A Personnel Protection Systems

A.1 Introduction

A Personnel Protection System (PPS) consists of electrical interlocks and mechanical barriers that prevent personnel from entering Radiation Safety Enclosures when particle beams may be operating. The interlocks also serve to shut off the radiation source if any of the gates into an enclosure are opened when beams are on. The interlock system must be operated and maintained in accordance with an extensive set of administrative procedures. These ensure that activities such as setting access states, searching an exclusion area, and testing the interlocks are carried out safely and thoroughly.

At SLAC, the Personnel Protection Systems serve primarily as Access Control Systems. This term is favored by the National Council on Radiation Protection. The DOE uses the name Beam Interlock Safety System. In the following description, PPS will be used because of its widespread and long-standing use at SLAC, and because the system does perform safety functions other than control of access. It provides the logic and the hardwired connections to beam shut-off devices that operate in response to signals from Burn-through Monitors (BTMs) and Beam Shut-Off Ion Chambers (BSOICs). These devices are described in separate documents under the titles "Beam Containment System" and the "Beam Shut-Off Ion Chamber System." In addition, the PPS limits the potential radiation exposure to persons inside the beam housing when access is permitted, by ensuring that beam-blocking stoppers are in place. The stoppers are designed so that the dose rate in the occupied areas remains below that which could result in a dose of 1 rem a year under normal conditions and less than 25 rem in one hour in the event of a system failure.

While the main function of the PPS is to prevent entry to radiation enclosures when beams are operating, and to turn off the beams when a security violation is detected, there are several other important functions that the logic circuits must accomplish. These include:

1. The provision of interlocks for orderly searching of an area before beam turn-on;
2. Interlocks for setting up the various entry states, such as Controlled and Restricted Access;
3. Provision for emergency shut-off;
4. The operation of annunciator signs and audio warning systems; and
5. Control of electrical hazards in tunnel areas — specifically, uncovered magnet terminals operating at 50 V and above.

It should be noted that the PPS is not designed to protect people against residual radiation when the beam is off, although it does present a somewhat formidable barrier against casual entry to tunnel areas when in the Controlled, Restricted, or No Access states. The reason for its relative ineffectiveness in protecting against residual radiation is because every entry door has an emergency entry (and exit) mechanism, and a determined or untrained person could easily gain access. During long shut-down periods, the Control Room is not manned, and an alarm signal indicating a forced entry would not be noticed. The emergency entry/exit devices are fitted with microswitch interlocks such that if beams were operating, the accelerator would be shut off immediately by the emergency entry interlock, and also by the interlocks associated with the door microswitches.

At SLAC, the PPS is implemented using relay logic. Fail-safe circuits are used wherever possible. For relay systems, this means that for the beam-on condition, all relays in the safety logic circuits are in the operated or energized state. Dual, redundant paths or chains are used to reduce the likelihood that a single unsafe failure would completely disable the protection system. An example of an unsafe failure would be a sticking contact on a relay or switch that failed to open when the relay was deenergized or the switch operated. The dual redundancy is carried from the input devices, such as door microswitches, through duplicate wiring to the dual chains in the logic. The logic output connects to redundant shut-off devices. At least two independent devices are used to ensure positive shut down of beams, but typically three and sometimes four devices are used.

A.2 Design Features

The PPS has been designed in accordance with guidelines that are in common usage in other accelerators, and at similar facilities where a life-threatening situation might arise if inadvertent entry were made to a restricted area. The guidelines have been heavily influenced by publications such as The American National Standard N43.1 [1] and the National Council on Radiation Protection and Measurements Report, NCRP 88 [2]. Many of the principles listed below are described in SLAC-327 [3] and are now incorporated in the guidance section of the DOE Accelerator Safety Order [4].

A.2.1 High Quality Components

Materials and components are of high quality for dependability and long life. Materials that resist radiation are used for components located in areas where radiation levels are high enough to cause radiation damage.

A.2.2 Fail-safe Circuits

Fail-safe circuits and components are used whenever practicable. Fail-safe design includes consideration of the effects of open-circuited or short-circuited cables, the failure of primary AC or DC power, and the loss of pressurized air that feeds air-actuated solenoids. In each case, the safety interlock system reacts to render the area safe. To achieve fail-safe operation, the logic has been implemented using relays that are maintained in the energized state for the normal running (beam on) condition. Thus, all normally open contacts are in the closed condition. Abnormal conditions such as a power loss, cable disconnection, or a conductor short or open circuit, will cause the relay to de-energize and the logic to go to the fault (safe) state. The relays operate at 24 V DC.

A.2.3 Redundancy

Duplicate circuits or redundant components are used in critical applications where the failure of a single circuit or device could lead to a hazardous condition. Most tunnel entrances have two doors, and doors used for routine entry have two microswitches. Double or triple redundancy is used for beam absorbers or magnets that serve as beam stoppers when entry is required into a downbeam area. In the case of logic wiring and circuits, two independent chains, or circuit paths, are used. The failure or activation of any one or both chains results in a beam shut-off and the removal of power to tunnel magnets operating at 50 V or above.

A.2.4 Protection of Equipment

Circuits, equipment, and connecting cables are protected against inadvertent modification, disconnection, or tampering. Logic equipment is located in locked racks or cabinets.

All cables have been protected by armor covering or conduit, except for long cable runs where tray cable has been used in metal trays. When the cable leaves the tray, protective conduit has been installed.

A.2.5 Test Features

To the maximum extent possible, "press-to-test" switches and status indicators have been incorporated into the equipment to permit efficient testing and certification. Thus, the use of clip leads and bypass boxes for testing individual chains has been reduced significantly.

A.2.6 Location of Control Panels

Wherever feasible, control and status of the PPS logic for a specific enclosure are available both at the radiation enclosure itself and at the operations control room. This is to permit maximum flexibility for operational efficiency.

A.2.7 Use of Computers

In some instances, the general purpose control system computer that is used to monitor and control the accelerator may be used for monitoring the status of a remote PPS logic chassis. However, if an operator response is necessary to maintain safety, status signals that are defined as alarms and warnings are also communicated by audible or visual indicators that are not generated by software (*SLAC Guidelines for Operations*, [5]). Control signals to a remote PPS logic chassis may operate through the general-purpose control computer, provided an additional hardwired permissive signal is also transmitted in parallel (logic AND). The control computer is not permitted to perform any PPS logic function because there is not adequate configuration control over hardware or software.

A.2.8 Interlocks for Safe Entry

Interlocks, such as door microswitches, are not used to shut off the beam for routine entries. Beams must be shut down, or stoppers inserted, in an orderly sequence. Entry to a beam housing is prevented (except in an emergency) until the PPS logic circuitry confirms that all machine-generated radiation sources and electrical hazards are turned off, or that the required beam stoppers are inserted or off. Only then is it possible to release a key, operate the electric door latch, and gain entry.

A.2.9 Stopper Integrity

When entry is permitted in an area that is protected by beam stoppers, beams in the up-beam area must be shut off immediately if there is any indication that a stopper is not properly positioned or if it is damaged.

A.2.10 Reset Requirement

If an interlock trips during normal beam operation, the accelerator cannot be restarted until the operator has reset the interlock at the PPS panel in the control area. In the situation where the security of an enclosure has been lost, or when an Emergency Off button has been pushed, a complete search of the area is required before the interlocks can be reset.

A.2.11 Search and Warning Provisions

Interlocks have been provided to ensure complete and effective searching of an enclosure. The interlocks consist of push button or key switches for:

1. Search Preset (search start),
2. Search In Progress, and
3. Search Complete.

The interlock circuits prevent beams from being turned on until the search has been completed and the audio and visual warnings are finished.

The audio warning is a voice recording that instructs persons who may have been overlooked in the search that they must push the nearest emergency-off button and exit immediately. In some areas, a siren is used as the audible warning. The visual warning is given by the flashing of the overhead lights. At the end of two minutes, the lights are left in the dim condition.

A.2.12 Emergency-off Switches

Emergency shut-off switches have been installed in all tunnel enclosures. The switches are large, clearly labeled, and easily accessible. A large red light is mounted on each switch assembly.

A.2.13 Radiation Warnings

Radiation signs and lights, or large annunciators have been installed outside all entrance doors.

A.2.14 Emergency Entry/Exit Provisions

Most doors have emergency exit and entrance mechanisms. These may consist of a crash-bar, a key kept in an adjacent key-box, or a pull-ring.

A.2.15 Access State

In addition to No Access and Permitted Access, many enclosures have Controlled Access and Restricted Access states. These are described in the following section.

A.3 System Description

A block diagram of a typical personnel protection system is shown in Figure A.1. The PPS logic circuits receive information from the accelerator about the status of doors, key banks, emergency-off switches, and other devices. Depending on the safe (or unsafe) state of these components, "permissive" or "enable" signals are generated (or withdrawn) to allow control of safety devices such as beam stoppers. The logic also issues control signals to release keys at remote doors, and to operate warning systems at entrance doors and in accelerator tunnels.

The operator interface to the logic circuits of the PPS may be achieved through a hardware or software control panel. Frequently, both types of panels are provided — a hardware panel near the entrance to the enclosure and a computer touch screen in a central control room area.

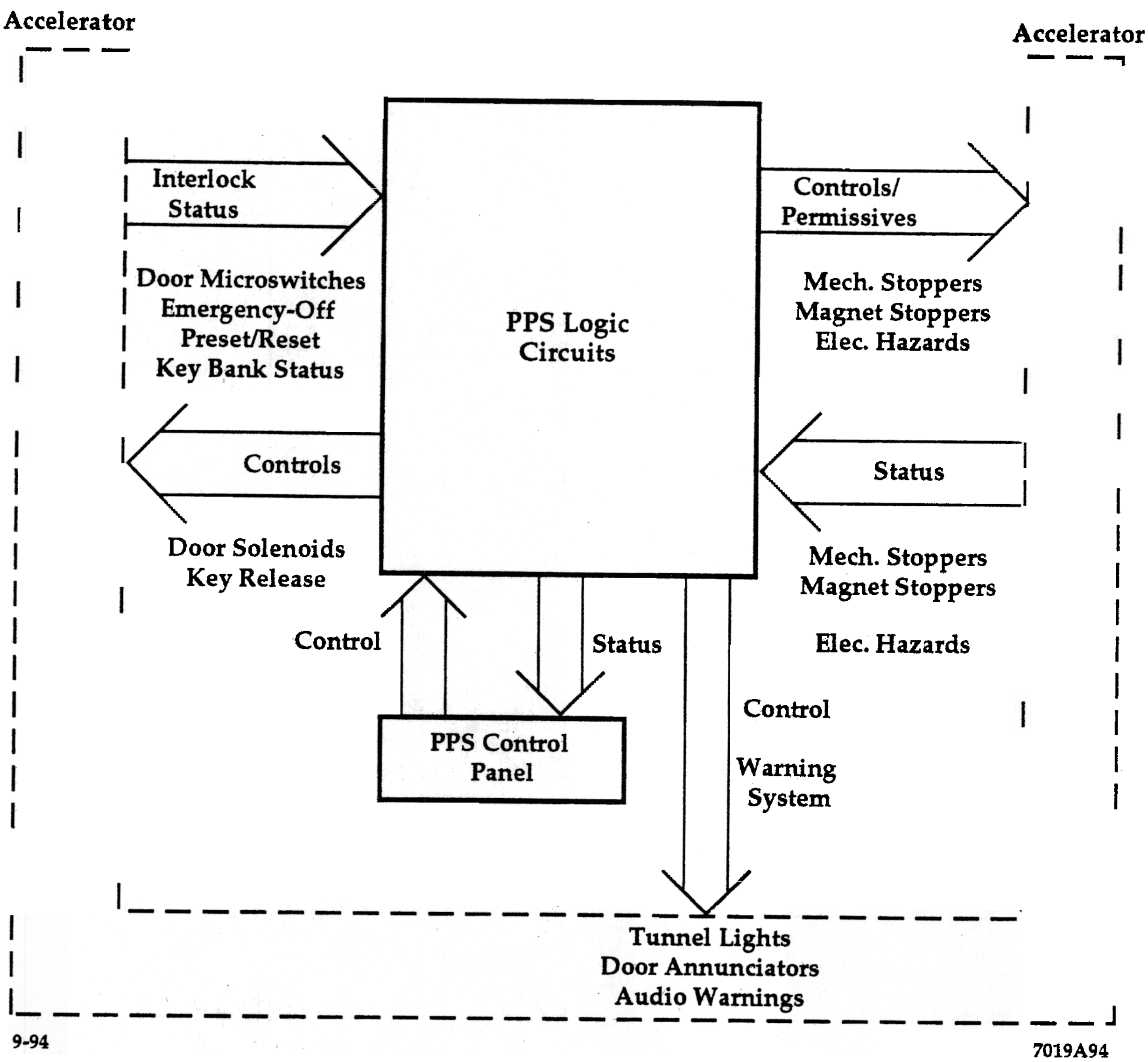

Figure A.1: Block Diagram of Typical PPS System

A.3.1 Stoppers

The term "stopper" refers to any device used to block the beam or prevent it from reaching occupied areas. Thus a stopper could be a mechanical assembly, a deflecting magnet, or the modulators that drive the klystron tubes. SLAC policy requires at least two beam stoppers for protection of personnel, but typically three, and sometimes four, are used. The specific requirements for stoppers are contained in the *SLAC Beam Containment Policy and Implementation* document, available from the Radiation Physics Department. In summary, the current requirements are:

a. If the beam line is designed to permit the beam to be incident on the first stopper when access is permitted to the beam line downbeam of the stoppers, two additional PPS stoppers (for a total of three) are normally required. If fewer stoppers are used, the design must be justified on the basis of adequate safety.

b. If the beam line is designed so that the beam cannot be incident on the first PPS stopper unless a prior failure occurs, then at least one additional PPS stopper (for a total of two) is normally required. If fewer stoppers are used, the design must be justified on the basis of adequate safety.

c. One or more magnets can function as one of the stoppers.

A.3.1.1 Entry Requirements

Stoppers must be inserted in a beam line before entry is allowed to a downbeam area. The PPS logic requires two status signals from each stopper confirming the "in" status before the area can be set to an entry state. In the case of mechanical stoppers, such as slits, collimators, dumps or scatterers, two microswitches are used to determine the "in" position. For magnets used as stoppers, the magnet power supply provides two independent status signals to the PPS logic to confirm that the supply is off. In the case of the linac, the Variable Voltage Substations (VVSs) that power the klystron modulators serve as stoppers. Each VVS provides two "off" status signals to the PPS logic.

A.3.1.2 Security Violation

A security violation of any zone must immediately shut off all machine-produced radiation and electrical hazards in the area. The internal PPS logic circuits respond within about 10 to 100 milliseconds to the opening of any gate or the pushing of an emergency-off button. This delay is due to the drop-out characteristics of the relays that constitute the logic elements in the PPS. Beyond this internal delay, there is an additional delay due to the time taken for mechanical devices to drop into the beam line or for large electromechanical contactors on power supplies or VVSs to release. This second delay could add as much as one or two seconds to the internal delay of 10 to 100 milliseconds.

Note that the logic circuits generate two permissives for each stopper and that both permissives are removed when there is a security violation.

A.3.1.3 Damage to Stoppers

Mechanical stoppers are protected from overheating and damage from accelerator beams by Protection Ion Chambers and Temperature Sensors. Burn-Through Monitors (BTMs) are also used to give an early warning of potential damage to stoppers. The BTM is a pressurized chamber placed in the beam line that ruptures when struck by a beam or beam shower. A pressure switch on the chamber acts through the PPS logic to shut down all beams. The protection of stoppers is covered in more detail in a companion report describing the Beam Containment System, and in the SLAC *Beam Containment Policy and Implementation* document.

A.3.2 PPS Access States

The PPS design provides for up to four access states — No Access, Restricted Access, Controlled Access, and Permitted Access. In some locations, such as the linac, only two states are available — No Access and Permitted Access.

A.3.2.1 No Access

Allows operation of the beam in that area and electrical hazards to be on. No personnel are allowed in the area.

A.3.2.2 Restricted Access

Allows electrical hazards to be on but no beam. No personnel are allowed in area except under RASK. (See below.)

A.3.2.3 Controlled Access

No beam and no uncovered electrical hazards may be on. Personnel access is allowed by contacting the control room. Each person entering must be logged-in by an operator, take a key from a keybank, and be in possession of the key at all times while in the radiation enclosure. In Controlled Access, searching of the area is not required before establishing the No Access state, and resuming of beam operation.

A.3.2.4 Permitted Access

No beam and no uncovered electrical hazards may be on. Personnel access can be made without restriction. Keys are not required. The area must be searched by operators before beams or electrical hazards can be turned on.

A.3.2.5 Restricted Access Safety Key (RASK)

This is a special operating mode that permits personnel to occupy a radiation enclosure with electrical hazards on. Beam operation is prevented by ensuring, through the PPS logic circuits, that the upbeam stoppers are inserted (or off) and that they cannot be removed (or turned on). This special operating mode is used when voltage or polarity measurements must be made on beam line magnets, or when it is necessary to check the integrity of bus and terminal connections on magnets. In this case, temperature probes are used to detect hot spots at connection points.

RASK mode testing is done in the Restricted Access state of the PPS (except for the linac). In this state, beam operation is prevented by the insertion of stoppers as noted above, housing lights are on at full brightness, and key release at entrance door key banks is prevented once the test team has entered the enclosure.

Testing is done in strict conformance with approved procedures. The procedures are somewhat different for each area, depending on the nature of the electrical hazards, and the particular design of the PPS logic, which in the recently constructed systems, provides more interlocked safety features than the earlier designs. For example, because there is no Restricted Access state available for the linac, RASK testing is done in the "Sector Secure" condition, with each team member required to carry an ODD-sector key. Sector Secure is the logic state for the linac PPS that is reached when the sector has been searched and reset; the gates, door, and hatch closed; and the light timer has completed its two-minute timeout.

A.3.3 Warning Lights and Signs

Each entry point to a beam enclosure has a warning light, or annunciator, and a radiation sign. In the klystron gallery, large yellow and magenta warning lights are mounted above the manway door. When the yellow light is on continuously, the linac is off, but there may be residual radiation in the tunnel. A steady magenta light means that the area has been searched and is ready for the beam. A flashing magenta light means that dark current may exist or that the beam is actually running in the accelerator tunnel. In other areas, each entry point has a large annunciator which indicates the access state for that area (No Access, Restricted Access, Controlled Access, Permitted Access).

A.3.4 PPS Control Panels

PPS controls and status are available to operators as either a software-generated display with a touch screen overlay, or as a conventional hardware panel with lamps and switches. For many areas, both hardware and software panels are available.

A.3.4.1 Hardware Panels

A typical hardware panel includes the following features:

- A key switch to enable the panel; the key is kept in the control room key safe.
- Stopper status and controls
- Electrical hazards status and controls
- Access state status and controls
- Door/gate status
- Warning tape status and control
- Interlock status and reset control for Emergency-Off Circuits, doors, and Beam shutoff Ion Chambers (BSOICs), where applicable
- Search preset status
- Search reset status and control
- TV monitor for remote monitoring of the zone entry doors
- Intercom or phone to communicate with persons entering or leaving an enclosure
- Control for release of key bank key
- Key bank status
- Control for release of door solenoid

A.3.4.2 Software Panels

Software-generated panels emulate all of the control and status functions provided by hardware panels, with the exception that no control function to a remote PPS logic chassis is active unless a hardware enable button is also pushed simultaneously with the computer software command.

This additional safeguard, the use of a hardware enable in conjunction with a computer-generated control function, is mandated by the Radiation Safety Committee and by the requirements of the *SLAC Guidelines for Operations*. The reason is that the computer control system is an open system, with no configuration control and no redundancy. Programming errors or software bugs introduced into a beam control program might inadvertently affect safety control programs. Hence the requirement for a hardware backup circuit whenever a safety control function is being exercised through a computer path. Remote key release and door solenoid control are examples of safety control signals requiring hardware backup.

A.3.5 Typical PPS Enclosure

Following is a description of a typical PPS enclosure at SLAC. Figure A.2 shows such an enclosure. It consists of a shielded beam area with a main entrance module and another gate leading to an adjacent beam enclosure.

Its features include:

- An interlocked outer door, with electric strike or magnetic lock, and an emergency exit/entry mechanism
- An interlocked and unlocked inner gate. In some locations, the inner barrier is a movable concrete shielding block or hatch.
- Key bank with 8 or 16 keys
- Door release key switch and push button
- Search preset button inside the enclosure
- Search reset button outside the enclosure
- Emergency-off buttons
- TV camera
- Intercom or telephone
- PPS annunciator sign
- Loud speakers for audio warning
- Flashing lights

A.3.6 Searching and Securing an Enclosure

Entry and exit procedures, and procedures for searching and securing a PPS area are fully documented for each of the SLAC facilities. Operators are required to be familiar with the procedures and to follow them meticulously.

A general description of the steps necessary to bring an area such as the one shown in Figure 2 from Permitted Access to beam operation is as follows. (For a specific enclosure, searchers would follow the documented procedures for that area.)

1. The PPS operator in the control room makes an announcement over the paging system that the area is about to be searched and that personnel should prepare to leave.
2. The operator sets the area to the Controlled Access state, and releases a key from the local key bank to each member of the search team after logging the entry in the control room security logbook for the specific area. In simple enclosures such as the one shown, it would be possible for one operator to safely search the area.
3. One member of the search team inserts the key into the door release box, and turns it clockwise, while the control room operator releases the electric door latch.
4. The searchers enter the enclosure, closing the outer door behind them but leaving the inner gate open. (The microswitches on the open gate serve as an additional pair of interlocks that prevent the beam from being turned on when an enclosure is occupied). The control room operator checks on the remote TV that each person entering has a key. One searcher goes to the far end of the enclosure, checks that the gate is closed and that the emergency entry mechanism is not faulted, and then pushes the Search Preset switch. Pushing the Search Preset sets a latch in the logic circuit, and in some areas, starts a timer that sets the maximum time allowed for the search.
5. The searcher starts the search at the area adjacent to the Search Preset button and walks back toward the entrance gate, making sure that there is no one on the far side of the beam line. The searchers complete the search, close the inner gate, and contact the control room operator who releases the latch on the outer door. The searchers leave the enclosure, close the outer door, and return all keys to the key bank.

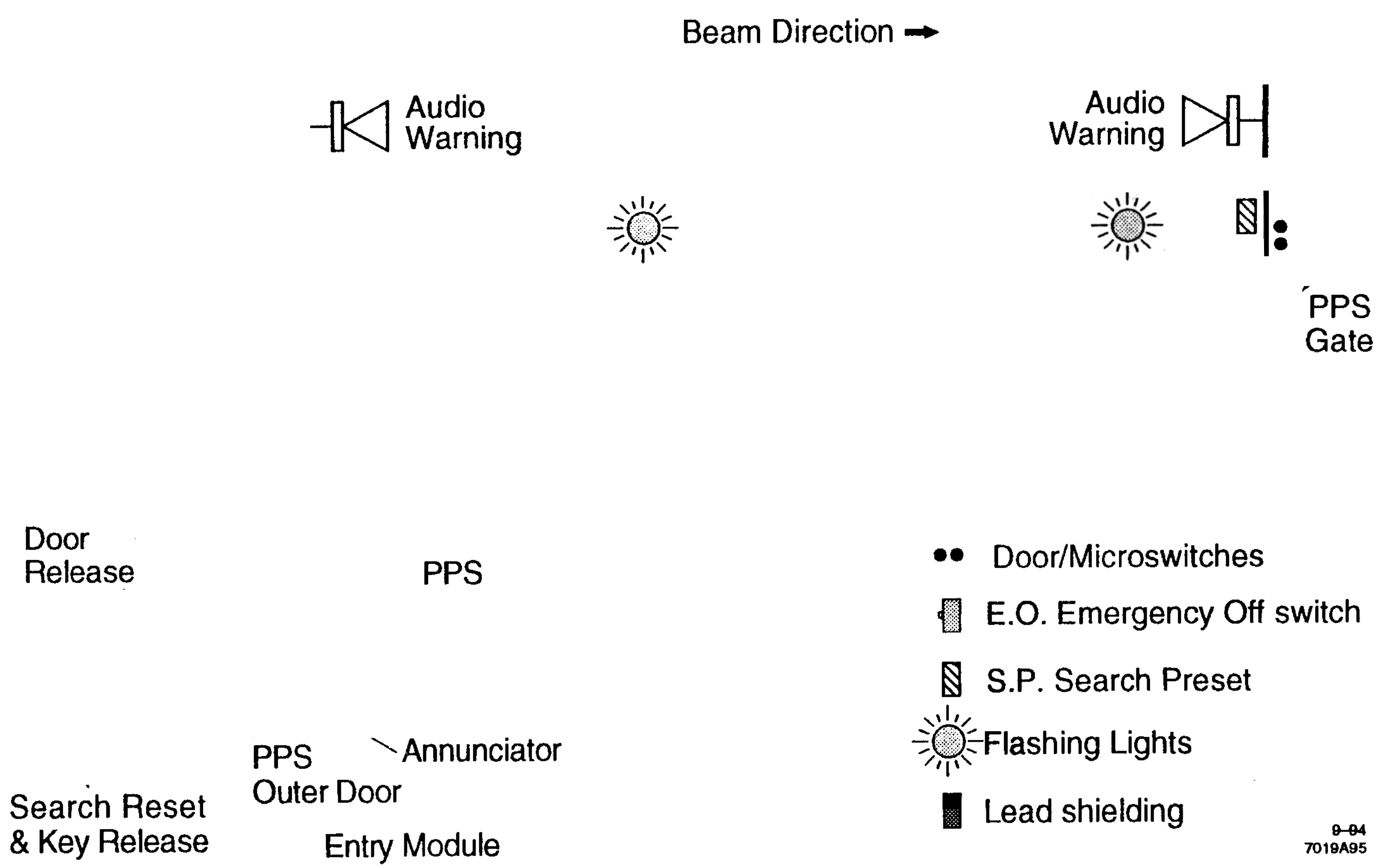

Figure A.2: Typical PPS Enclosure at SLAC

6. The control room operator may now reset the interlocks. Alternatively, in many locations, this may be done at the local control panel outside the enclosure. Resetting interlocks sets latches, or memory circuits on all momentary contacts that connect to the PPS logic circuitry. Momentary contacts are associated with door microswitches, emergency shut-off buttons, and emergency entry/exit mechanisms. Providing memory circuits for these contacts ensures that all interlock trips must be acknowledged and reset by an operator. Also, troubleshooting is much easier because momentary failures can be easily detected even if the transient fault disappears.
7. To complete and confirm the search, one of the searchers pushes the Search Reset button outside the door, simultaneously with the control room operator who pushes the Search Reset button for that area. This sets the state called "Search Reset Complete," assuming that all emergency-off switches and emergency entry/exit circuits are in the normal state. Simultaneous operation of the Search Reset function is to ensure that the control room operator remains fully aware that an area has been searched.
8. When Search Reset has been set, the area may now be raised to the Restricted Access or No Access state.
9. Once in the NO-ACCESS or RESTRICTED ACCESS state, the operator acivates an audio warning system which provides a siren sound alternating with a voice warning to the effect that either radiation hazards or electrical hazards may be coming on in the zone concerned. There is also an instruction to push the nearest emergency-off button and to call the operations control room. In addition to the audio warning, the housing lights are flashed from bright to dim for two minutes. They remain in the dim state until the area is set to one of the access states, or until an interlock trip causes loss of security.
10. When the visual and audio warnings are complete, the area is ready for the beam, and permissives are generated by the PPS logic to allow the beam stoppers to be removed or the electrical loads to be energized.

A.3.7 Circuit Logic Description

There are several major logic blocks that make up a typical personnel interlock system.

These include the:

- Search and secure logic
- Stopper permissive logic
- Electrical hazard logic
- Access state change logic
- Key and door release logic
- Annunciator and warning system logic
- RASK logic

Formal circuit schematics show the detailed interconnections of relay coils and contacts that comprise each logic block and that join logic blocks together. These circuit schematics and wiring diagrams are essential for the construction and maintenance of the system. They are not so useful if only a quick overview of the logic is required. It is often difficult to locate a specific switch or contact on one of the five or six large circuit schematics that describe the logic of a typical zone. For this reason, shorthand methods are often used to describe PPS logic functions. One common method is to use AND/OR logic symbols.

Figure A.3 is an AND/OR diagram that shows the Search and Secure functions (Search Preset and Reset) for the enclosure described above. It illustrates the level of complexity contained in a typical logic block. Other functions such as electrical hazard and stopper

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permissive circuits, key bank key release, door release, and access state change circuits (so-called bailing circuits) can be described on similar logic diagrams.

Operation of the search logic circuit is as follows:

The Search Preset is made up by pushing the preset button which sets an electrical latch or holding circuit shown on the bottom of Figure A.3. The latch is set when the signal labeled "Search Preset Cmd, S/Pc" is "high" or "true." The momentary command signal is held at the output of OR Gate 12 if the output of OR Gate 11 is "true." This signal is "true" when the output of AND Gate 10 is "true." This AND Gate is satisfied when the key bank is incomplete, which it must be because the searcher has a key, and when the inner PPS Gate is open. This gate would be open for a Controlled Access entry. Note that there is a timer at the output of AND Gate 10. The timer output is initially "true," and remains "true" for about two minutes after the inner gate is closed. If the Search Reset has not been made up before this time, the Preset drops out.

To make up the Search Reset, the searcher closes the inner gate and outer door, returns all keys to the key bank, resets the interlocks, and pushes the Search Reset button (S/R C{L}) simultaneously with the control room reset button (S/R C{R}). At this time, all inputs to AND gates 5 and 7 are "true," and the Search Reset state is "true" at the output of OR Gate 8. This state is held by the latch formed by AND Gate 6.

The loss of any of the input signals such as emergency-off, key bank complete, etc., will drop the latch and cause the reset to be lost. This, in turn, unlatches the preset circuit which remains in the "false" state until the search process is repeated.

If a beam had been operating in the enclosure when security was lost, the PPS logic would withdraw permissive signals from the radiation stoppers. Loss of these signals causes the mechanical stoppers to drop into the beam line, the electrical stoppers (magnets) to turn off, and other radiation sources, such as klystrons, to be shut down. Electrical hazards would also be turned off.

A.3.8 Zone Entry Requirements

A planned entry into a zone may be made in the Permitted Access state or in Controlled Access, depending on the number of people requiring entry and the time that the area is expected to be open. In either case, the stoppers required for entry to the area must be in place before the PPS logic can generate permissives to release keys and to operate door latches. In addition to the requirement that stoppers be inserted, all electrical hazards in the area must be turned off before door latch and key permissives are given.

A.3.9 Security Violation

A security violation in any zone that is receiving or is ready to receive the beam, must immediately turn off electrical hazards and remove beam-related radiation by inserting the upbeam stoppers and turning off the klystron modulator power sources (VVSs). Thus while normal entry to an area requires only that the appropriate beam line stoppers be inserted and electrical hazards be off, a security violation turns off the electrical hazards, inserts stoppers, and turns off VVSs.

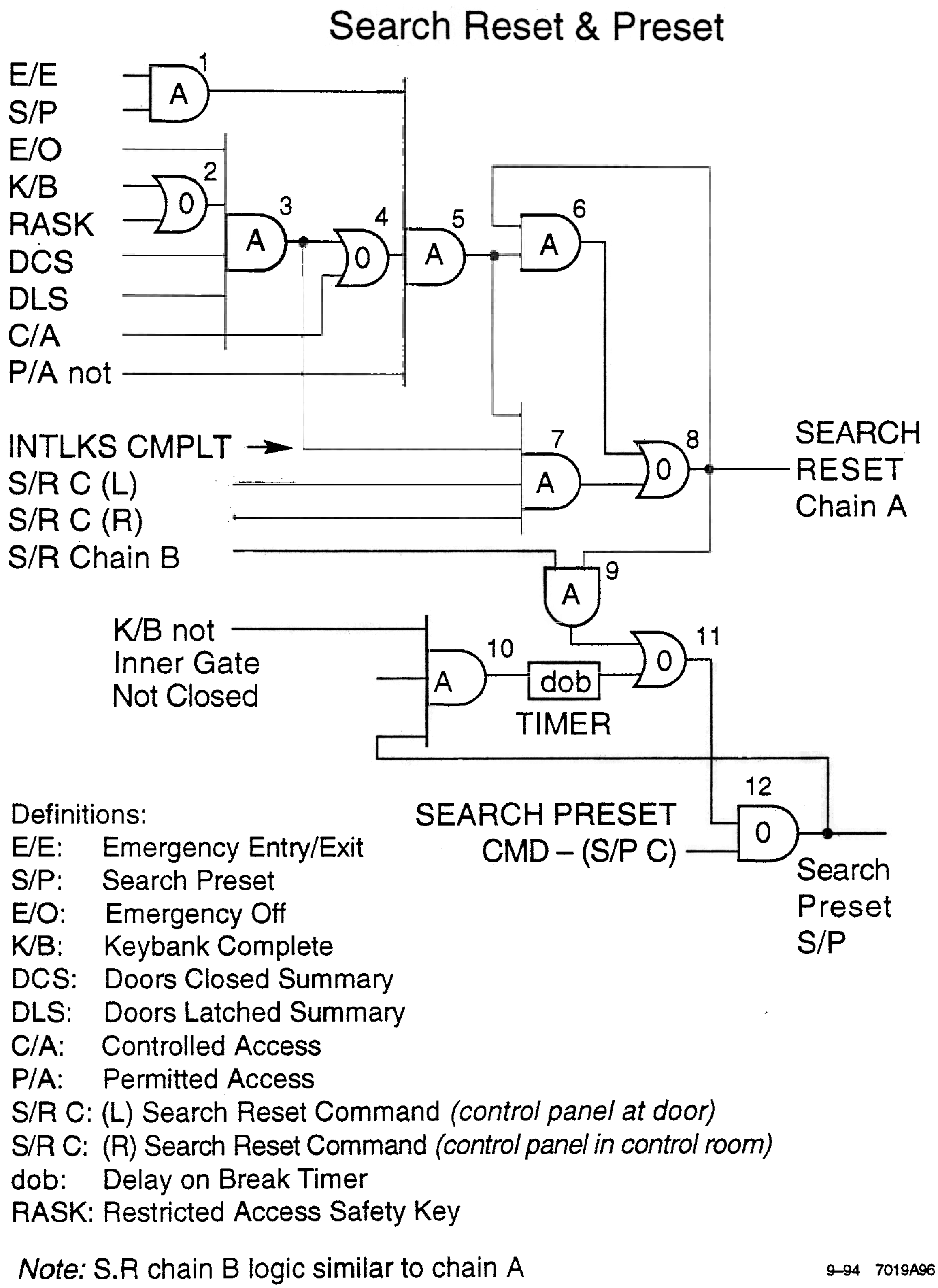

Figure A.3: Search and Preset Functions

A.4 Administrative Procedures

Even the most carefully engineered interlock system can fail to provide protection if not augmented by administrative rules and procedures covering operation, testing, and modifications. These are summarized below.

A.4.1 Training

Operators and other users of the PPS are trained by the ES&H Division in the Radiation Worker Training course. Further guidance and reference material is provided in the SLAC Radiological Control Manual and the *SLAC Guidelines for Operations*. Operators receive advanced training in the use of the PPS by senior personnel, and the progress and status of their training is carefully monitored and recorded in PPS Certification Workbooks for each area.

A.4.2 Search Procedures

These are formal documents that must be rigidly followed. All unusual or unsafe conditions must be reported to the Accelerator Department Safety Office and these must be corrected or mitigated before beam operation.

A.4.3 Validation

Validation of the PPS is done semiannually, following detailed procedures and checklists prepared by the Controls Department and approved by the Accelerator Department Safety Office. The procedures include radiation interlock tests, electrical hazard tests, and system tests.

A.4.4 Testing

Whenever an area is searched, specific tests must be done on door microswitches and emergency-off buttons by members of the search team. These tests are described in the Accelerator Department PPS Interlock Checklists. Also, whenever an area is open for more than two hours, a safety inspection of the radiation protection devices must be made in accordance with written procedures. These are described in the Safety Inspection Checklists issued by the Accelerator Department.

A.4.5 Configuration Control

Procedures that control the modification and retesting of PPS systems are described in the *SLAC Guidelines for Operations*. All changes must be carefully reviewed and approved, and retesting must be done in accordance with an approved procedure.

A.4.6 Beam Authorization Sheets

For each beam running cycle, specific safety instructions on beam parameters, the operational safety envelope, and required safety devices, including any special requirements for the PPS operation, are given in the Beam Authorization Sheet (BAS). This is a formal document prepared by the Radiation Physics Department and approved by the Accelerator Department Safety Office. It specifies the operational requirements for a particular beam cycle as authorized by the Radiation Safety Officer. Operations are constrained to levels which may be significantly below the Accelerator Safety Envelope.

A.4.7 Electrical Hazard Testing

Procedures for testing energized magnets in tunnel areas are issued by the Accelerator Department. All personnel involved in high voltage testing must adhere to these procedures.

A.5 References

[1] "Radiological Safety in the Design and Operation of Particle Accelerators." American National Standard N43.1 1978.

[2] National Council on Radiation Protection and Measurements. Radiation Alarms and Access Control Systems, NCRP Report No. 88, December 1986.

[3] *Health Physics Manual of Good Practices for Accelerator Facilities*. SLAC-327 R. C. McCall, April 1988.

[4] "Safety of Accelerator Facilities," US Department of Energy, DOE 5480.25, November 3, 1992.

[5] *SLAC Guidelines for Operations*, Chapter 19, "Use of Software-Based Control Systems."

[6] *SLAC Guidelines for Operations*, Chapter 14, "Configuration Control of Radiation Safety Systems."