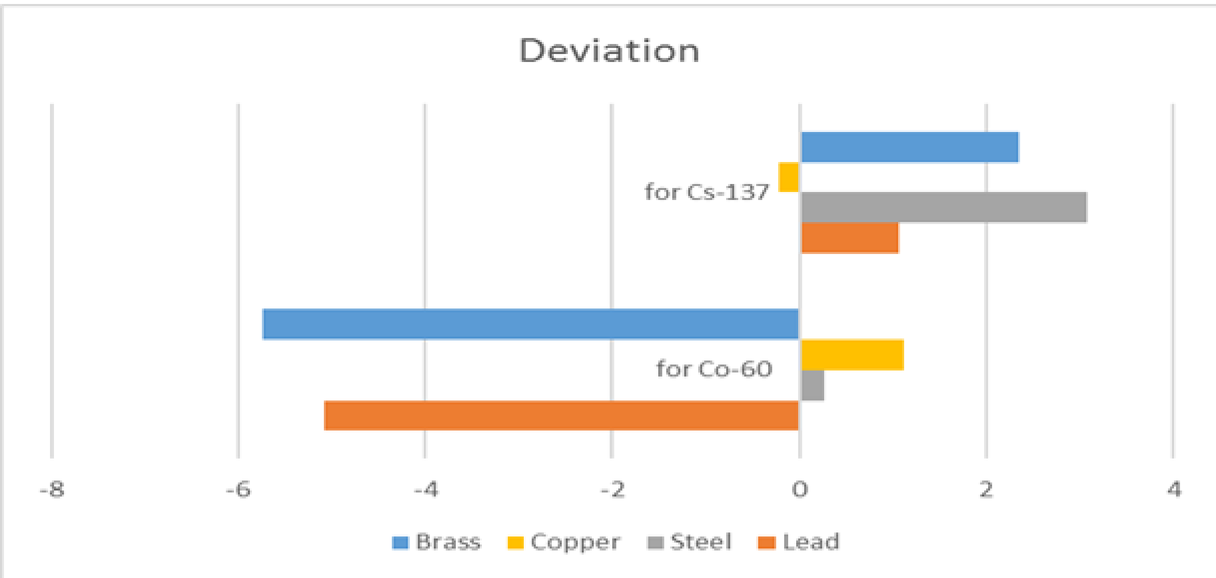

Figure 5. Differency grafic (Deviation %)

6. Tables

Table 1. Count Rates for different samples, counted by Co-60 source.

Nm	Sample	Count (I_0)	Average (Triple/3) Net Count (I)	Standart Deviation	**Relative Count Rate (I/I_0)**
1	Lead	7861±89	6375	69.59	**0.811**
2	Steel	7861±89	6864	25.16	**0.873**
3	Copper	7815±88	6693	74.01	**0.856**
4	Brass	7861±89	6869	17.93	**0.874**

Table 2. Obtained densities by Equation 1 (source: Co-60)

Sample	Thickness (cm)	μ_m (cm^2/g)	Relative Count Rate (I/I_0)	**Obtained Density (g/cm^3) by using [Eq.1]**	Given Density (g/cm^3)
Lead	0.32	0.0613	0.811	**10.68**	11.25
Steel	0.32	0.0544	0.873	**7.82**	7.80
Copper	0.32	0.0534	0.856	**9.10**	9.00
Brass	0.30	0.0535	0.874	**8.39**	8.90

Table 3. Count Rates for different samples, counted by Cs-137 source.

Nm	Sample	Count (I_0)	Average (Triple/3) Net Count (I)	Standart Deviation	**Relative Count Rate (I/I_0)**
1	Lead	6595±81	4427	32.57	**0.671**
2	Steel	6463±80	5344	67.34	**0.827**
3	Copper	6251±79	5069	00.71	**0.811**
4	Brass	6370±80	5216	59.01	**0.819**

Table 4. Obtained densities by Equation (2) (source: Cs-137)

Sample	Thickness (cm)	μ_m (cm^2/g)	Relative Count Rate (I/I_0)	**Obtained Density (g/cm^3) by using [Eq.1]**	Given Density (g/cm^3)
Lead	0.32	0.0613	0.671	**11.37**	11.25
Steel	0.32	0.0544	0.827	**8.04**	7.80
Copper	0.32	0.0534	0.811	**8.98**	9.00
Brass	0.30	0.0535	0.819	**9.11**	8.90

Table 5. Analysis for Differencies of sample densities.

Sample	Density (g/cm^3)			Differency (%)	
	Obtained by Co-60	*Obtained by Cs-137*	*Given*	*for Co-60*	*for Cs-137*
Lead	10,68	11,37	11,25	**-5,07**	**1,07**
Steel	7,82	8,04	7,8	**0,26**	**3,08**
Copper	9,1	8,98	9	**1,11**	**-0,22**
Brass	8,39	9,11	8,9	**-5,73**	**2,34**

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