REAL TIME DOSIMETRY MEASUREMENTS AT AN INDUSTRIAL IRRADIATION PLANT

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An electronic real time dosimeter has been developed for use in industrial Co-60 irradiation plants. The system employs an ionisation chamber and thermistor to measure dose rate and temperature respectively. Data from the sensors are processed using an intrinsically radiation resistant electronic system placed in the product carrier. The data are transmitted via a radio link to a receiving station located outside the irradiation cell. The dosimeter has been designed to withstand a total dose of about 5 MGy. The system is described in outline, and dose rate and temperature data from trials in industrial plants presented. Measured dose rate data are compared with those predicted by a numerical model.

Introduction

Dose measurements in industrial Co-60 irradiation plants are typically made using chemical dosimeters such as alanine, dichromate solution or dyed polymers and polymer films. These dosimeters are capable of providing accurate data on the total dose received, but give no information about the how the dose accumulated, or how the dose rate varied with position in the plant. Such data is of potential interest both for the efficient design of irradiators, and also for their subsequent operation. In addition to dose rate, the temperature profile of product passing through a plant is of increasing concern, as the Co-60 loading of plants becomes larger in order to maximise throughput. A number of computer models have been developed to predict dose rate distributions within plants (Mosse et al, 1988; Pina-Villalpando and Sloan, 1995; Raisali, Sohrabpour and Hadjinia, 1990). These models are usually validated by comparing the total doses measured with the summed results from the modelling calculations. Because of the difficulty in using chemical dosimeters to obtain dose rate data in industrial Co-60 irradiators with large numbers of irradiation positions, very few systematic validation studies have been carried out to directly compare these models with the actual dose rates in an operating commercial plant. Temperature variations are potentially even more difficult to model mathematically, and require direct measurement. In this paper we describe an electronic dosimeter system which is intrinsically radiation resistant and is capable of traveling through an irradiation plant in a product box (Sephton and Sharpe, 1998). Dose rate and temperature sensors transmit data in real time via a radio link to a receiver located outside the radiation cell.

The NPL real time dosimeter

The NPL Real Time Dosimeter (RTD) was designed to withstand a total dose of 5 MGy, which severely limited the range of electronic components that could be used (Holmes-Siedle and Adams, 1993; Sharp and Garlick, 1994). The RTD is based largely on miniature thermionic valves (vacuum tubes), although a small number of semiconductor devices, such as discrete transistors and Zener diodes are also used. Some of the semiconductor components used are not able to withstand the total design dose of 5 MGy, but they are easily accessible and can be replaced when necessary. Drifts in the electronic circuits, caused by incident radiation, temperature changes and battery voltage changes, are compensated by interleaving a series of known reference voltage signals in between the signals from the radiation and temperature sensors. The data analysis software uses these reference signals to continuously calibrate the system. Dose rate is measured by a sealed, nitrogen filled ionisation chamber and temperature is measured by a small thermistor probe. The sensitivity of the dose rate scale can be changed by using different load resistors in the ionisation chamber circuit. Full scale ranges from 2 to 250 kGy/hr are achievable. Temperature measurements can be made between -20°C and +70°C. A complete data cycle takes approximately 30 seconds.

The RTD is shown in block diagram form in Figure 1, and a photograph of the transmitter unit, with top cover removed, is shown in Figure 2. DC signals from the voltage references, ionisation chamber and thermistor are cyclically switched to the electrometer by the multiplexer. The output voltage of the electrometer controls the frequency of the low

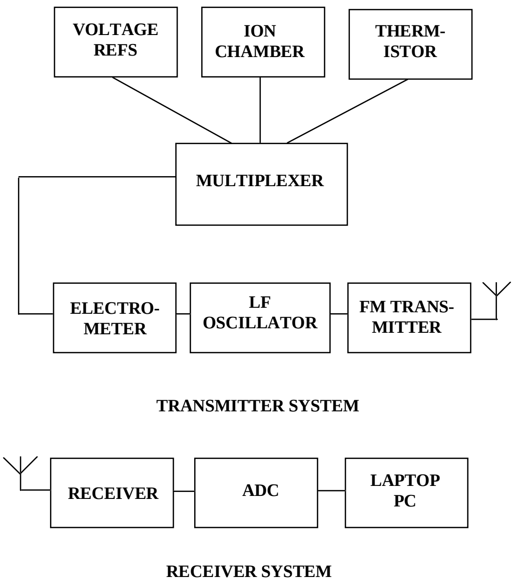

Fig. 1 Block diagram of Real Time Dosimeter System.

frequency (audio) oscillator. The low frequency tone is then transmitted over an FM radio link (27 MHz) to a receiving station outside the irradiation cell - only the receiver antenna is located in the cell. Signals from the radio receiver are digitised by the ADC and fed to a conventional PC. A highly selective ten stage active audio filter is used to enhance signal to noise ratio. The frequency of the transmitted tone is determined by a Fast Fourier Transform routine in the data analysis

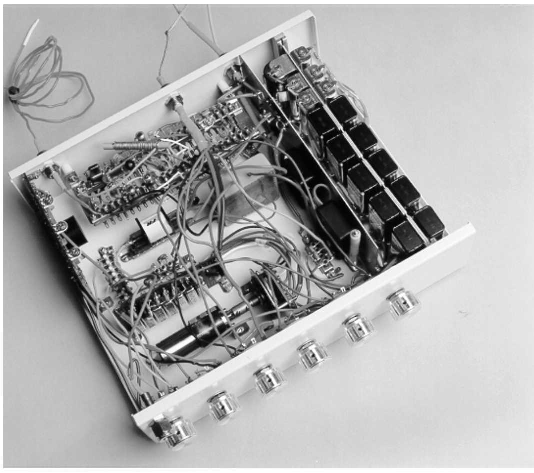

Fig. 2 Photograph of transmitter unit with cover removed.

program. The computer displays the temperature and dose rate in real time and also stores the data for subsequent analysis.

For this work, the ionisation chamber was calibrated in terms of current per unit dose rate by irradiating in a standard irradiation field in a MDS Nordion Gammacell 220 irradiator. The ionisation chamber had steel walls and the response was shown to be significantly influenced by the radiation spectrum. Because of these spectral effects, the uncertainty associated with the dose rate measurements is relatively high and is estimated to be of the order of ±10% (2σ). For the irradiations described in this paper, an alanine reference dosimeter was attached to the ionisation chamber to measure the total delivered dose. Agreement between the integrated ionisation chamber dose and the alanine dose was within 5%. The uncertainty associated with the temperature measurements is estimated to be ±2°C (2σ). An aluminium walled chamber has now been installed, which it is anticipated will reduce these spectral effects and improve accuracy.

Results from measurements at an irradiation plant

The system has been extensively tested at a number of irradiation facilities. Data obtained from a typical irradiation plant are given in

Figures 3 and 4. The plant concerned is a "product overlap" tote box Co-60 irradiator (MDS Nordion JS 7500), each tote making two passes on either side of the source at each of

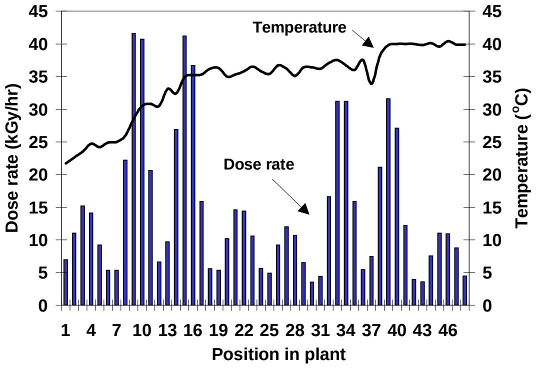

Fig. 3 Dose rate and temperature profiles measured at a MDS Nordion JS 7500 irradiator. Sensors approximately in centre of tote.

two levels. There are 24 positions on each level, the lower level is traversed first.

The data presented in Figure 3 were obtained with the sensors placed approximately in the middle of the tote. The plant dwell timer setting was 181 seconds and the density of product in the plant 0.1 g/cm^3. Over the cycle, the dose rate varied from 7 to 41 kGy/hr, and the temperature climbed gradually to 40^{o}C. The passage on both sides of the source at two different levels is clearly apparent, the dose rates on the upper level being significantly smaller than those on the lower level. Although the reason for this asymmetry was not confirmed, it may have been caused by the sensitive volume of the probe being somewhat

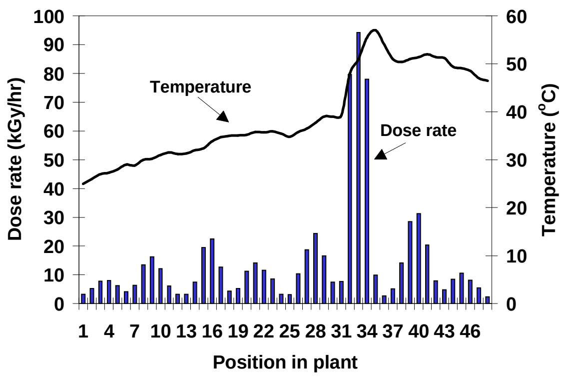

Fig. 4 Dose rate and temperature profiles measured at a MDS Nordion JS 7500 irradiator. Sensors in bottom corner of tote.

offset from the centre. With the sensors placed in a bottom corner of the tote a much more asymmetric pattern was obtained, see Figure 4. The plant dwell timer setting in this case was 165 seconds and the density of product in the plant 0.09 g/cm^3. The dose rate varied from 3 to 94 kGy/hr, and the temperature rose rapidly to 57^{o}C as the sensor passed close to the source on the upper level.

Comparison with computer simulations

One of the most promising potential applications for the RTD is the validation of computer models used to predict dose rate distributions in commercial plants. As an example, we show in Figure 5 a comparison

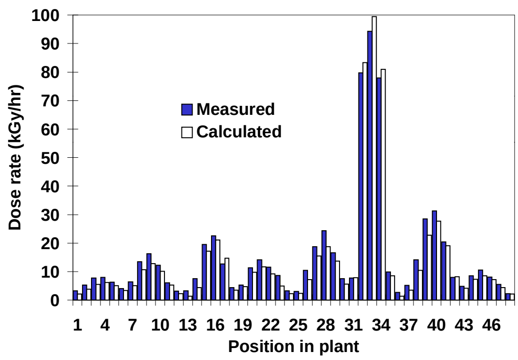

Fig. 5 Comparison of measured and calculated dose rate profiles in a MDS Nordion JS 7500 irradiator. Sensor in bottom corner of tote.

between the RTD measurements of Figure 4 and calculations made using a MDS Nordion computer model.

The MDS Nordion Irradiator Absorbed Dose Modelling Program Version 2.00I used for performing dose rate calculations for comparison with the RTD measurements is a modification of Version 2.00 used by MDS Nordion for modelling the performance of Co-60 irradiators. Version 2.00I provides printouts of the dose rates at each irradiation position while Version 2.00 only provides printouts of the summed doses.

The MDS Nordion Irradiator Absorbed Dose Modelling Program uses the Point Kernel method to model the transport of radiation through matter such as product, source and irradiator components in parallel row industrial irradiators. The code is written in Borland Pascal and runs in a DOS environment on a

Pentium computer. The output includes detailed data tables, including dose distributions and graphic representations of how the irradiator was modeled. The software was validated by comparing the dose calculations for individual C188 industrial Co-60 sources and for several parallel pass MDS Nordion irradiator models.

At the bottom corner of the product tote, the difference between measured and calculated dose rates at the positions of peak dose rate (positions 32, 33 & 34) is approximately 5%, which is within experimental uncertainties. At positions further away from the source, however, there do appear to be systematic differences between measurement and calculation, which require investigation.

Conclusions

A real time dosimeter system for use in industrial irradiation plants has been developed and successfully tested. The dosimeter provides dose rate and temperature data for each location in a commercial irradiator. The information is of direct relevance to the optimisation of plant design and operation, and provides a unique method for the validation of computer simulations.

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