9 Accelerator Safety Envelope

9.1 Safety Envelope — Ionizing Radiation

The NLCTA Facility has the capability of delivering particle beams which may vary from a few particles per pulse to a current equivalent to a power of 1.45 kW at 10 pulses per second (after planned upgrades). SLAC has chosen to consider that the maximum credible power capability of the accelerator after upgrades is the Safety Envelope boundary for all applications. This being so, no operator action can cause the facility to exceed the beam power limits of the Safety Envelope.

Shielding design has been chosen such that in the case of the maximal credible accident, where only passive devices are considered, the effective dose equivalent that can be experienced by a person outside the secured areas will not exceed the limit specified for a Low Hazard facility,[1] which is required to be less than 25 rem in any 1 hour.[2]

Beam stoppers, collimators, and dumps are designed such that an inadvertent excess power situation which may exceed the power absorbing capability of the device results in a failure mode, whereby the failure itself triggers a shutdown process, either destructively by spoiling the vacuum in the main accelerator structure, or by sensing burn through and turning off the beam through the Personnel Protection System.[3]

The facility is also protected by a Beam Shut-Off Ion Chamber system which will turn off the beam should radiation dose rates external to the shielding exceed a pre-set value (usually 100 mrem/hr).

It is also required that the annual dose outside shielded or secured areas not exceed 1 rem per year, and no person be permitted to exceed the Administrative Control Level of 1.5 rem per year.[4]

9.2 Maximum Power Capabilities of the NLCTA

Maximum beam power is limited by the following factors:

- **The maximum repetition rate delivered by the gun**, which is limited by three independent one shot circuits in the gun, each of which prevents a pulse being delivered less than 0.1 second after a preceding pulse.
- **The maximum average current which can be accelerated**, which is set by the design of the pulser circuit in the thermionic gun. The design is such that if all three of the above circuits fail, and the nominal pulse rate of 10 pps is exceeded, the pulse current from the gun begins to be reduced such that the average current does not exceed 11 microamps.[5] The integrity and functionality of this circuit are a check-off item on

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1 Radiological Protection Guidelines, 20 May 1994, Ken Kase.
2 *Accelerator Safety Order, DOE 5480.25*, Guidance, page 10, September 1, 1993.
3 See Section 7.1.2, "Beam Containment System."
4 *SLAC Radiological Control Manual* (SLAC-I-720-0A05Z-001), Article 211.
5 For further information see: Browne, M. J., "Average Current Limit for the NLCTA Thermionic Gun," NLCTA Note #48, May 25 1995, and Brown, M. J., "Analysis of Failure modes of the Average Current Limits for the NLCTA Thermionic Gun", NLCTA note #61, September 26, 1995.

the Beam Authorization Sheet, and the circuit enclosure is locked with a controlled key.

- **The maximum energy capability of the accelerator,** which is set by the number of klystrons installed and available for acceleration, the length of accelerating structure, and the power delivered by each klystron, as modified by beam loading. The initial design provides four 50 MW Klystrons, providing a no-load accelerating gradient of 50 MV/m. The planned upgrade would provide eight 75 MW Klystrons, providing a no-load accelerating gradient of 87 MV/m. In both cases, there is a total length of accelerator structure of 12.6 meters in the injector plus linac. Thus the maximum no-load energy in the initial configuration is 630 MeV, and after upgrade is 1096 MeV.

To summarize: The maximum power capability is restrained by redundant methods. Although the trigger hardware has the capability of delivering a repetition rate of 180 pps, the actual rate reaching the gun is limited by three separate one-shot circuits which prevent rates in excess of 10 pulses per second from reaching the gun. The circuits are independently powered and not subject to common mode failures. Should all three of these circuits fail, the average current from the gun is independently limited (see above: maximum average current). It is judged that the possibility of all three one-shot circuits plus the average current limiter failing at the same time is a non-credible scenario.

For the purposes of maximum power calculation the second limit (average gun current = 11 microamps) is used.

The resultant maximum power capability is:[6]

Initial	Upgrade
3,230 W	5,750 W

The highest credible dose rates external to the shielding are calculated to occur in the utility tunnel under the accelerator. If misteering causes the full beam to target close to this location, and the shut off mechanisms of the Beam Containment System and the Beam Shut Off Ion Chamber System fail to work (Maximum Credible Accident), then the dose rates are:[7]

Initial	Upgrade
5.4 rem/hour	9.6 rem/hour

(At full power under normal operating conditions, the dose rates in this location are in the range of 15 mrem/hour.)

These then constitute the physical limits of the Accelerator Safety Envelope for prompt ionizing radiation at this facility. The various administrative and engineered systems involved in assurance that the safety envelope will not be exceeded are summarized in Table 9.1 below. The administrative systems are described in more detail in Chapter 4, "Operating Organization" and in Chapter 7, "Safety Analysis — Ionizing Radiation."

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6 Two different numbers are derived; the first being the initial configuration as of Fall 1996 with 50 MW klystrons, and the second being that appropriate to the later upgrade with with pairs of 75 MW klystrons replacing the initial complement of 50 MW klystrons.

7 These dose rates will cause the beam to be turned off by the Beam Shut Off Ion Camber system. See V. Vylet and T. Lavine "Radiation Protection in the NLCTA," NLCTA # 46.2, December 5, 1995, and Section 7.1.3 above.

Table 9.1: Means of Assurance of Accelerator Safety Envelope; Ionizing Radiation

Restraint	Means of Assurance
Beam Power	Intrinsic capability of linear accelerator. Average current limiting circuit required to be periodically checked by BAS.
Radiation Shielding Design	1. Beam line design and shielding arrangement by the Radiation Physicist, in accordance with the Radiological Protection Guidelines. 2. Review by the Radiation Safety Committee. 3. Field Inspection(s) by the Radiation Physicist and the operations staff. 4. Radiation measurements during commissioning to validate the design.
Configuration Control	1. Beam Authorization Sheet (BAS) requires inspection of moveable shielding, and other safety-related items on start up. 2. Configuration control via Guideline 14.
Radiation Safety Systems	1. Personnel Protection System (PPS), Beam Containment System (BCS) and Beam Shut Off Ion Chamber (BSOIC) system design, maintenance and periodic inspection controlled by formal procedures. 2. Design changes are initially reviewed by the Radiation Safety Officer, who is authorized to approve minor changes. If proposed changes are major modifications, proposal is reviewed by the Radiation Safety Committee. 3. Operation of PPS and BCS and BSOIC system controlled by formal procedures. 4. Configuration control via Guideline 14.
Significant Modification	1. Modifications which may impact Safety Envelope require review by the Safety Overview Committee.*
Operations	1. Control room is required to be staffed by specified complement of qualified operators.† 2. Operators are required to be qualified in accordance with the training plan.‡

* See *SLAC Guidelines for Operations*, Guideline 24, "Safety Review of Major Modifications."
† See NLCTA Operations Directives, (in preparation).
‡ See Section 5.2 above.

Operations may be constrained to levels which are significantly below the maximum power level by administrative and technical means specified in the Beam Authorization Sheet.[8] The limits set from time to time by the Beam Authorization Sheet then constitute the Operations Envelope for the facility. The Operations Envelope will be chosen such as to restrain power to conform to annual radiation dose limits and/or to avoid damage to system hardware. The means of assurance employed to control the Operations Envelope are shown in Table 9.2 below.

Table 9.2: Typical Means of Assurance of Operations Envelope; Ionizing Radiation

Restraint	Means of Assurance
Beam Power	1. Specification in BAS 2. Specified BCS devices (Average Current Monitors, etc.) 3. Operator Surveillance and sign off of BAS 4. Verification of calibrations and configuration control
Path Allocation	1. Legitimate beam path specified in BAS

[8] See Section 7.1 above.