

Personnel Protection and Beam Containment Systems for the 3 GeV Injector*

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Abstract

The 3 GeV Injector is the electron beam source for the SPEAR Storage Ring, and its personnel safety system was designed to protect personnel from both radiation exposure and electrical hazards. The Personnel Protection System (PPS) was designed and implemented with complete redundancy and is a relay based interlock system completely independent from the machine protection system. A comprehensive monitoring of the system status, and control of the Injector PPS from the SPEAR Control Room via the control computer is a feature. The Beam Containment System (BCS) is based on beam current measurements along the Linac and on Beam Shut Off Ion Chambers (BSOIC) installed outside the Linac, at several locations around the Booster, and around the SPEAR storage ring. An outline of the design criteria is presented with more detailed description of the philosophy of the PPS logic and the BCS.

I. INTRODUCTION

A Personnel Protection System can be considered to have two main parts, an access control system and a radiation alarm system.

The access control system is intended to prevent unauthorized or accidental entry into radiation areas. Elements of this system include physical barriers, beam stoppers, signs, closed circuit TV, flashing lights, audible warning devices including the associated interlock system, and a body of administrative procedures that define conditions where entry is safe. The radiation alarm system can include radiation sensors which monitor radiation field directly, or indirect methods like the use of beam current detectors.

The Injector is divided into two independent Personnel Protection Systems, one for the Linac vault and Diagnostics room and the second for the Booster ring and transport line. The SPEAR storage ring is controlled by and independent PPS.

The LTB (Linac-To-Booster) beam stoppers separate the Booster from the Linac and are controlled from the Booster PPS Control Panel. The BTS (Booster-To-SPEAR) beam stoppers separate the SPEAR storage ring from the Booster and are controlled from the SPEAR PPS Control Panel.

The Linac, the Booster, and the SPEAR Storage Ring are operated as independent systems. Linac studies can

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be carried out by switching the Linac beam into the Diagnostics room while permitting entry to the Booster, and Booster studies can be carried out by inserting the BTS stoppers, which allows entry to SPEAR. The various modes of operation are summarized in table 1.

Table 1

The Linac, Booster, and SPEAR Storage Ring modes of operation.

Linac	BOOSTER	SPEAR
Operates	Operates	Operates
Operates	Operates	Does not operate
Operates	Doesn't Operate	Operates
Operates	Doesn't Operate	Doesn't Operate
Doesn't Operate	Operates	Operates
Doesn't Operate	Operates	Doesn't Operate
Doesn't Operate	Doesn't Operate	Operates
Doesn't Operate	Doesn't Operate	Doesn't Operate

II. PHILOSOPHY

The Injector PPS provides the operational flexibility required for the various modes of operation yet is sufficiently interlocked so that reliance on administrative procedures is minimized. The aim of the PPS is to protect people and not the machine, therefore the system is fully independent and distinct from the machine control system. The main design rules for the PPS [1] are: (1) The using of components with high degree of reliability (2) Designing fail-safe circuits (3) Building duplicate circuits or redundant components in critical applications where the single failure of a circuit or device could lead to a hazard.

III. SYSTEM DESIGN [2]

A. Access Interlocks

The Linac vault and Diagnostics room Access Interlock is designed to provide the following Security Levels:

- Permitted Access** — Unrestricted entry to the Linac vault and the Diagnostics room. The Linac RF and the electrical hazards are OFF.
- No Access** — The Linac vault and Diagnostics room are searched and secured. Linac may be turned ON.

The Booster Access Interlock is designed to provide the following Security Levels:

Permitted Access — Unrestricted entry to the Booster area. Beam OFF, LTB stoppers and Booster RF are IN/OFF, electrical hazards are OFF.

Controlled Access — Entry under control of the Booster operator; requires a key release and logging of entries. Beam OFF, LTB stoppers and Booster RF are IN/OFF, electrical hazards are OFF.

Restricted Access — Booster has been searched and secured. Beam OFF, LTB stoppers and Booster RF are IN/OFF, electrical hazards may be energized.

Restricted Access Safety Key (RASK) — Booster has been searched and secured. Beam OFF, LTB stoppers and Booster RF are IN/OFF, electrical hazards may be energized.

The RASK mode provides a mechanism for a Hazard Test Team to enter the Booster and test electrical hazards.

No Access — The Booster has been searched and secured. LTB stoppers may be opened and Booster RF may be turned ON, electrical hazards and beam may be turned ON.

The transfer of the Booster access mode is always done in a sequence:

$$PA \Rightarrow CA \Rightarrow RA \Rightarrow NA$$

$$PA \Leftarrow CA \Leftarrow RA \Leftarrow NA$$

Table 2
Access/Stopper Requirements.

Requires that	SPEAR Ring Stoppers	BTS Stoppers	Booster Stoppers	Additional Requirements
Access to				
SPEAR Ring	IN	IN	N/A	SPEAR RF and Electrical Hazards OFF
BTS Transport Line	IN	IN	IN	
Booster Ring	N/R	N/R	IN	Booster Electrical Hazards OFF
Linac/Diag. Rooms	N/A	N/A	N/R	Linac RF and Elec. Hazards OFF

—N/A = not applicable, N/R = not required—

The access to the SPEAR or Booster ring requires that the appropriate stoppers be "IN". The Access/Stopper status are given in table 2.

Table 3
PPS Violation and Response.

RESPONSE PPS VIOLATION	SPEAR RING STOPPERS	BTS STOPPERS	BOOSTER STOPPERS	LINAC	SPEAR INJECTION SEPTUM MAGNET PS	HUTCH STOPPERS	ADDITIONAL RESPONSE
SPEAR RING	IN	IN	IN IF BTS STOPPERS ARE NOT IN	OFF IF LTB OR BTS STOPPERS ARE NOT IN	N/A	N/A	DUMP SPEAR ELECTRICAL AND RF HAZARDS
BTS	IN	IN	IN	OFF IF LTB OR BTS STOPPERS ARE NOT IN	N/A	N/A	DUMP BOOSTER ELECTRICAL AND RF HAZARDS
BOOSTER RING	N/R	N/A	IN	OFF IF LTB STOPPERS ARE NOT IN	N/A	N/A	DUMP BOOSTER ELECTRICAL AND RF HAZARDS
LINAC AND DIAGNOSTICS ROOMS	N/R	N/R	IN IF LTB STOPPERS ARE NOT IN	OFF	N/A	N/A	
SYNCHROTRON BEAM LINE HUTCH	IN	IN	IN IF BTS STOPPERS ARE NOT IN	N/R	N/A	IN	

—N/A = not applicable, N/R = not required—

B. Rules and Functional Description

1. All doors have provisions for opening mechanically in emergency situations.
2. Emergency Off units are installed in the Linac vault and Diagnostics room, and in the Booster ring.
3. Opening the gates for entrance to the Booster or exit from inside while the Booster is in the Controlled Access, is supervised by an Operator. A solenoid release mechanism is used.
4. In Restricted Access only the electrical hazards may be energized. The Booster RF power system is interlocked Off during this access mode.
5. When the Booster is in Restricted Access or No Access, NO gate is allowed to open under any circumstances except emergencies. Any time a gate is opened a Security Fault results.
6. Opening any interlocked gate or door when not allowed, or actuating an Emergency Off button or Emergency Entry/Exit, in the Linac vault and Diagnostics room, after they have been searched and secured results in a Security Fault and terminates the secured state. The Linac vault and Diagnostics room must be re-searched and re-secured. The response to a PPS violation in the Linac vault or Diagnostics room is shown in table 3.
7. Opening any interlocked gate or door when not allowed, or actuating an Emergency Off button or Emergency Entry/Exit, after the Booster has been searched and secured results in a Security Fault and terminates the secured state. The Booster must be re-searched and re-secured. The Booster must be re-searched and re-secured. The response to a PPS violation in the Booster is shown in table 3.

The response to PPS violations in the SPEAR ring [3], the Booster-To-SPEAR transport line and in a synchrotron beam line hutch is also shown in table 3.

C. The RASK Mode

The personnel protection system is designed to protect personnel from both radiation exposure and electrical hazards. As such, the Access Interlock prevents the operation of electrical hazards while personnel are in the ring. The RASK mode provides a mechanism for a test team to enter the Booster and test electrical hazards. RASK is the acronym for Restricted Access Safety Key. When in the RASK mode: (1) The Booster can not be transferred to No Access (2) The keybanks at the entry points to the Booster cannot release additional keys. (3) The keyswitches on each Emergency Off unit are active, and the Safety Key can switch ON the Hazard Enable Permissive. (4) The emergency off units in the Booster provide a local shut-off of the all electrical hazards in case of an emergency.

D. Operation of the Booster PPS from SPEAR Control Room

The PPS is interfaced to the control computer through isolated digital input and output modules known as IDIMs and IDOMs respectively. The IDIMs and IDOMs are CAMAC based modules. For each hardware PPS status lamp and control button there is an equivalent digital signal interfaced through IDIM and IDOM modules. This facilitates the construction of the computer status monitoring and control system menu which is designed to look very similar to the actual PPS panel, and to minimize any potential source of confusion about the differences in operation between the two. Operating the Booster PPS by computer has the same effect as pushing the physical buttons on the PPS control panel. The PPS logic is in control of the system and will not respond to erroneous remote commands unless the correct conditions exist. One additional feature of the computer interface is that the digital control functions are interlocked with a hardware enable button located in the SPEAR Control Room which must be pushed for any computer control commands to have effect. This is to prevent accidental commands sent to the Booster PPS by the computer user at the SPEAR Control Room.

E. Beam Containment

The Beam Containment System (BCS) [4] is based on beam current measurements along the Linac, on monitoring the chopper high voltage pulse, and on Beam Shut Off Ion Chambers (BSOIC). The Beam Containment Interlock for the Injector is designed to remove power from the three Linac sections that accelerate particles from ≈ 2.5 MeV to ≈ 150 MeV by interrupting trigger signals to the Linac modulators and to the RF amplifier that provides the s-band drive signal to the Linac klystrons if: (1) The number of accelerated particles in the Linac pulse exceeds a preset limit. (2) The high voltage pulse applied to the chopper is too high, allowing more than a few s-band bunches to enter the Linac. (3) An excessive radiation level is detected by any one BSOIC connected to the interlock. Redundancy

in the beam current measurement is provided by measuring the current at two locations using two toroids and two Average Current Monitors (ACM). The output signal from each toroid is amplified and integrated. If the integrated current exceeds a preset value, a system fault is generated. The BSOIC's are installed in the following locations: one BSOIC inside the Booster ring shielding adjacent to the LTB line, (the fault channel of this BSOIC is automatically bypassed when the Booster is in No Access); two BSOIC's outside the Linac room; five BSOIC's outside the Booster ring and the Booster-To-SPEAR transport line, and twelve BSOIC's around the SPEAR ring. All BSOIC's are adjusted to produce an alarm signal if the radiation level exceeds 10 mrem/hr, and produce a trip if the radiation level exceeds 50 mrem/hr. All BSOIC's faults are latched and are individually resettable locally with Interface Chassis reset buttons, or they can be reset collectively via the Injector computer.

IV. GLOSSARY

LTB stoppers:	Two mechanical stoppers and one dipole magnet
Booster stoppers:	LTB stoppers and the Booster RF
BTS stoppers:	One mechanical stopper, BTS dipole magnets, and Ejection Septum magnet

V. REFERENCES

- [1] SLAC, "Health Physics Manual of Good Practices for Accelerator Facilities," April 1984. SLAC Report - 327.
- [2] R. Yotam, R. Hettel, and J. Cerino, "Design Proposal for the SSRL Injector Project Booster Personnel Protection System," August 1990. SSRL Engineering Note 169.
- [3] H. Smith and R. Yotam, "Design Proposal to Rebuild the SPEAR Personnel Protection," January 1991. SSRL Engineering Note 170.
- [4] R. Hettel, "SSRL Injector Beam Containment Interlock," May 1991. SSRL Engineering Note.