DETERMINATION OF THE ABSORBED DOSE AT THE ^{60}Co PANORAMIC IRRADIATION FACILITY WITH DIFFERENT DOSIMETRY SYSTEMS

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ABSTRACT

Doses at ^{60}Co gamma ray irradiation facilities are usually determined with secondary dosimetry systems for quality control of irradiation processes. This work shows the results of several materials used in dose determination. Fricke solution, IAEA-IDAS alanine, radiochromic films, thermoluminescent (TLD) pellets and an ionization chamber were located at the same irradiation point in a gamma panoramic device. A comparison of all results was made along with the M-Shield computational software data that is also used to determine approximate dose values in shielding evaluations. Slight differences were observed among the results in spite of some dose meter calibration that was made with different ^{60}Co gamma sources.

Key words: gamma dosimetry, alanine, ionization chamber, Fricke solution, CTA film, FWT film, $CaSO_4$:Dy pellets, LiF:Mg,Ti pellets.

I. INTRODUCTION

An irradiation ^{60}Co panoramic source device was installed at Coordenadoria de Aplicações na Engenharia e na Indústria, in the late seventies. This irradiationa facility is used for several applications and basically gives the support to all researchers that are studying new materials as well as used to irradiate different kind of materials of users of the industry or other institutions. In 1991 the ^{60}Co source was recharged and new calibrations were necessary at that time. Presently, the activity is lower than the half of the initial value. Calibrations are performed yearly.

Questions are: In a specific gamma field, different dosimetry systems, located at the same fixed irradiation position, have the same dose rate values? Which material, among those used, is more sensitive and practical to be applied in industrial irradiation processes?

The aim of this work is to answer these questions that are frequently made by irradiation devices users, technicians or new incoming researchers.

The selection of dosimeters based on the most important factors such as precision, accuracy, stability during storage and ruggedness, is not easy. Especially if a systematic calibration and testing programme of evaluation is necessary to establish all source of errors and lack of precision of routine dosimetry materials. In some kind of irradiations the lack of precision of the dosimeter lecture could be somewhat great. Could be great but is not less important than that value that is determined when the dose is evaluated for irradiation of a new materials or products that are under a specific research programme or when very low doses are required.

The evaluation was made by using materials as TLD pellets of calcium sulphate produced at IPEN[1] lithium fluoride pellets or plastic materials as cellulose triacetate (CTA) [2,3] and nylon (FWT) films[4] found at the market and calibrated against standards as alanine[5], Fricke solution[6] and ionization chamber[7].

Comparing the obtained data, an analysis was made by a direct comparison and by using an outlying observation also. It is known that the outlying observation can give two kinds of information. The first is, the results are inherent of each dosimetry systems and lay in a random of acceptance values. The second is, there is the dispersion from the prescribed value, given by secondary dosimeters. And also by a special service like the International Atomic Energy Agency through its International Dose Assurance Service, IDAS, that certainly should give rise to an investigation that will apprise errors in measurement or in ultimate case the discharge of the method and its response.

It was seen that all commercially available dose meters used in this work have their merits for routine use in industrial irradiations. Ones are more sensitive for very low doses and special applications as TLD materials others for their practical evaluation of doses such as films.

II. IRRADIATION DESIGN

General points. The panoramic ^{60}Co source has presently a source strength of 9.06×10^{13}Bq . The source is a pencil with 20cm high and is mounted inside a shielding housing under a platform located at the centre of the irradiation room. The platform is 1.5m x 1.5m and has a hole on its geometrical centre to allow the source to be positioned. The source is elevated up to the platform and down to the shield by an electrical motor controlled from the control room. It is dislocated inside a guide pipe. This pipe, centred on the platform, is made of stainless steel and has a thickness of 8.6mm and contains an aperture (source without shielding – front side) that leads part of the platform area to have different dose rates than form the back side (source shielded by the pipe). Figure 1 shows a view of the device and Figure 2 the cross section of the pipe mounted over the platform.

Samples positioning. Samples can be positioned around the pipe in two main areas on the platform: front and the back sides. Both have different absorbed dose rates. The back area is more adequate to be used because a significant number of samples can be positioned to undergo irradiation. Irradiation can be made at distances varying from 10 to 60cm. The sample are always positioned at the half height of the source, i.e. 10cm, to undergo irradiation. When special materials, as biological or thick products become to be irradiated, a device is used to let the samples rotate around its own axis to allow the uniformity of the dose. In other cases the samples are simply rotate twice (180^0) or four times (90^0) during the whole irradiation time.

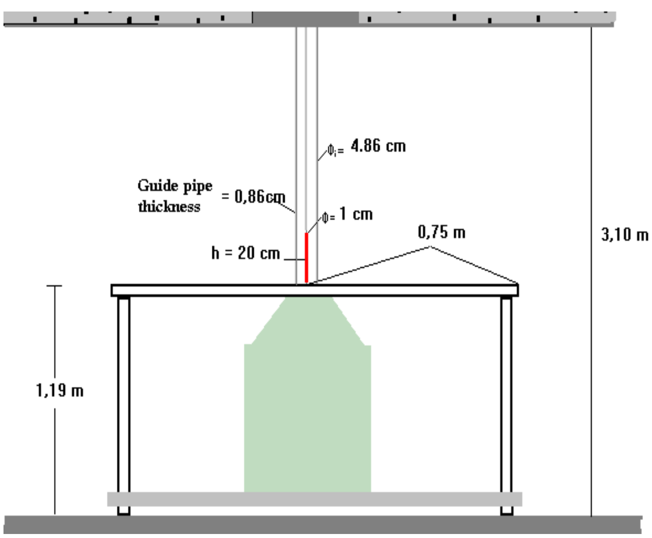
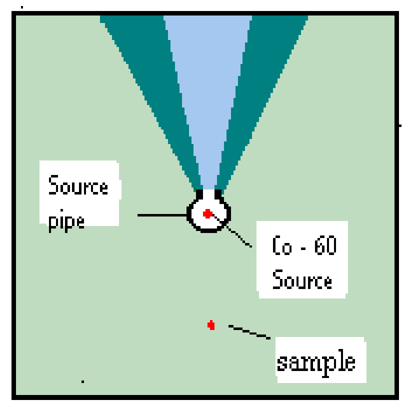


Figure 1. Irradiation device view.

Dosimetry systems tested in this study were positioned for a free-in-air irradiation in the back side and all were irradiated in electronic equilibrium and static form.

Front side



Back side

Figure 2. Cross section of the pipe guide.

III. DOSIMETRY SYSTEMS

Different dose meter systems were used to determine the dose rate at one specific point on the irradiation platform.

Fricke solution. A ferrous sulphate chemical solution, simply denominated Fricke solution, is accepted as a secondary standard dosimeter [1]. The method involves the oxidation of ferrous ions when irradiated. Ferric ions thus produced form a complex with O-Phenantroline hydrochloride and are measured by spectrometry at a wave of 520nm. The useful dose range is between 20 and 400Gy. Care must be taken since the water used to prepare the solution, in this method, is very sensitive for the presence of minerals and organic compounds. The solutions were conditioned inside thin glass ampoules. In this work the Fricke solution was used for mapping the exposure field, to determine the dose rate at the point of interest and calibrate the routine plastic dosimeters.

Reference dosimetry system. Alanine is the reference standard dosimetry system used in this work and was provided by IAEA – IDAS [5]. It was irradiated in electronic equilibrium. The IDAS attested dose rate values.

Ionization chamber. The ionization chamber is classified as primary dosimeter. A Thimble Ionization Chamber from Nuclear Interprises Limited, model 2505/3A, was used to measure the exposition rate in air. The chamber has a volume of $0.6cm^3$ and is covered with a build up cap made of Perspex with a wall thickness of 4.6mm. For dose rate measurements a Farmer 2502/3 model was used. The ionization chamber was also used for calibration of the TLD materials.

Thermoluminescent materials. Crystalline materials as dysprosium doped calcium sulphate, from IPEN, and magnesium-titanium doped lithium fluoride, from the Bicron Co. former Harshaw Co., in pellet form, are used as dosimetry materials. When irradiated, colour centres are produced in the crystal network. The imparted energy is measured by thermal heating of the pellets that emit light of certain intensity depending on the absorbed quantity of energy. The irradiations were made under electronic equilibrium by using a special plastic badge. The approximate useful dose range of these materials are 1µGy-100Gy for calcium sulphate and 10µGy-10Gy for lithium fluoride. The calibration curves were made using other ^{60}Co source, calibrated with the ionization chamber.

Radiochromic films. The films were irradiated under electron equilibrium conditions. For this experiment CTA films and FWT nylon films were used. CTA films are from FUJI Film Co. The CTA films have a width of 8 mm and a thickness of 0.125mm. FWT films are from Far West Technology Inc., type FWT-60.20. They have been bought as sheets of 15cm x 15cm and have a thickness of 0.12mm. The response range of these films is 10Gy-150kGy for FWT and 10-300kGy for CTA.

Dose evaluation. Thermoluminescent response of calcium sulphate and lithium fluorite was measured in a Harshaw-5500 TLD reader, model 5500. The optical absorption of CTA and FWT films as well of the Fricke solution were obtained by using an UV-VIS spectrophotometer from the Shimadzu Co, model UV 1601PC.

IV. RESULTS AND DISCUSSION

All irradiaitons were carried out with the same geometric design, placed at the same height, the same distance from the source and the same ambient conditions. The difference was the irradiation time, since the dose range of each one is not equal. TABLE 1 shows the data calculated for each dosimetry system by using at least three samples for each dose value. Fig.3 shows the graph of these values.

Fricke solution is used to determine the dose rate at irradiation point of interest. IDAS alanine and the ionization chamber were used in order to have calibrated field by primary standards.

Beyond the routine dosimeters the nylon FWT films are sensitive to UV light so care must be taken to avoid light during preparation, irradiation and dose evaluation. TLD pellets and films are very practical for industrial irradiation processes and showed to be accurate, precise and reproducible.

It is well known that in all measurement systems there exist uncertainties. These can be originated in deviations associated with different problems. These can be: calibration of the gamma source, source quality itself, dislocation time of the source in the irradiation position, smooth dislocation of the samples in the irradiation position, calibration of each dosimetry system and so many others.

TABLE 1. Data obtained for different dosimetry systems for a panoramic ^{60}Co source.

Dosimetry system	Dose rate (Gy/min)
Standards	
Alanine (IAEA - IDAS)	2.017 ± 0,01
Ionization chamber	1.919 ± 0,13
Fricke solution	2.020 ± 0,13
Routine dosimeters	
Calcium sulphate ($CaSO_4$:Dy)	2.353 ± 0,09
Lithium fluoride (LiF:Mg,Ti)	2.319 ± 0,04
Cellulose triacetate film (CTA)	1.975 ± 0,14
Nylon film (FWT 60.20)	1.822 ± 0,19
Calculated values	
M-Shield Programme	1.897

It can be seen from TABLE 1 that the standard dosimetry systems used in this evaluation have almost the same response. The agreement between alanine and the ionization chamber is within ±4.8% and between alanine and the Fricke solution is 0.1%.

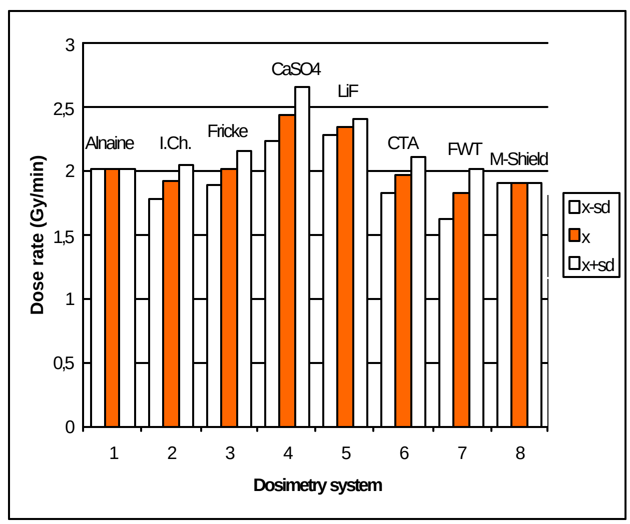


Figure 3. Graph comparison of obtained data for different dosimetry systems.

The mean of the three values for standard systems is 1.985±0.057Gy/min and the mean for the routine dosimeters is 2.117±0.26Gy/min. The percentage difference between these means is 7.2%.

It must be consider that the TLD calibration curve were made by using other ^{60}Co source that was calibrated with the ionization chamber. Applying the correction factor the highest values of the resulting dose rate should be 2.238Gy/min for $CaSO_4$ and 2.206Gy/min for LiF.

The quality of the measurements, made with routine dosimetry systems, can be determined by a normalised deviation D given by:

$$D = (x_i - y) / | s_y / \sqrt{n} |$$

where x_i is the value of each measurement, y the mean, s_y the standard deviation and n the number of considered values. Let consider a certain value x: if the result lays between –2 and +2 is considered good, if lays between -3 and –2 or +2 and +3 is considered acceptable and below –3 or above +3 is unacceptable. This evaluation can be made separately for TLD and films. If the dose rates for TLD and ionization chamber are evaluated the results are to be considered good. Same occurs with the films, alanine and Fricke solution.

V. CONCLUSIONS

It can be stated that standard measurements, as IDAS alanine, Fricke solution and the ionization chamber gave almost very close values. The dispersion observed for routine materials in comparison to the standard systems response can be attributed to different cobalt sources used for calibration curves construction and some other slight deviations. But as a whole it can be consider that all the results, even that obtained with the M-Shield calculation, can be accepted as good. So it is possible to measure dose rates, at the same gamma field and irradiation position, with different routine dosimetry systems when calibrated against a primary or secondary dose rate meters.

So the answers to the questions are:

- In this particular ^{60}Co irradiation facility all mentioned dosimeters can be used and have almost the same response if all are correctly calibrated against the same primary standard;

- All routine dosimeters used in this evaluation are sensitive to the dose ranges depending on each particular response range. All are adequate, but depending on the irradiation temperature and humidity conditions, care must be taken to avoid this kind of influences.

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