Collider-Accelerator Department

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Memo

Date: *November 23, 2011*

To: *P. Sampson, P. Bergh, and P. Cirnigliaro*

From: *D. Beavis and R. Karol*

Subject: *Estimated Effective Dose Rates from C3 during Testing*

You requested an estimate of the potential effective dose rate from the C3 inflector. Personnel are currently excluded from being inside the Booster enclosure by procedure when the C3 inflector is energized. There is a desire to conduct some low voltage testing in the Booster with experts nearby to examine the conditions of the modified C3 inflector.

The maximum voltage is 80 kV, but the test with the C3 inflector would be done at a lower voltage. The power supply limit is limited to a maximum of 3.5 micro-amps, which is assumed to be voltage independent. The C3 housing is 9.5 mm of stainless steel [1]. There are no optical inspection windows on the device.

Using table 6.9.1 (Attachment 1) from Reference 2, a linear curve fit was obtained in order to extrapolate down to 20 kVp:

$$\text{Effective dose per minute per mA at 1 meter} = -3.9544 + 9.6785 \times 10^{-2}\ (\text{kVp})$$

Converting this to mrem/h per mA at 30 cm:

kVp	mSv/min per mA at 1 meter	mrem/h per mA at 30 cm
20	0.51	3.29×10^{4}
40	0.73	4.71×10^{4}
60	2.06	1.33×10^{5}
70	2.88	1.86×10^{5}
80	3.76	2.43×10^{5}
100	5.64	3.64×10^{5}

Assuming that the current is independent of the voltage yields:

$$(\text{mrem/h at 30 cm}) = (\text{mrem/h per mA at 30 cm at } V \text{ kVp}) \times (\text{mA current})$$

Thus at various voltages with a constant 3.5 micro-amps of electron current would result in the following unshielded effective doses at 30 cm:

kVp	mrem/h at 30 cm
20	115
40	165
60	466
70	651
80	851
100	1274

The C3 inflector has a substantial vacuum box that the x-rays must penetrate. The vacuum box will substantially reduce the x-ray effective dose, especially for the lower voltages. Figure 6.17 (Attachment 2) of Reference 2 plots the transmission of x-rays through steel for a broad beam. Assuming a broad beam instead of a point source adds more conservatism to the computed effective dose.

The broad beam transmission values through 9.5 mm steel and the resulting effective dose rates at 30 cm are summarized below:

kVp	Transmission	Shielded mrem/h at 30 cm
20	~0	~0
40	$<10^{-11}$	~0
60	5×10^{-6}	0.002
70	4×10^{-5}	0.026
80	5×10^{-4}	0.43
100	3×10^{-3}	3.82

It is concluded that with proper work planning that personnel could be inside the Booster enclosure to observe the initial testing of the C3 inflector to full voltage of 80 kVp with no significant risk from x-rays. Radiation measurements should be recorded to provide a baseline of actual conditions for future reference.

Reference:

1. Verbal information from V. Badea.
2. Handbook of Health Physics and Radiological Health, 3rd Edition.

Copy:
T. Curcio
K. Gardner
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RSC
RSC Booster file

Attachment 1

Table 6.9.1 Useful Beam Data for Constant-Potential Generation, GE Maxiray-125B X-Ray Tube (After Fewell *et al.*, 1981)

Potential (kVcp)	Normalized Output (mSv/mA-min at 1 m)	First HVL (mm Al)
70	2.88	2.64
100	5.64	3.77
120	7.62	4.51
140	9.66	5.26

Attachment 2

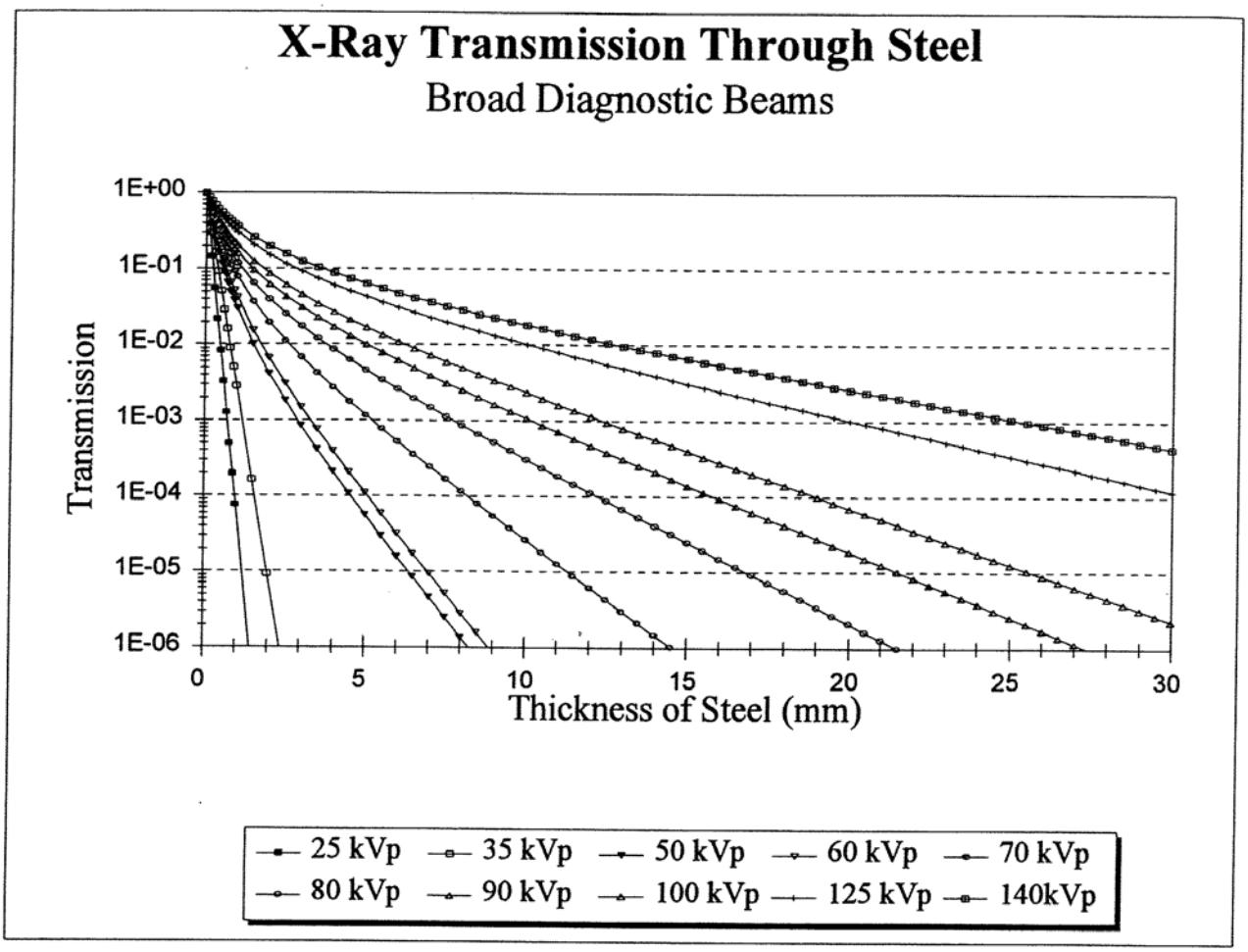

Figure 6.17 Computed Broad-Beam Transmission ($K_{\mu x}$) of Constant-Potential-Generated X-Rays Through Steel.