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To: R. R. Wilson

From: R. H. Thomas

Subject: 400 GeV Accelerator Project Radiation Problems

1. General

Chapter 12, "Radiation Problems," in the Berkeley 200 BeV Design Study Report (UCRL-16000)[1] sets out the basic radiation problems and estimates their magnitude to be expected around a high energy proton accelerator. At the time this chapter was written (early 1965) several uncertainties in available data existed and were pointed out. In the subsequent two years, considerable theoretical and experimental effort has been expended in an attempt to resolve these uncertainties.

This work has largely substantiated the conclusions of Chapter 12 and while small changes in estimates of shielding, induced activity and radiation damage have resulted, these are of no great significance in determining changes in "radiation policy."

2. Radiation Policy for the Weston Accelerator

Input — Estimates of the radiation field around the accelerator are only as good as the input assumptions. The acceptable radiation fields around the accelerator are, however, fixed by AEC regulations.

Non-Radiation Workers — A large proportion of the staff working at the laboratory will not be radiation workers and should not experience any significant radiation exposure in the course of their normal working day. Normal radiation background is approximately 100 millirem yr^{-1}, and in my judgment "no significant exposure" should be defined as no more than a doubling of the natural background. By designing the accelerator shield thickness in the neighborhood of the laboratory buildings so that maximum radiation levels under normal operations are 0.25 millirem hr^{-1}, this may be achieved. Whilst this radiation dose rate corresponds to 500 millirem yr^{-1} (in a normal working year), additional safety factors of distance, enhanced shielding away from the ring top and machine operation duty cycle will provide the necessary reduction of a factor of five.

Radiation Workers "Radiation workers" (e.g., fitters, engineers, physicists) involved with the operation of the accelerator will be most efficiently used (in a radiation sense) if exposed to radiation when working directly with the accelerator (e.g., maintenance, machine tune-up, etc.). Consequently there should be no large relaxation of these general principles when siting offices, laboratories, and workshops in which these people will spend a large fraction of their time.

Beam Loss Estimates Radiation problems will, in general, scale as the beam power dissipated around the ring. Ultimate design goals for circulating intensity and energy are policy decisions, but projected estimates of beam loss are difficult. It is hard to believe that general losses distributed in some random way around the vacuum chamber will be less than 1 - 2%. Machine tune-up and development can easily account for this much. Beam extraction efficiency may be improved from the average (fast and slow) of 85% assumed in UCRL 16000. However, it seems unlikely that efficiencies much better than 90 - 95% will be achieved on a time average basis. It could, in my view, prove embarrassing if design decisions demanded extremely high average beam extraction efficiencies. Despite many optimistic estimates of beam loss, the loss mechanisms around the CPS and AGS are not yet well understood.

The experience of BNL's AGS improvement program with the AEC committee which looks at radiation matters should be remembered!

Summary In brief, the UCRL 16000 estimates of radiation damage, induced activity, and radiation field outside the accelerator are fairly good. Improvement in beam extraction efficiency should be regarded as a welcome and useful bonus but is unlikely that beam losses will be reduced by more than a factor of 5 - 10. The cost of this uncertainty in fixed earth shielding and special magnet design is relatively small.

3. Neutron Shielding

New experimental data from a recent experiment at CERN have substantially solved this problem.[2] Final analysis is not yet complete but new shield thicknesses based on the latest available information have been calculated. Essentially exact neutron shields will be calculable in a few months.

4. μ-Meson Shielding

Additional studies of μ-meson shielding have been carried out at LRL, DESY, and ORNL since the publication of UCRL 16000. Kühlmann and Wüster[3] have extended Keefe's work to different materials (earth, light concrete, heavy concrete, iron, lead, and concrete) for proton energies between 25 - 300 GeV. These calculations refer to the simplest possible situation with a proton beam interacting in a target upstream of a backstop using CKP to estimate pion production. Further studies will be made to determine the effect on the backstop of bending magnets near the target using better representations of the pion production. Keefe[4] has a similar report in preparation.

More sophisticated calculations in range straggling and energy loss fluctuations will be introduced and have started at ORNL. Preliminary results show good agreement with the emergent muon flux calculated by simpler methods but some difference in the muon spectrum.[5]

It is extremely important in estimating mu-meson backstops to have a reliable estimate of availability and unit costs of uranium.

The picture-frame magnet construction may prove helpful in trapping both positive and negative muons (see Chapter XII, Sec. 2.5.7). This effect should be investigated for the proposed accelerator.

5. Induced Activity

More detailed calculations will not change the estimates of UCRL 16000 greatly. The thinner magnet yoke will increase radiation levels in the tunnel. Computer programs have been developed at LRL which can solve this problem and should be run. This increase in radiation levels could be substantial.

On the present evidence available, boron loading of the concrete is necessary if access to the accelerator tunnel is required in an unshielded cart.

6. Radiation Damage

New estimates of radiation dose to the vacuum chamber have been made from measurements made at CERN and are given in a separate report. At an intensity of 1.5×10^{13}, about 10% of the machine magnet coils will be subjected to a dose rate of greater than 10^{9} rads yr^{-1}.

REFERENCES

[1] 200 BeV Design Study UCRCL 16000, June 1965.

[2] Shielding Experiment at the CERN PS, UCID 10199, April 1967.

[3] Muon Shielding Experiments I, Kühlmann and Wüster, CERN/ECFA 66/WG2/US-SG5

[4] Keefe, D., Private communication.

[5] Allsmiller, R. G., Private communication.