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# RADIATION AND ELECTRICAL SAFETY SYSTEMS FOR PEP*

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## Summary

At SLAC, the Personnel Protection System (PPS) protects people from radiation hazards. For PEP, the system has been expanded to include protection against electrical and RF hazards. This paper describes the overall system design, giving particular attention to the novel features not found in similar systems in other areas of SLAC. These include the "Restricted Access Mode" to allow limited occupancy in the ring while high voltage or RF may be present, the automatic badge reader system for improving the efficiency of entry logging and control, and the solid state lighting control system for switching large lighting loads with minimum electromagnetic interference.

## Introduction

In the design stage of the PEP PPS system, it became evident that costly duplication of interlocks, controls and displays could be avoided if the PPS entry control system were extended to include safeguards against electrical hazards. This led to the development of the Safety Systems Interface (SSI) described later. The combined protection system has five different access states for each of fifteen zones of the ring (including the interaction regions), and the two injection lines (see Fig. 1).

The Personnel Protection System consists of (1) door control equipment; (2) an extensive protected cable plant connecting all doors to a central location in the PEP control Room; (3) relay logic racks; (4) operator displays and controls; (5) the Safety System Interface (SSI) which uses interlocks from the PPS to control hazardous electrical equipment; (6) tone loops for distributed control and interlocking; (7) lighting control; and (8) communication facilities. Beam Shut-off Ion Chambers located at several points around the ring and near the injection points provide signals to the PPS logic circuits. When excessive radiation is detected, the injected beam is shut-off and injection line stoppers and ring stoppers are inserted. If a door violation is detected, the dual microswitch circuits act through the PPS logic to turn off 15 variable voltage substations in the accelerator[1] and to drop the stoppers.

There are occasional requirements for people to be in a zone under special conditions to check components under power - magnet field polarity for example. Strict procedures have been developed which require written approval for each situation when access is necessary under this special condition. Permissives are required from the PPS system to operate each of the hazardous systems. No zone may be entered if any hazardous system within that zone is powered, but hazards may be energized under certain conditions of occupancy as described under "Restricted Access Mode." All doors defining a zone have electrical control to prevent access. Emergency entry and exit is provided through any door. All zone-defining doors are interlocked to trip off appropriate systems.

A new mode called IN SEARCH has been provided. It allows search teams to isolate specific zones for search and prevents access by anyone other than the search team into the zone currently being searched. Passage through an IN SEARCH zone can be accomplished with a special search key from a keybank located in the PEP Control Room (PCR).

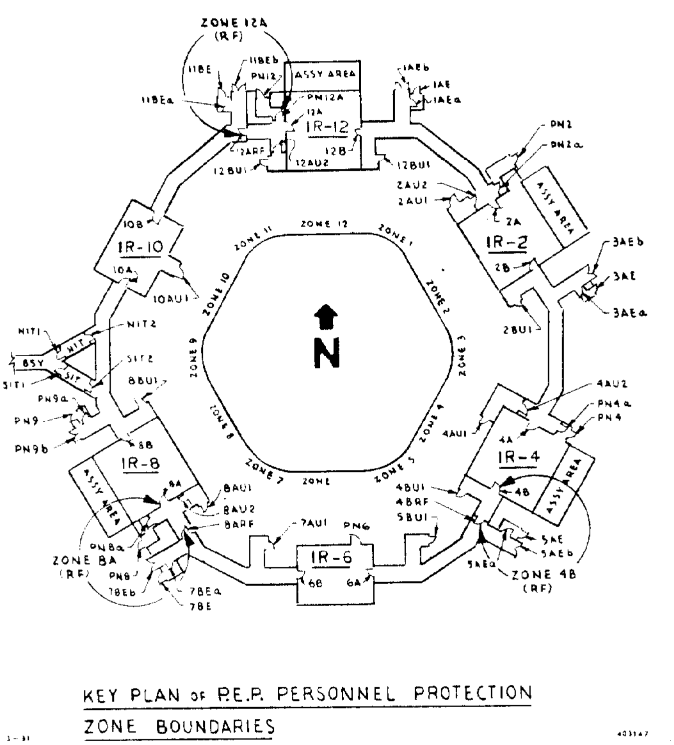


Fig. 1. PEP PPS zone boundaries.

## System Description

There are three main states for the PEP ring - No Access, Limited Access and Unlimited Access. Within the Limited Access category, there are three possible states - In-search, Controlled Access and Restricted Access.

Six main personnel entrances ("PN" doors) provide access into the ring. The doors include facilities for controlling personnel entry by the PEP operators - TV camera, intercom, annunciator panel, electric door latch, keybank, telephone and badge reader. Passage between zones is controlled by electrically locked barrier doors with manual over-ride for emergency use. Unrestricted passage between zones is allowed when the access states of adjacent zones are compatible: i.e., Controlled-access on both sides or Permitted-access on both sides. All doors and gates have dual limit switches connected to dual interlock chains. These are then summarized with other critical interlocks, e.g., Emergency-off stations, to form zone summaries, which are used as inputs to the main tone-loop interlock chain, through Tone-interrupt units described later.

### In-Search Mode

When a zone is to be secured, the area must be searched in the IN SEARCH mode and a search reset must be obtained. The following requirements must be met before a search reset latch can be accomplished: (1) The zone must be in the IN SEARCH mode; (2) all zone doors and gates must be closed and door resets obtained; (3) the emergency off circuit must be reset; and (4) the local control box search reset push button and the PEP Control Room (PCR) search reset push button must be simultaneously pushed. To maintain the search reset

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latch: (1) The zone must not be transferred to the PERMITTED ACCESS mode; (2) the emergency off circuit latch must not be broken; (3) there must not be any door emergency entries; and (4) the zone must be either in CONTROLLED ACCESS or the interlock complete signal must not be interrupted.

Zone Emergency Entry/Exit

During an emergency situation, entry or exit through any door may be accomplished by using the thumb-knob located above the door handle on both sides of the door. Any time there is an emergency entry or exit at a door, a door fault signal is sent to the door emergency entry/exit latch circuit. This signal breaks the interlock - complete circuit and the search-reset holding circuit, thus requiring a new search of the faulted zones.

Restricted Access Mode

This mode permits electrical and RF hazards to be energized at full power. Occupancy in this mode is allowed with hazards limited to safe power levels for special measurement purposes. This requires management authorization and proper supervision. It is accomplished through the use of the RESTRICTED ACCESS SAFETY KEY (RASK).

The procedure for the RASK team is as follows: The PEP Control Room (PCR) operator logs out a search key to each member of the team. The operator in charge of the team turns the RASK key from its captive center-normal position to either the RF hazard position or to the electrical hazard position. The key can then be removed and logged out. The team goes to the appropriate entry way and gains entry under normal CONTROLLED ACCESS. The team then enters the desired zone under CONTROLLED ACCESS and resets the door with the Search-key. The zone is then transferred to RESTRICTED ACCESS. This prevents further entry into the zone.

When the test or measurement is ready to begin, the operator-in-charge enables the hazard by inserting and turning the safety key in a local key-switch located on the "emergency off" boxes that are placed every 80 feet around the ring. This key-switch enables the PCR operator to turn on the selected hazard.

When the test is complete or if there is an emergency, the hazard may be turned off by removing the RESTRICTED ACCESS SAFETY KEY or by pushing the "Emergency off" push button.

When the team is ready to exit, the zone is transferred down to CONTROLLED ACCESS. The team returns to PCR, resetting doors with the search key as they go. At PCR, the key is re-installed in the RASK panel, turned to the captive center normal position and the search keys are returned to the keybank.

Safety Systems Interface

The primary objective of the SSI is to interlock the hazard systems off unless the appropriate ring zones are in RESTRICTED or NO ACCESS. The SSI is an intermediate block of relay logic that communicates between the Personnel Protection System, and systems in the PEP beam housing that present potential electrical and x-ray safety hazards to personnel. Table I is a summary of those hazardous systems. The security status is provided by the access control portion of the Personnel Protection System.

Redundant interlocking is used to increase the margin of safety. Each hazard system requires a minimum of two independent permissives from the PPS/SSI. One permissive is an indication that the appropriate zones are secured. The other is a summary of required zone boundary door-closed status.

Each hazard system provides two OFF/SAFE signals to the SSI. One is taken from an auxillary contact of a main power input contactor and the other from another source within the control circuitry. The SSI summarizes

TABLE I. SSI-Controlled Safety Hazards

| | SYSTEM | NATURE OF HAZARD |
|---|---|---|
| 1. | Ring and Transport Magnets | High Voltage and High Current |
| 2. | Radio Frequency Cavities | X-Ray |
| 3. | Distributed Ion Pump | High Voltage |
| 4. | Injection Kicker | High Voltage |
| 5. | Electro-Static Separating Plates and Quadrupoles | High Voltage |

the OFF/SAFE status for each hazard within a particular zone. If all hazards are off in the zone, the PPS will allow the operator to set that zone to a state which allows personnel access.

SSI signal processing is performed in each of the six major support buildings at PEP. The PPS and SSI share a common network of secure (armored) cables that interconnect these buildings. The main bend magnet power supply is distributed around the ring, and SSI interlocks are connected to it, via a tone loop system.

Tone Loops

Ultra-sonic audio tones are used in a dual-redundant loop configuration for distributed control and interlocking. These are used because they are more secure than D.C. levels - they are harder to simulate and are relatively immune to accidental connection to other interlock and control systems.

Two widely separated tones in the range of 10 kHz to 100 kHz (typically approximately 15 kHz separation) are generated and transmitted over wire pairs around the PEP ring and through the support buildings at each interaction region. These tones are received and verified by filter/comparator networks which generate redundant output interlocks for distributed control. There are presently three sets of tone loops in use in the PEP system as follows: (1) Main PPS Summary and VVS Shutdown; (2) PEP Ring Stopper Control; and (3) Safety System Interface for Control of bend magnet power supplies.

A typical tone loop system (TLS) consists of one transceiver, several tone interrupt units, and might include intermediate line receivers for distributed control (e.g., two are used in the SSI). Tones are generated in the transmitter section of the transceiver using monolithic integrated waveform generators (e.g., Intersil 8038). These have an overall stability of 0.4%. Metering is provided to faciliate field measurements and adjustments.

The tones are interrupted by Tone Interrupt Units (TIU) located in the support buildings. Special interlocks, zone summaries, etc., are used as TIU inputs using optical couplers and redundant circuitry for enhanced reliability. In a fault condition, tones are open-circuited on the upstream side of the TIU and short-circuited on the downstream end to provide adequate attenuation of the audio levels.

The receiver circuitry utilizes an active filter (e.g., Datel FLT-U2) tuned to each input tone with a Q of about 20. A comparator circuit is used to establish a -3db threshold as a back-up to a pair of phase locked tone decoder I.C.'s (e.g., Signetics 567) which are tuned to provide a narrow (approximately 3%) overlap. This effectively establishes a steep sided, narrow bandwidth filter network with TTL level output for interlocking purposes (see Fig. 2). Long term overall system drift has been found to be less than 1% per year.

Badge Reader

One of the innovations to the PEP PPS was to enhance the record keeping requirement of logging entry/exit data, during controlled access conditions. The system uses an optical bar-code reader at the entr' and an intelligent terminal in the control room.

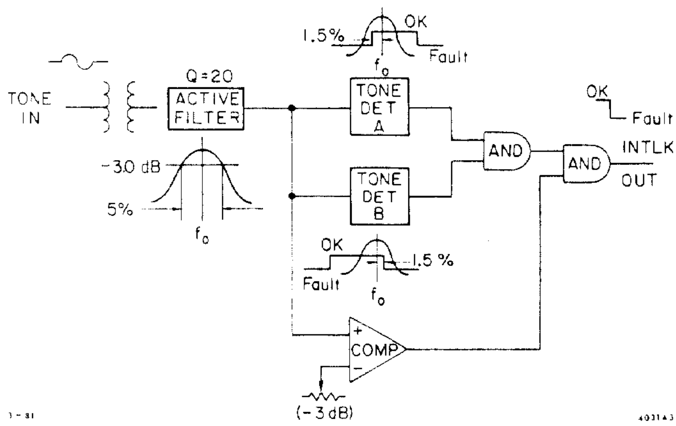


Fig. 2. Tone receiver logic diagram.

terminal consists of two Z-80 microprocessors, 80K of memory (64K shared), integral dual disk drive and screen printer, operating in a multitasking software environment with a real-time clock and flexible file control and indexing. It can be programmed in an Extended BASIC or in Z-80 assembly language and the software package includes integrated system utilities to support all these functions.

The badge reading program is written in BASIC and provides the operator with a "quick-look" display and record of the name, point of entry, date and time of personnel who enter or exit at a controlled access door and are issued a key. This is accomplished by reading a bar-coded number currently affixed to the back of each person's dosimeter card (future plans call for a photographic image of the bar code at the bottom of the card). Numbers are arbitrarily assigned by Health Physics. The system saves records of entry and exit in "historical files" stored on a 5" floppy disk which may be accessed for display in several formats as follows: (a) Personnel inside PEP; (b) most recent PEP entries; and (c) historical file of all entries at specific PN door.

Each display is presented on a page-by-page basis and hard-copy can be generated by use of the integral screen printer or through an external printer connected to an existing parallel interface connector at the rear of the terminal.

The system also includes facilities for building a file of qualified badges, modifying and updating the badge file, assigning temporary badges and searching for "duplicate" assignments. Currently there is only one badge reader located at PN-8 on a trial basis, but future plans call for a reader on either side at each PN door. The same reader must presently be used for both entry and exit and the system uses a "toggle" principle for logging the data. The dual drive floppy storage provides all system software and badge read programs on one disc drive and badge reader data files which are continually updated and extended on the second disc drive. Becuase of disc space limitations, the system issues appropriate advance warnings with instructions for clearing and re-establishing specific "history" files.

The system is automatically "booted up" on power start-up or master reset and, after the loading sequence is complete, it is under the control of the BADGEREAD program. It can be transferred to the keyboard mode for program development or other uses via a "menu" and "cursor" selection feature.

The menu allows five modes of operation as follows:

1. USE KEYBOARD
2. READ BADGE
3. CHANGE NAME FIELD
4. ASSIGN TEMPORARY BADGE
5. DISPLAY "IN" STATUS

A mode is selected by positioning the cursor (blinking character) up or down on the numbers 1 through 5 of the menu and then depressing the "ENTER" key. The "default" mode is the "Read Badge" position and the system automatically positions the cursor on "2" of the menu after each operation and restart to allow the operator to immediately select this mode. The screen "message" indicates that the user must depress the ENTER key to transfer control to the badge reader; the system will then wait until a character stream is received from the bar-code reader. The numeric bar-code is scanned by an infra-red bar code sensor and decoder into serial ASCII data. It is then transmitted over a wire pair into an RS-232 I/O port of the terminal.

After a badge is read, the system will search a file "PERSONNEL" to convert the five digit number code to a qualified name and present the number, name, date, time and point of entry in a message box just below the menu. The space under the message box is a scratch-pad memory into which previous messages are written and retained until they fall off at the bottom of the screen; once gone, messages can no longer be retreived. The current screen and scratch-pad are saved during all other modes of operation and restored each time the badge-read mode is entered. A new screen is established after every system reset or power-up operation.

The badge-read system takes the drudgery out of record keeping and improves the quality of communication between the PEP operator and personnel requesting keys for entry into the PEP ring.

## Solid-State Lighting Control

Typical of a Personnel Protection System is the control of lighting levels, i.e., lighting is reduced and flashed for a short period after an area is transferred to a "NO ACCESS" state and locked up. At PEP, we have used an all solid-state system to accomplish this without the use of any electro-mechanical devices.

The PEP ring is divided into six major lighting control areas, each of which is subdivided into three lighting zones including an IR (interaction region) and an arc (which is split into two zones). The normal lighting in the arcs and access tunnels is provided by long strings of fluorescent fixtures and in the IR's by large metal-halide lamps. These are on at all times when personnel have some form of access to the ring and switched off during NO-ACCESS periods. Reduced lighting is provided by long strings of incandescent fixtures operated at half power and flashed to full power levels for two minutes after establishing the NO-ACCESS state.

Power transfer between fluorescent/metal-halide lighting and incandescent lighting is accomplished via solid-state relays which can switch up to 30 amperes at 277 VAC. These relays can handle one-cycle surge current in excess of 650 amperes peak and have 2500 VAC isolation. They turn on at zero-voltage cross-over and off at zero-current cross-over to minimize electro-magnetic interference generated by switching transients. Care has been taken to provide a conservative heat sink with $1^{o}C/w$ thermal resistance. PEP lighting loads vary from 1.5 to 10 kva distributed on a 480 VAC, three phase system. All loads are single phase operating at 277 VAC.

Control commands supplied by the PEP PPS logic are buffered by optical isolators and suitably gated to form the input drive to the solid-state relays.

## Acknowledgements

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## References

1. R. B. Neal, editor, The Stanford Two-Mile Accelerator (W. A. Benjamin, Inc., New York, 1968); Chapter 21.