

USING THE SCATTERED RADIATION ENERGY IN EB INSTALLATIONS

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ABSTRACT

Scattered electromagnetic and backscattered electrons ionizing radiation are present outside of the beam-target geometry in direct electron beam treatments and also with the use of X-Ray converters. Most industrial EB applications do not generate neutrons or radioisotopes and the scattered radiation is treated as X-Rays for shielding calculation purposes. This scattered ionizing power has been studied as the radiation to be attenuated by the shielding and mazes. The amount of scattered radiation generated depends mainly on the material being irradiated, beam energy and current and the overall geometry. It is not constant or isotropic and its spectrum is relatively wide but, for industrial applications where irradiation conditions are maintained in narrow ranges, the average scattered radiation behavior can be estimated by previous local measurements. The behavior of the scattered radiation field can be considered chaotic, but may be evened by fluids or fluidized systems and also by fixed exposure places around the target and scan-horn. The use of these EB applications "side effects" may replace some radioisotope and lower dose rates EB applications. For example, based on the NCRP-51, for a 1.5MeV - 60mA accelerator with low-Z target, the estimated X-ray dose rate in sideward direction is higher than from a 75kCi Cobalt-60 source. This work intends to show empirical measurements using cellulose triacetate (CTA) films in a particular geometry, exposed during some hours for each assay to establish the repeatability of the scattered radiation dose averages. An industrial application, which is normally held in almost steady state operating condition, is performed during these measurements as main irradiation. The main objective of this work is to prove that the radiation scattered, mainly from the targets, in industrial electron beam accelerators may be used for other applications where lower dose rates are needed, instead of being simply absorbed by the shielding and mazes.

1. INTRODUCTION

Scattered electromagnetic and backscattering electron ionizing radiation are present outside of the beam-target geometry in direct electron beam (EB) treatments and also with the use of X-Ray converters, near the converter itself. Most industrial EB applications do not generate neutrons or isotope activation and the scattered radiation is treated as X-Rays for shielding purposes.

This scattered ionizing power has been studied as the radiation to be attenuated by the shielding and mazes, or, the radiation to be annulled. The amount of X-Ray and backscattered electrons generated depends mainly on the material being irradiated, beam energy and current and the overall geometry. It is not constant or isotropic and its spectrum is relatively wide but, for industrial applications where irradiation conditions are maintained in narrow ranges, the average scattered radiation behavior can be estimated by previous local measurements.

The behavior of the scattered radiation field can be considered chaotic, but may be evened by fluid or fluidized systems and also by fixed exposure places around the target and scan-horn. Other applications where high doses or high penetration are not desired can be held with the use of proper conveyors.

The use of these EB applications "side effects" may even replace some radioisotope applications. For example, based on the NCRP-51 [1], for a 1.5MeV - 60mA accelerator with low-Z target, the estimated dose rate in sideward direction is higher than from an 80kCi Cobalt-60 source.

The results obtained with the first assays indicated that electron backscattering can also be used. Placed 91.5cm from the beam path, the dosimeters registered dose rates almost one thousand higher than the expected X-Ray dose. This dose rate indicates that the doses due to this scattering behavior can also be used.

This work is intended to show the results of empirical measurements using cellulose triacetate (CTA) films in a particular geometry, exposed during some hours for each assay to establish the repeatability of the scattered radiation dose averages. An industrial application, which is normally held in almost steady state operation, is performed during these measurements as main irradiation.

The main objective of this work is to show that the radiation scattered, mainly from the targets, in industrial electron beam accelerators may be used for other applications where lower dose rates are needed, instead of being simply absorbed by the shielding and mazes. Thus, one of the most referenced publications for shielding calculations was used for the estimates presented [1].

2. MATERIALS AND METHODS

To perform dose rate measurement of the scattered radiation from the electron beam in an industrial process using the Dynamitron JOB 307 - DPC2000 accelerator. The EB accelerator is installed at the Radiation Technology Center (CTR) and it was used in a routine irradiation of the wire insulating layer.

The EB accelerator operational setting for this wire processing was:

- EB Energy: 0.820MeV;
- Operating Current: 36.7mA
- Scan length: 112.0cm
- Scan frequency: 200Hz

The startup takes about 10 minutes from lower current (15.7mA) to the operating condition value. The other parameters are kept unchanged from the start. The under beam dose rate is 186.7 kGy/s (11,202.0 kGy/h) when the operating current is reached.

The dose measurements were made using cellulose triacetate CTA dosimeters placed parallel to the scan horn, as shown in Fig. 1. They were calibrated for doses up to 300kGy.

The distance from the beam scan line to the dosimeters is 91.5cm, the maximum distance available for centered parallel disposition, due to the accelerator installation devices.

The dosimeters were placed side by side along the dosimeters fixing device, with 5cm between dosimeter centers and sequentially numbered. The odd numbered dosimeters were irradiated for 43 minutes and the even numbered dosimeters, for 140 minutes. The figure 1 shows the dosimeter placement

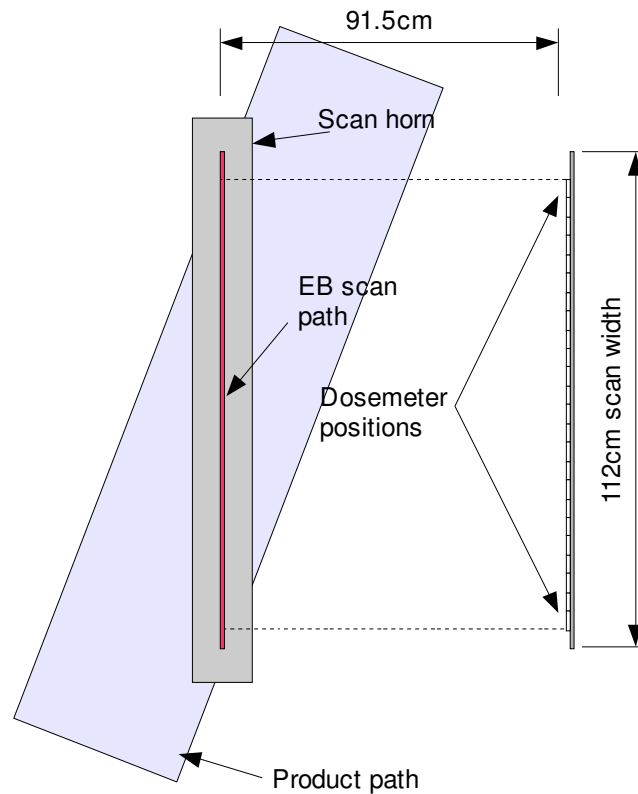


Figure 1. Schematic top view of the dosimeters positions.

The dosimeters were positioned about 5cm lower than the scan-horn window and 20cm higher than the wire insulations on the treatment device.

The system takes about 10 minutes to reach the operating conditions. The EB current rises from 15.7mA to 36.7mA during the process startup and the dose rates rises proportionally. The total dose considered the dose taken during this time.

3. RESULTS

The dose rates obtained on the 20 measured points, 10 for 43' exposition and 10 for 140' exposition, is presented on the Table 1. To obtain these doses, the startup time exposition doses were not subtracted from the total dose.

As long as the CTA dosimeter dose calibration ranged to 300kGy, doses beyond this value must be considered as reference, only.

Table 1: Dose rates measured 91.5cm distant and sideward from EB scan

Time* (minutes)	Point	Total Dose (kGy)	Dose Rate (kGy/min)	Average dose rate (kGy/min)
43	1	119.6	2.78	2.76 ± 0.31
	3	115.2	2.68	
	5	138.7	3.23	
	7	132.2	3.07	
	9	110.4	2.57	
	11	126.6	2.94	
	13	125.3	2.91	
	15	117.8	2.74	
	17	107.6	2.50	
	19	92.1	2.14	
140**	2	368.9	2.64	2.93 ± 0.29
	4	482.4	3.45	
	6	399.9	2.86	
	8	434.7	3.11	
	10	428.1	3.06	
	12	435.9	3.11	
	14	429.4	3.07	
	16	391.9	2.80	
	18	338.0	2.41	
	20	392.5	2.80	

*Irradiation time

**CTA certified calibration ranged up to 300kGy measurement may be considered only as reference.

4. DISCUSSION

The dose rates present in the dosimeter positions are considered very high, if compared to radioisotope irradiation, but very low if compared to the EB dose rate.

The scattered radiation around the EB scan horn window and the irradiated material is composed by X-rays and backscattered electrons.

The average scattered radiation dose rate, measured in this work, is 151.8 ± 18.6 kGy/h.

The X-Ray dose rate and energy may replace some radioactive sources with similar gamma-ray energy with many advantages. Using the NCRP-51 [1] as base for X-ray shielding calculations, we verify that a 820keV electron-beam will generate X-rays with about 600kV of average energy and the dose rate, 1m distant from the source, would be about 165Gy/h, for low-Z targets.

This available dose rate can be generated only by more than 50kCi of ^{137}Cs .

If the operating conditions change to 1.5MeV acceleration and 60mA current, reachable by the EB accelerator, the scattered X-rays would create the 1.08kGy/h at 1m of distance from

the beam target with energy behavior of about 1.0MeV. It can replace about 200kCi of a radioisotope with one 1.0MeV gamma emission per decay. The same dose rate would be obtained by about 80kCi of ⁶⁰Co.

Also, according to the NCRP-51 [1], the fraction of backscattered radiation for 0.820MeV incident electron beam is about 8% in aluminum, with about 0.40MeV of average energy.

Having this energy, the range for these electrons is about 0.15g.cm⁻². In dry air, the estimated range is about 125cm.

Based on these facts, it is expected that more than 98% of the dosimeter absorbed doses are due to a little part of the electron backscattering.

The purpose of this work is to verify that the industrial EB scattered radiation can be used for other applications.

This ionizing power may be used for lower dose rates applications.

Due to the lower average energy of backscattered electrons, the low penetration characteristics can be used for surface irradiation applications development.

The X-rays generated, once the isodose curves are identified, may be used as in a gamma panoramic device with power equivalent to tens of kCi radioactive sources.

There may be some reasons to discard this new feature for EB Accelerators. Some of them are:

- As stated before, the dose rates are not constant they vary with the beam instant position and the under beam material type and geometry;
- The scattered radiation doses are too small, if compared to the main irradiation dose rates;
- The costs of the second material transport devices may be too high.

Analyzing the items above, it's worth to present the following:

- The doses rates really fluctuate along short periods of time. Otherwise, it has a repetitive average behavior that can be adopted for irradiation periods high enough to have many repetition cycles;
- The scattered X-ray radiation doses are very high if compared to some radioisotope irradiation devices, avoiding the need of these isotopes;
- The costs involving a second transport device should be compared to the costs of building a new irradiation system that would perform the same irradiation as the EB scattered radiation.

5. CONCLUSIONS

This work is intended to demonstrate that the presence of the industrial electron beam scattered radiation field can be used for a side application, instead of being simply absorbed by the radiation shielding. The measurement of the dose rates fractions from the scattered X-ray or backscattered electrons depends on each industrial process and was not done for this work. The known industrial applications and the trends on radiation processing for 0.3 up to 10MeV accelerators in Brazil [2] and in other countries can become subjects for many other researches, directed to evaluate the possible use of their scattered radiation power.

Although more than three thousand times smaller than the under beam dose rate, the scattered radiation field can really have many applications and can replace some radioisotope irradiation processes without stopping the main use of the EB accelerator.

As future developments, the applications with the use of this ionizing power can open new research fields, like establishing the dose from backscattered electrons and X-rays from various main applications and the availability to use them in commercial or scientific purposes, specially in places where dealing with radioactive sources are unavailable or forbidden, and where very high dose rates are not desired.

REFERENCES

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