SIMULATING ^{60}CO GAMMA IRRADIATION SYSTEMS

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ABSTRACT

The use of Cadgamma, a software dedicated to simulate ^{60}Co gamma irradiation systems, can lead to an optimized process and simulating, in a few hours, many configurations setups for the irradiation elements. The software can also simulate changes in product's path and the influence of any steady body like product's support and source shoulders. These simulations minimize the number of dose mapping tests in industrial applications and allow the study of unusual setups. Cadgamma was developed at IPEN to simulate it's multipurpose ^{60}Co irradiation system, under construction and planned to be operating by the second half of 2001. The software was used on project stage and will help to optimize the irradiation process for each product to be treated.

I. INTRODUCTION

The use of computer programs to simulate industrial processes can improve the overall performance with low cost. The development of a dedicated software to do this job, avoids the need of expensive softwares and allows the software development team to introduce customized features and optimize the results.

Cadgamma[1] was developed at IPEN (Instituto de Pesquisas Energéticas e Nucleares – Energy and Nuclear Research Institute) to simulate it's multipurpose ^{60}Co irradiation system, under construction and planned to be operating by the second half of 2001.

The software was used on project stage and will help to optimize the irradiation process for each product to be treated. It can simulate, in few hours, many position setups for the irradiation elements, or pencils. The software can also simulate changes in product's path and the influence of any steady body, like product's support and source shoulders. These features allows the study of unusual setups and minimize the number of dose mapping tests to optimize the irradiation process.

II. THE SOFTWARE'S FEATURES

General Features. Cadgamma is intended to be used with industrial ^{60}Co, planar sources. Applying the Point Kernel method[2], the software splits the source in pencils and each pencil in many parts. This feature allows the numerical integration of a single pencil and the calculation of doses from non uniform sources. The precision and computation time rate is balanced to get useful information in few minutes. The calculation method and it's simplifications tolerate up to 5 % error in outputs with exact inputs.

Cadgamma can calculate the influence of any steady body inside the irradiation room, like transport trays and source shoulders. It is intended to simulate symmetric and asymmetric irradiation systems.

Operating System**.** Cadgamma was developed in C++ to be used with Windows 95. It is also compatible with newer versions of Windows for PCs. The language adopted is brasilian portuguese. Versions to be used with other O. S. (Operating System) and languages may be created, if required.

Outputs. The calculated dose rates are shown in the calculation window and stored in two ASCII (American Standard Code for Information Interchange) files, one with the irradiation setup data, to be read with any word processor, and the other containing the dose data, tabulated to be read by any commercial worksheet like, Lotus 123, Microsoft Excel and Corel Quattro Pro. The ASCII files can be also analyzed in non Microsoft O. S. like MacOs and Linux.

Customization. The development of Cadgamma was directed make it customizable. It can be used to simulate non standard irradiators and products. The figure 1 shows an example of a product in it's package, with different density blocks. Cadgamma can calculate the dose rate in any of the homogeneous block of the package.

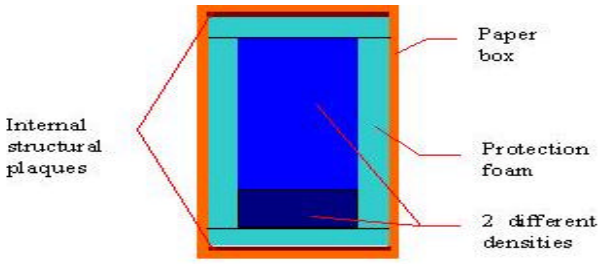

Figure 1.: An export package model with two different materials to be irradiated.

Benchmark. Cadgamma verifies the influence of each pencil in the studied point and the transmission coefficient of any body in the radiation path, like the source shoulders and the irradiated material between the source and that point. Considering these influences, it calculates the mean dose rates of 125 points in a product box, treated on a 25 carriers loaded irradiation room with a 70 active pencils source, in about 360 seconds using an obsolete Pentium 100MHz computer. That means that it performs 218750 pencil to point dose calculations (3125 points in the irradiation room for all the 70 pencils), verifying, for each one, the influence of the 25 batches and all the steady bodies that might be in the irradiation path. With a 450MHz Pentium III desktop computer, the calculation time to get the same results is about 60 seconds.

Limitations. Cadgamma does not has the purpose to replace all the dose mapping tests, but to minimize the number of tests needed to setup an irradiation process.

The software is intended to deal with industrial tolerances on the data input and to accept simplified data, like the material density instead of it's composition. The deviation on the simulation results match most of the industrial measurement systems commonly used to control the quality of an industrial irradiation process. It's precision is enough to get a deep knowledge on the doses distribution.

The Monte Carlo method based applications, like EGS[3] or MCNP[4], and detailed input data should be used to get more precise results, if needed, but it can take too much time to calculate the doses for more than a few points.

III. THE IPEN ^{60}Co IRRADIATION FACILITY

The IPEN is carrying out a multipurpose ^{60}Co irradiation plant. The facility is meant to provide a new tool to the nuclear and others R&D (research and development) community. Unlike the industrial and commercial irradiation plants, were changes in the irradiation process can reduce the profits, the IPEN's facility will lead with very different jobs. It can be used, for example, to develop new applications on food irradiation, on the development of packaging materials, study the limits on biological control for many purposes, like sterilization and disinfestation, and help the development of new material recycling methods.

The IPEN ^{60}Co irradiation plant can also be used as a commercial facility, as a backup for new coming industrial applications or to avoid an industrial process to be fully stopped while the industrial irradiator is under repair.

The shielding and mazes of the irradiation facility are planned to be safely operated with activities up to 37.0 PBq (3.7 x 10^{16} Bq or 1000 kCi) source, but the initial load will be about 10 times lower.

The bunker will be raised near the IPEN's CTR (Centro de Tecnologia das Irradiações – Irradiation Technology Center), were electron beam accelerators are operating. This location was strategically determined in order to share the laboratories and the staff already working with the applications of ionizing radiation.

The irradiation plant is primarily planned to be operating by the second half of 2001.

IV – USING CADGAMMA

Design Stage. The design of the irradiation plant is guided on cost-performance basis and some decisions were made with the Cadgamma simulations data. This computer tool is intended to optimize the irradiation setup, but some parameters, like the costs and availability of the transport system, must be considered in the design of the irradiator. The velocity limits of the product carrier in the IPEN's irradiator were studied with Cadgamma.

Operating Parameters. One of the uses of the simulating software is to optimize the irradiation parameters, like the position of the ^{60}Co pencils and the position of the modules on the source rack. When these parameters are already set, Cadgamma can be used to seek for the best product positioning and to get the maximum and minimum dose rate points. It can also provide the dose rate data for each position in the irradiator.

Changes During Operation. As the software is highly customizable, it can be used to study changes in the product parameters during the process, like loading a different density batches without stopping the former loading.

Studying the Process. Cadgamma can simulate the mean dose rates on hundreds of points in few minutes, with less than 5 % error, and it's results can be used to generate isodosis curves with many graphic generating tools. The figure 2 shows an example of a 3D isodosis curve generated with Microsoft Graph 97. This computer tool can also be used in training courses.

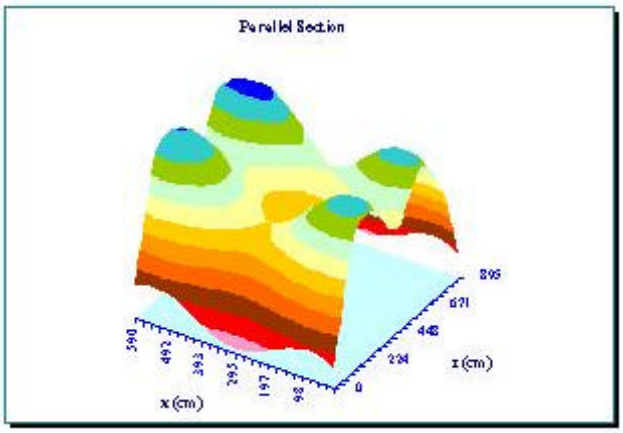

Figure 2: 3D graphic presentation of a case study.

Deeper Knowledge of The Process. The analysis of tabulated output is, often, the better method to compare results from many studied cases. Providing the calculated dose rates for hundreds of points in ASCII tables, Cadgamma can show, for instance, how the positioning a single ^{60}Co pencil can affect the minimum dose point, or

how one thin aluminum plaque can affect the product's dose uniformity.

V – CONCLUSIONS

The use of Cadgamma to set a ^{60}Co irradiation process parameters can significantly reduce the operational cost. It reduces the number of expensive dose mapping tests to optimize the use of pencils with different activities and, if the source rack is already set, to get the irradiation parameters, like the dose uniformity ratio, maximum and minimum dose point and a good approaching for the irradiator timer setting. These parameters should be checked by one dose mapping test because input data carry some tolerances and the software was meant to have, at most, 5 % of deviation on simulation results with exact input data.

To get more exact results, as those get in laboratory measurements, the Monte Carlo method based programs are recommended, but this practice can take several times longer to get the results for detailed dose mapping, and it is of fundamental importance on the design optimization of new irradiation facilities.

VI – REFERENCES

[1] OMI, N. M., SAMPA, M. H. O., RELA, P. R., - **Desenvolvimento de Aplicativo Dedicado à Simulação de Processos de Irradiação Industrial com o uso do ^{60}Co** – *Proceedings on the 2nd. International Radiation Protection Meeting.,* p.70-79, 1999, São Paulo

[2] JAEGER, R. G. - ***Shielding Fundamentals and Methods.*** Berlin Heidelberg New York: Springer-Verlag, 1968. (Engineering Compendium on Irradiation Shielding, v. 1)

[3] NELSON, W.R., HIRAYAMA, H and ROGERS, D.W.O. ***The EGS4 Code System,*** Standford University, 1985.

[4] BRIESMEISTER, J. F., ***About MCNP^{TM}*** [on line], University of California – Los Alamos National Laboratory, 1987 [cited jun. 2000], available from Internet http://www-xdiv.lanl.gov/XCI/PROJECTS/MCNP/about.html