Further Energy Deposition Measurements

on MINI-C Electron Beam

Observations of the broadening of the X-ray polar diagram from carbon targets irradiated by MINI-C "flat" e-beam indicate that the mean electron angle is of order 15°-20° with respect to the beam axis. (See NRN 7/71, J G Locke and A C Simmons and SSWA/JCM/714/162, D W Forster et al). Similar measurements on the "peaky" (self-pinched) e-beam confirm a mean angle of about 45° as previously found by comparing stacked foil measurements with theory (ZEBRA) (G W sentance, P Fieldhouse and D W Large).

Whereas for the latter situation energy deposition profiles are now well established between 0.8 and 2 MeV - theory (ZEBRA) being used to interpolate between experimental measurements on carbon and tantalum - only a few calculations (but no experimental results) are currently available in the case of flat beams at low mean angles $\lesssim$ 20°.

Table 1 compares the peak energy deposited and fractional energy transmitted by electrons incident at 15 and 45° on carbon. (A depth of 0.3 gm cm^{-2} corresponds roughly to 0.2 cm of carbon or beryllium).

TABLE 1

ETRAN RESULTS FOR CARBON

Peak of Complex Spectrum, MeV	Electron Angle	Peak Deposition cal/gm	Fractional Transmission at Depth gm cm^{-2}		
			0.2	0.3	0.5
0.8	15°	5.1	0.16	0.011	
	45°	6.5	0.09	0.003	
2.0	15°	1.6	0.74		0.30
	45°	2.2	0.57		0.16

Peak depositions are seen to be about 20-30% smaller for the lower angle and transmissions up to a factor of 2 or more greater towards the end of the electron range. Experimentally it is important to know the latter with some precision to correct for spall losses and the former to evaluate the spall threshold etc. The overall shape is required for shock calculations. Do we therefore rely entirely on calculation (either ZEBRA or ETRAN) to tell us the shape of the flat beam deposition profile - assuming of course we are able to specify the electron energy spectrum and angular distribution - or should we attempt some experimental measurements as well. At high fluence levels causing target blow-up we have no choice of course and only the former would be available to us.

Our initial calculations indicate that there is little difference between the profiles for 0° and 20° electrons and so a knowledge of the precise angular distribution is not essential and it should suffice to specify a single mean angle (ZEBRA, however, has recently been modified and will now accept any chosen angular distribution, should this be deemed necessary). In contrast, the profile shape does appear to be rather sensitive to the energy spectrum, particular to the lower energies below a few hundred keV where the errors of measurement (by V and I unfolding) are likely to be greatest and where prepulse may have a significant effect.

It would therefore seem both sensible and necessary to carry out a few experimental spot checks to establish the reliability of the theoretically predicted deposition profiles; these would also of course at the same time check MINI-C repeatibility. Some proposed experiments are detailed in Table 2. Carbon and tantalum are selected as being convenient materials to compare with existing calculations and previous work; a few measurements on beryllium, although not essential, have been included because of its present importance and because of the increased dependence of deposition on atomic number below carbon ($Z = 6$). It is proposed that shots on carbon (being an optimum low Z material for the purpose) should incorporate an array of TLDs to measure the X-ray angular distribution and hence give an indication of the mean electron angle and on-axis dose simultaneous to the deposition measurement.

Excluding beryllium, which would require a separate short run of its own, I estimate, conservatively, that a total period of about 1 to 2 weeks of machine time will be required to complete the experimental programme outlined in Table 2. None of the foils and slabs ought to seriously spall, with perhaps the exception of Ta at the higher energies, and so shot to shot speed will be mainly governed by cathode/anode replacement.

In the meantime a limited number of ZEBRA deposition calculations are being run for Be, C and W and for electron angles of 0° and 20° and energies between 0.8 and 4 MeV.* For the latter the same complex energy spectra as determined previously for the peaky beam are being used as a temporary expedient until we are able to devise a means of satisfactorily measuring total beam current close to the target under near fully neutralised drift conditions. Since the deposition variation between 0° and 20° is small and, further, since the mean electron angle in the drifted beam is unlikely to exceed 20°, the two angles chosen should be adequate for future interpolations and comparisons with experiments. Results of the above calculations should be available shortly and information on these (and all previous calculations) may be obtained from either myself, D W Large or G W Sentance.

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* The calculations at low energies are also probably applicable to SPLATTLET and IT and at high energies to EROS.

TABLE 2

PROPOSED DEPOSITION EXPERIMENTS ON MINI-C FLAT BEAM

Material	Marx Voltage kV	Peak Electron Energy MeV	Number of Shots	Cone	Press. τ	Exten. inches	Slab Thickness cm		Experiment
							front	rear	
C	30	0.7-0.9	2*	10°		-	-	-	Stacked Foils ⸗
	45	1.3-1.5	2*	10°		-	-	-	"
	55	1.6-1.8	2*?	10°		-	-	-	"
	45	1.3-1.5	2*	10°		2"(P)	-	-	"
	45	1.3-1.5	2*	20°		-	-	-	"
Ta	30	0.7-0.9	2	10°		-	-	-	"
	45	1.3-1.5	2	10°		-	-	-	"
Be ø	30	0.7-0.9	2	10°		-	-	-	"
	45	1.3-1.5	2	10°		-	-	-	"
	45	1.3-1.5	2	10°		2"(P)	-	-	"
C	30	0.7-0.9	2*	10°		-	0.05	0.6	2-slab #
			2*	10°		-	0.10	0.6	"
			2*	10°		-	0.15	0.6	"
	45	1.3-1.5	2*	10°		-	0.05	0.6	"
			2*	10°		-	0.10	0.6	"
			2*	10°		-	0.20	0.6	"
			2*	10°		2"(P)	0.20	0.6	"
Be ø	45	1.3-1.5	2	10°		-	0.05	0.6	"
			2	10°		-	0.10	0.6	"
			2	10°		-	0.20	0.6	"

* These shots to incorporate several TLDs to measure the X-ray angular distribution.

P = photographic position.

⸗ Stacked foil arrangement is the same as used previously.

\# 2 slab geometry comprises a thin slab (facing e-beam) mounted in front of a thick slab and spaced from it using about 1 mm of graphite felt to provide thermal and shock isolation; both slabs are monitored with thermocouples and mounted inside a graphite guard-ring as usual

ø Use, if possible, porous material ($\gtrsim 10\%$) to minimise spalling.