Title

RADIATION CONTROL AT THE CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF), A NEW HIGH POWER CW ELECTRON ACCELERATOR INSTALLATION

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Publication Date

1989-02-01

LBL-26821 c.2

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OCCUPATIONAL HEALTH DIVISION

To be presented at the 4th International Symposium
for the Society of Radiological Protection,
Malvern, England, June 4–9, 1989, and
to be published in the Proceedings

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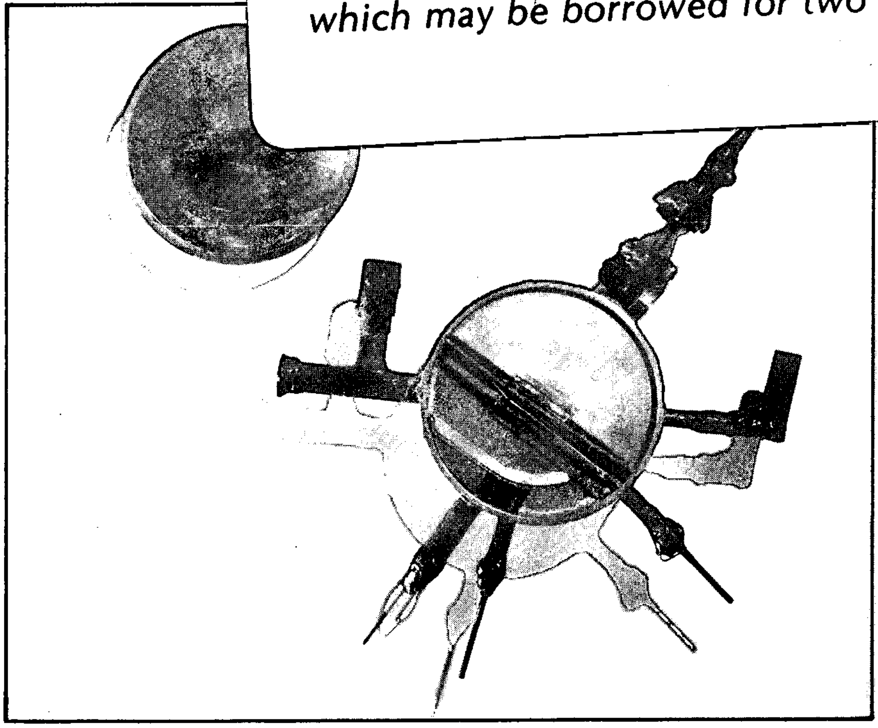

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

DISCLAIMER

LBL-26821

Radiation Control at the Continuous Electron Beam Accelerator Facility (CEBAF), a New High Power CW Electron Accelerator Installation

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ABSTRACT

A description is given of the design goals and radiation control measures, for a new 4 GeV, 1 MW electron accelerator under construction in the USA. The paper illustrates the importance of cooperation between designers and regulators.

INTRODUCTION

The need for a high duty factor, high-energy, and high-current electron accelerator to explore the nucleus and in particular its quark structure has been recognized for more than a decade (NSA79). Such a facility, not available anywhere else in the world, is at present under construction by the Southeastern Universities Research Association (SURA) on behalf of the US Department of Energy (DOE) at Newport News, Virginia. A brief history of the project and a summary of the design features may be found in (CEB86). This paper discusses environmental radiological control measures.[3]

ENVIRONMENTAL CONSEQUENCES

There are four pathways for exposure to the public from accelerator operation which, in order of importance, are:

- The production of "prompt" radiation during accelerator operation
- The production of radionuclides and noxious chemicals in the air in the accelerator vault and their subsequent release
- The production of radionuclides in the soil and groundwater near the accelerator with their possible migration to water supplies
- Induced activity in machine components which may subsequently be recycled into the general environment.

The contribution to population dose equivalent by airborne radionuclides is at least an order of magnitude lower than that from prompt radiation. No significant population exposure is expected from the remaining two pathways (Tho79, Goe87). However, generalizations based on the body of scientific knowledge do not suffice to demonstrate to regulators that accelerators may conform to standards and regulations intended to control the siting and operation of facilities with a far greater potential for harm than can result from research accelerators.

REGULATING AGENCIES AND STANDARDS

The DOE has the responsibility and authority to ensure that the CEBAF accelerator is operated in a manner that protects public health and safety, but its authority is not pre-eminent. The US Environmental Protection Agency (EPA) has the responsibility to develop guidance on radiological protection for all Federal Agencies, and to implement the Clean Air and Safe Drinking Water Acts (CFR 87a, b, & c). The EPA has limited the annual dose equivalent to the public resulting from radioactive air emissions to 25 mrem and from drinking water to 4 mrem. To implement this latter limit the EPA has set standards for contaminants in drinking water, but it often delegates authority to the separate States. When doing so it requires that a statewide anti-degradation policy be adopted.

The Commonwealth of Virginia has adopted an anti-degradation policy for groundwater (Vir88). Strictly interpreted such a policy requires authorization for any release. Table 1 gives the "groundwater" standards for radioactivity for the Commonwealth of Virginia (Vir88). Table 2 summarizes the dose equivalent limits and action levels for the different exposure pathways which are used to limit environmental exposure from CEBAF operation.

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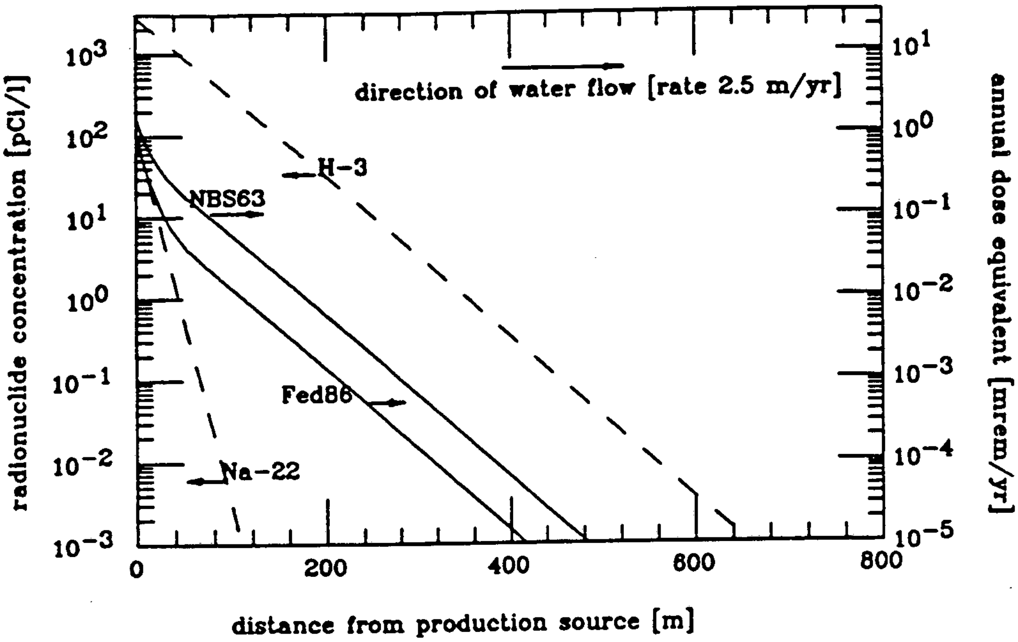
[3] A complete summary of the work described here may be found in (Sta89).

Figure 1: Concentration of H-3 and Na-22 from point of production for unidirectional groundwater flow (left scale) and annual dose equivalent given by the sum of both radionuclides using NBS63 and Fed86 conversions (right scale).



In Figure 1 the initial condition for 1 mrem/yr is based on FED86, which is used in the CEBAF design.

RADIATION CONTROL REQUIREMENTS

To provide a stable foundation the accelerator is being constructed on a geological formation some 25 ft below ground. The resultant overburden provides more than adequate radiation shielding. The experimental halls are partially buried and side shielding can be provided by low-cost berms, but thick roof shielding is needed to limit skyshine. The cost of supporting this thick roof is high. It has been shown that a roof thickness of 1 m of concrete will produce an annual dose rate of less than the design goal of 10 millirem (CEB88).

The beam dumps require modest additional berming to reduce direct radiation but the activation of the surrounding earth and groundwater merits consideration because of the high water table at the site (an average of 7 ft below the ground surface).

Induced activity in the ground and groundwater may be reduced by the use of underground shielding. The most favored solution is concrete poured in place.

Monitoring procedures for prompt radiation, radioactive air, and radionuclides in groundwater are well understood and will be routinely employed at CEBAF.

ESTIMATED COST OF MEETING STANDARDS

It is not feasible to give an overall estimate of radiation protection costs at CEBAF since this encompasses many priorities including the general configuration of the facility. However, it is of interest to see what the excess cost of the thick roofs for the end-stations would be over a conventional roof and likewise the cost of the extra concrete needed to reduce the concentrations of radionuclides in groundwater to meet the standards: project civil engineering costs $\simeq$ \$40 m, excess cost of thick roof shielding $\simeq$ \$0.7 m, and excess cost of concrete for groundwater protection $\simeq$ \$2.3 m.

Table 1

*Radioactivity	
Total Radium (Ra-226 & Ra-228)	5 pCi/l
Radium 226	3 pCi/l
Gross Beta Activity*	50 pCi/l
Gross Alpha Activity (excluding Radon & Uranium)	15 pCi/l
Tritium	20000 pCi/l
Strontium-90	8 pCi/l
Manmade Radioactivity	
– Total Dose Equiv.**	4 mrem/y

* The gross beta value shall be used as a screening value only. If exceeded the water must be analysed to determine the presence and quantity of radionuclides to determine compliance with the tritium, strontium and manmade radioactivity standards.

** Combination of all sources should not exceed total dose equivalent of 4 mrem/y."

Table 2

EXPOSURE PATHWAY AGENCY & AUTHORITY	ANN DOSE EQUIV mrem/a	 (μSv/a)
EXTERNAL RADIATION (Vau85)		
DOE Occasional exposure to general population	500	(5000)
DOE Prolonged exposure to general population	100	(1000)
DOE Action level	25	(250)
CEBAF Design goal at boundary	10	(100)
AIRBORNE RELEASES		
EPA Clean Air Act	25	(250)
DOE Reporting level	12.5	(125)
DRINKING WATER (Applied to groundwater)		
EPA Safe Drinking Water Act	4	(40)
CEBAF Design goal close to accelerator	1	(10)

DOSIMETRIC CALCULATIONS FOR WATERBORNE RADIOACTIVITY

Two radionuclides have been identified in groundwater at high-energy accelerators: H-3 and Na-22. It may be shown that at radioactive saturation the concentration of H-3 will be about 26 times greater than the concentration of Na-22 (CEB87 & CEB88). Table 3 summarizes two sets of conversion coefficients for calculating dose equivalent rate from specific activity. Column 2 gives values presently mandated by law (based upon data in NBS Handbook 69, [NBS63]) and Column 6 values proposed in Fed86 (based on ICRP82). Values are given for H-3, Na-22 and several other radionuclides identified in earth around accelerators but not observed in groundwater. Use of these conversion coefficients gives the concentrations of H-3 and Na-22 which would together yield a dose equivalent rate of 4mrem/y summarized in columns 3 and 7. The actual dose equivalent and the percentage of the total are given in columns 4 and 5, 8 and 9 respectively.

Table 3

Radio-nuclides	NBS Handbook 69 (NBS63)				(Fed86)			
	conv coef (pCi/l per 4 mrem/yr)	calc conc (pCi/l)	H (mrem/yr)	H_{tot} %	conv coef (pCi/l per 4 mrem/yr)	calc conc (pCi/l)	H (mrem/yr)	H_{tot} %
Observed in groundwater								
H-3	20000	6810	1.4	34	90000	11283	0.5	13
Na-22	400	264	2.6	66	500	437	3.5	87
Examples observed in the ground								
Be-7	6000	–	–	–	100000	–	–	–
P-32	30	–	–	–	700	–	–	–
Ca-45	10	–	–	–	2000	–	–	–
Mn-54	300	–	–	–	3000	–	–	–
Co-60	100	–	–	–	200	–	–	–

Figure 1 shows the concentration of H-3 and Na-22 as a function of distance from the point of production assuming a unidirectional water flow. When the rate of water-flow is small the concentration of radionuclides at the point of production may reach radioactive equilibrium. This assumption has been made in figure 1 at the source of production because it is simple and conservative.

CONCLUSIONS

Radiation shielding has always been recognized as a substantial component of the civil engineering costs for accelerator radiation control. In the case of CEBAF we are fortunate in that the accelerator must be constructed deep enough below ground that no additional shielding (except for beam dumps) is required for controlling direct radiation.

For the large experimental halls where local shielding cannot be used for experimental reasons, then roof shielding against skyshine is necessary. For large spans this becomes very expensive. The exposure pathway through groundwater which might at first be regarded as of minor consequence also represents a major cost. Groundwater standards are, in the case of CEBAF, based on a limit at or close to the site of production, unlike the others which apply to the critical population. In effect, such a standard would result in virtually zero population dose increment from ingestion.

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This work was supported by the US Department of Energy under contracts DE-AC05-84ER40150 and DE-AC03-76SF00098.

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