Use of the Radiation Budget Concept at Jefferson Lab

The Thomas Jefferson National Accelerator Facility (commonly referred to as Jefferson Lab) is located on a small footprint within the Newport News, Virginia community. JLab has a requirement to maintain the radiation dose at the site boundary to less than 10 mrem per year to the maximally exposed individual due to accelerator operations. As this number is small in light of the currents and energies run in the Continuous Electron Beam Accelerator Facility (up to 200 microAmps and up to 6 GeV, with a technical capability to exceed this boundary dose limitation), considerable effort is put forth in the shielding and scheduling of specific experiments, such that the site boundary dose limit is not exceeded. One tool that Jefferson Lab has developed to streamline and manage this process is the concept of "radiation budgeting."

The radiation boundary dose of each proposed experiment is estimated in advance using the running condition parameters of the experiment such as beam energy and current, materials and geometries of the beam-line setup, and duration of the experiment. This estimate serves as an experiment specific "radiation budget". If the estimated combined dose at the JLab boundary significantly exceeds 10 mrem per calendar year, then shielding must be improved, experimental run conditions must be changed, or the experiment schedule must be rearranged.

The calculation methods include the analytical approach, which is used for the standard experiment configurations, and the more detailed Monte Carlo simulation approach, which is needed when the experiment configuration is far from standard. The standard analytical models of the halls include different experimental targets and radiators positioned close to the center of the hall, and the standardized beam line components. It is implemented in the computer code ELEC5b, which takes into account the processes of electron scattering as well as electron and photoneutron production in the experimental targets and beamline equipment in the experimental hall, shielding attenuation in the roof, and neutron skyshine radiation which is the main source of the dose at the site boundary. This method is inevitably simplistic but shows very good qualitative and reasonable quantitative (within +/-50%) agreement with the measured doses. The main advantages of this method as compared with the detailed Monte Carlo simulations of the experimental halls, targets and beamline structures, are that it does not require large computational resources, and the results are formatted into an easy to read EXCEL spreadsheet format. It has been implemented as a FORTRAN code and used in the dose calculations for the majority of experiments run from 1996 until the present time. Several "non-standard" experiments during this time period required the Monte Carlo simulation method to be implemented to evaluate their contribution to the radiation budget. The reasonably detailed models of the experimental setups were developed, and the GEANT Monte Carlo program was used, modified specifically to be able to reproduce neutron production in the GeV-energy-range electron and photon interactions with materials and structures. The two methods were crosschecked, compared with each other and with the measured data, and showed good agreement when applied to standard setups.

The results of the radiation budget evaluations, when an experiment configuration has been finalized and approved for running, are included in an experiment-specific Radiation Safety Analysis Document (RSAD), which is required safety documentation prior to commencement of an experiment. The Jefferson Lab Radiation Control Department continuously monitors boundary radiation dose, and issues semiannual reports that analyze the current radiation budget status. In the event that the 10 mrem site boundary dose may be exceeded based on budget estimates, and actual site boundary dose measured, senior laboratory management is engaged in altering the experimental schedule.

An example of a radiation budget form, and a comparison of site boundary dose estimated versus actual site boundary dose measured are attached.

For more information, please contact:

Erik Abkemeier
Jefferson Laboratory RadCon Manager
Phone: 757-269-7551
Email: abkemeie@jlab.org

.

Hall: C

RADIATION BUDGET FORM

Exp. # E00-006 rev: A run dates: 2003-2004 name of liaison:

setup number			1	2	3	4	5	6	7	
beam	energy	GeV	3.026	3.026	3.026	3.026	3.026	3.026	3.026	*totals:*
	current	uA(CW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	
expt target	element		H	Al	Al	H	W	H	Fe	
	thickness	mg/cm2	1420	1	1	1420	164	35	3	
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Z		1	13	13	1	74	1	26	
	A		1	27	27	1	184	1	56	
add'l target 1	element		He		Cu	He	Al	He		
	thickness	mg/cm2	67		1	67	202	67		
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Z		2	0	29	2	13	2	0	
	A		4	0	64	4	27	4	0	
cryo tgt window	element		Al			Al		Al		
	thickness	mg/cm2	124			327		124		
	dist. to pivot	m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Z		13	0	0	13	0	13	0	
	A		27	0	0	27	0	27	0	
critical window	radius	cm	30.5	30.5	30.5	30.5	30.5	30.5	2	
	dist. to pivot	m	10.00	10.00	10.00	10.00	10.00	10.00	18.00	
scattering weighting factor			0.50	0.50	0.50	0.50	0.50	0.50	1.00	
time	run time (100% eff.)	hours	1056	12	12	12	228	12	36	1368
		days	44.0	0.5	0.5	0.5	9.5	0.5	1.5	57.0
	installation time	hours								0
		days	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dose rate at the fence post (run time)	method 1	urem/hr	0.81	0.00	0.00	1.31	0.72	0.25	1.36	
	method 2	urem/hr								
	conservative	urem/hr	0.81	0.00	0.00	1.31	0.72	0.25	1.36	
dose per setup		urem	855.9	0.0	0.0	15.7	165.3	3.0	48.9	1088.7
% of annual dose budget		%	8.559	0.000	0.000	0.157	1.653	0.030	0.489	10.887
% of allowed dose for the total time										69.718
% of allowed dose for the run time only										69.718

If > 200%, discuss result with Physics Research EH&S officer

date form issued: October 13, 2003 *authors:*

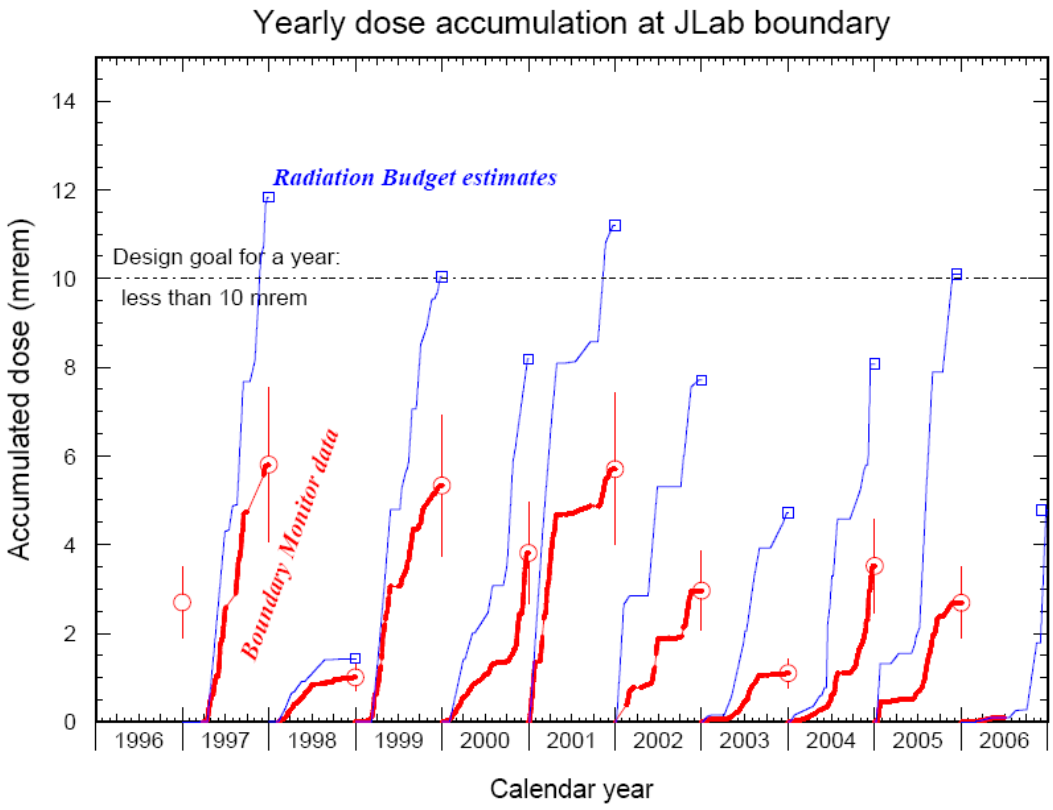

Fig.1 Yearly boundary dose accumulation due to Continuous Electron Beam Accelerator Facility (CEBAF) operations for the period starting in 1996 through the first two quarters of 2006. Open circles show the measured dose accumulated during each calendar year. Error bars indicate 30% estimated systematic error of the measured value. Thick solid lines show accumulation of the dose as a function of time in the corresponding year. Thin-line gaps between thick portions of the lines indicate that only integral dose measurement data were available. No differential data is given for 1996. Thin solid lines ending with open squares show the integral estimated boundary dose produced by all experiments planned to run in the corresponding year. Every estimate is made before the actual run time. Dash-dotted line illustrates the design goal not to exceed 10 mrem yearly dose accumulation at the boundary.