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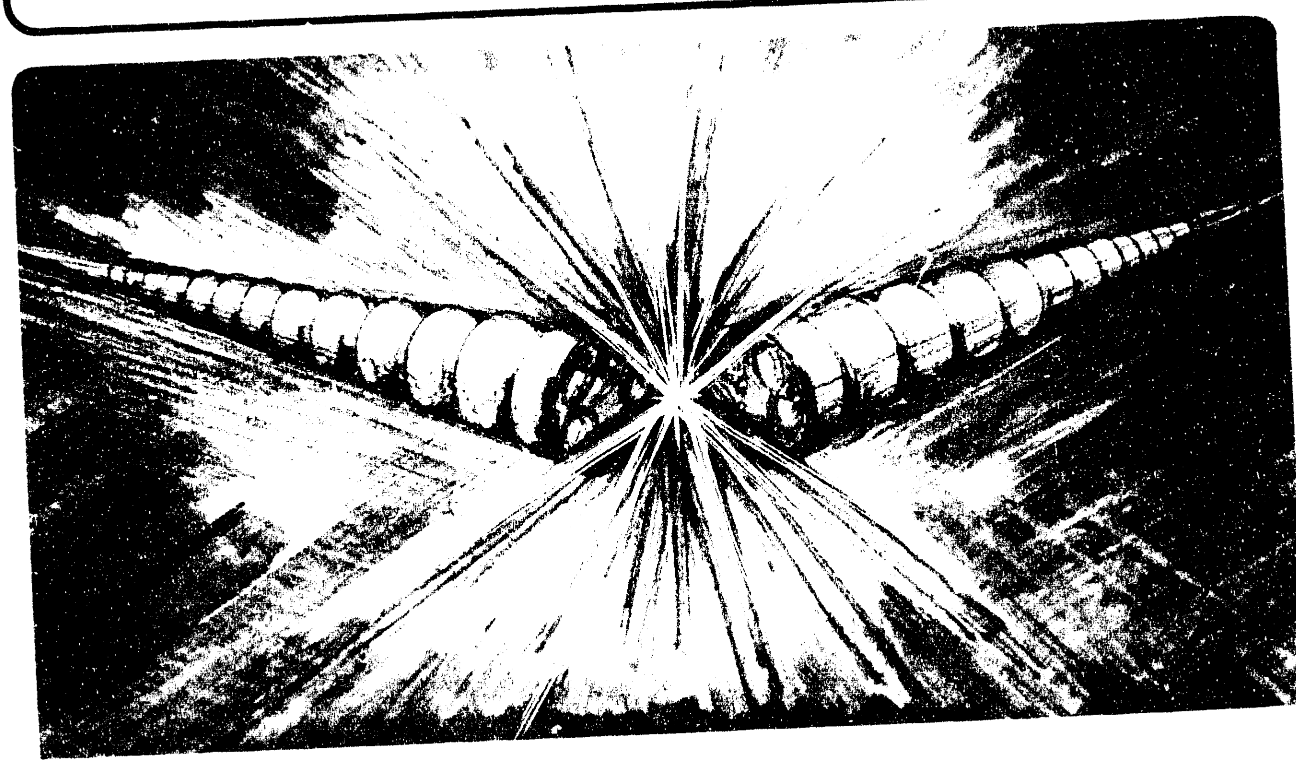

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The Advanced Light Source (ALS) Radiation Safety System

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Abstract

The Advanced Light Source (ALS) at the Lawrence Berkeley Laboratory (LBL) is a 1.5 Gev synchrotron light source facility consisting of a 120 kev electron gun, 50 Mev linear accelerator, 1.5 Gev booster synchrotron, 200 meter circumference electron storage ring, and many photon beamline transport systems for research. See Figure 1.

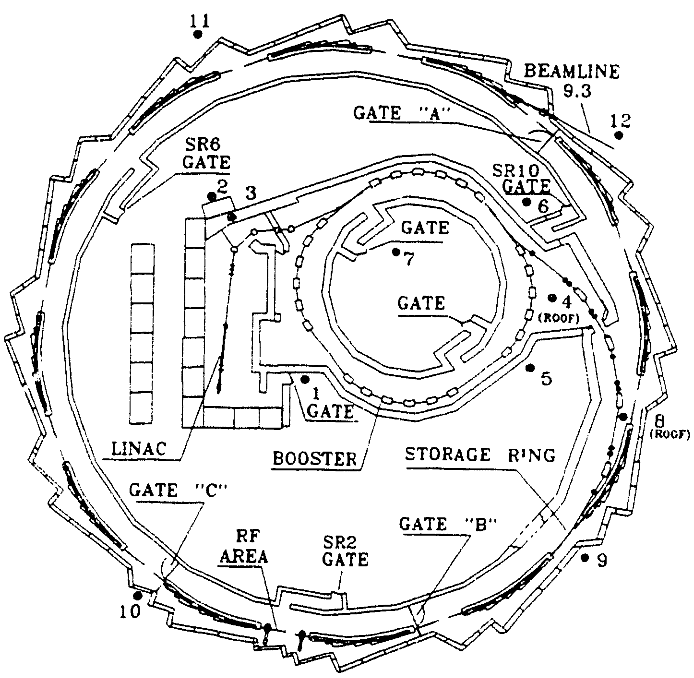

Figure 1. ALS floor plan. Pairs of neutron and gamma radiation monitors are shown as dots numbered from 1 to 12.

The Radiation Safety System for the ALS has been designed and built with a primary goal of providing protection against inadvertent personnel exposure to gamma and neutron radiation and, secondarily, to enhance the electrical safety of select magnet power supplies.

I. INTRODUCTION

The initial review process called for a preliminary design review of the complete system followed some time later by a final design review but, because of the construction and operation schedule, it was decided to separate the project components into sub-areas and review each separately. These designs were subjected to many in-house ALS staff reviews, followed by an LBL design review and, eventually, by an outside team of interlock safety professionals from other DOE labs. The DOE conducted overall project safety (fire, electrical, radiation, etc.) reviews as well. Throughout this process a number of recommendations for improvement were made and incorporated into the design.

II. DESIGN CONSIDERATIONS

A very important factor in designing the ALS radiation safety system was future component availability for maintenance spares and circuit expansion. With typical accelerator lifetimes of 30 to 50 years or more, circuit components with a high probability of being manufactured in the distant future narrowed the design process but the foremost factor in the component selection process was component reliability, failure modes, and predictability.

For all of these reasons, and others, a 24 volt direct current system using electrical-mechanical relays to perform the logic functions was selected. The 24 volts is well below the 50 volt level set by OSHA for hazardous working conditions requiring lock-out/tag-out or special safety equipment for "live" work. This voltage is also widely used in industrial and military control circuit designs, thus a large number of components are available from manufacturers to solve design problems. Because of the proliferation of relays in control and safety circuits dating back to the early part of this century, a long history exists regarding their ruggedness, reliability, and predictability. Solid state devices, around since the late 1950's, quickly become obsolete and unavailable, and quite often fail in the unsafe (shorted) mode. Programmable devices often have software quality assurance and control problems. The broad worldwide use of electrical-mechanical relays and large number of manufacturers tends to guarantee future availability.

Except for short lengths at interlocked radiation monitors and beamline safety shutters, radiation safety system cables are routed in separate enclosed wireways or conduit apart from other accelerator wiring and not allowed in open ladder trays. An audio intercom system uses #20 AWG shielded twisted pair and a video system uses RG-59 coax cables, otherwise, all interlock cables are specified to have a minimum wire size of number 16 AWG, stranded, tinned copper, with an abrasion resistant, flame retardant, low smoke insulating jacket, and be listed and approved by the Underwriters' Lab with a type TC (tray cable) rating.

All switch and relay contacts have a minimum 5 amp rating at 24 volts dc and all relay coils must operate at 75 percent of their coil voltage rating. In an effort to prevent accidental wiring errors or tampering all radiation safety equipment, cabinets and junction boxes are locked.

All interlock chains are tested on a six month basis and all radiation monitoring equipment is calibrated quarterly.

III. ACCESS CONTROL

The system permits three types of access control. The first being no access allowed during accelerator operations. Second is controlled access inside the shielding under certain

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conditions. After an area inside the shielding has been searched and secured, controlled access can be allowed back into that area. Accelerator operations are inhibited and guaranteed by requiring each person entering under controlled access to take a key from a "controlled access key cache" located outside each entrance gate. This key cache has redundant interlocks preventing accelerator operation until all keys are returned. This type of access control does not require the accessed area(s) to be searched and secured after a controlled access has been allowed. Any uncontrolled, inadvertent access or activation of any emergency crash-off push button switch in a previously searched area will interrupt accelerator operations and require a new search and secure of that area. The third type of access is uncontrolled access and occurs when the accelerator is shut down for modifications or maintenance and the access gates entering the shielding are propped open.

An audio and color video intercom system links the six shielding entrance gates with the control room and is used for controlled access activities. A commercial video and audio switching unit made by Pelco Inc. is located in the control room along with a color monitor and speaker/mic assembly.

IV. SEARCH AND SECURE

The search of a given area of the accelerator is done using keys and key-switches. The "search keys" are removed from key-switches in the main control room. Removal insures the safety of the search party. Areas to be searched have key switches that mate with the search keys. These key-switches must be reset in a prescribed sequence, and in some cases, an extra push button is installed whereby two switches must be operated in tandem, thus forcing a two person search. Accelerator operation is inhibited until the search keys are returned to the control room and turned to the operate position and a 60 second time delay occurs. During this 60 second delay, normal white lighting inside the shielded radiation areas is immediately turned off, red lighting is turned on and a two tone audible alarm inside the shielding is sounded. Backlit status indicator signs located in numerous locations change from "safe" to "operational" and after the 60 seconds has timed out, the indicator signs change to "unsafe leave area", the audible alarm ceases and red flashing beacons outside the entrance gates commence flashing. Controlled access entry turns the normal white lighting back on and turns the red lighting and flashing beacons off. After the person(s) has exited from a controlled access and returned the keys to the key cache, the 60 second time delay sequence is re-initiated with the audible and visual warnings as described above.

V. SYSTEM DESCRIPTION

The interlock system consists of three main interlock chains each having a number of sub-chains; all with redundancy throughout. The first of the three main interlock chains is the linac chain which controls the 120 keV electron gun as well as the 50 MeV linac. Both have redundant interlock controls. The electron gun, for example, has its ac main interrupted and the 120kV power supply external interlock turned off should an interlock be violated. The linac chain has three sub-chains capable of interrupting the electron gun/linac operation. A description of these sub-chains is as follows:

A. Because of thin shielding in the booster-to-storage ring beam transport area, a portion of the storage ring (between internal gates "A" and "B") is interlocked as a sub-chain to the linac chain, and occupancy of that portion of the storage ring is not allowed while the linac is operational. Shielding is adequate when backed up by interlocks. These same interlock devices (gate/door micro switches, search switches, crash-off switches, etc.) in this storage ring area are also a part of the storage ring interlock chain described later. After the storage ring is filled and operated in a "stored beam" mode, and the linac is shut down, occupancy of this area is still prohibited because of the radiation produced by the stored electron beam. Access to this area is only permitted when both the linac and the storage ring are shut down. Controlled access to this area inhibits operation of both the linac and the storage ring.

B. The second sub-chain controlling the linac chain is the booster interlock chain. Originally the booster interlock chain was to be a separate interlock system allowing access to the booster while limited linac operations were permitted. Shielding design changes mandated the booster interlock system control the linac operation. Access to the booster through either of its two entrance gates or activation of any booster crash-off push button switch will inhibit the linac operation. As with the linac chain having sub-chains, the booster has a sub-chain consisting of active radiation monitors that eventually control the operation of the linac. Should gamma or neutron radiation above a preset trip level be detected outside the shielding , the radiation monitor will interrupt the linac operation indirectly via the booster chain. The tripped radiation monitor interlock is latched off and requires control room investigation and manual reset in the area of concern. These radiation monitors are commercially manufactured by Health Physics Instruments Inc. and are designed for pulse operations. In addition to an active interlock output, they have a number of features including analog and digital output signals for remote data collection of the radiation being detected.

C. The third sub-chain of the linac is another radiation monitoring system using the same type of detectors as described above for the booster sub-chain. These detectors are located in areas just outside the linac shielding and if radiation above a preset trip level is detected, the linac operation will be inhibited. As with the booster radiation monitoring chain, the tripped monitor is latched off and requires control room investigation and reset before operations can resume.

The second main ALS interlock chain is the storage ring chain. It eventually becomes an input along with the third main ALS interlock chain (storage ring fill/run described later) to control the storage ring RF system and the booster-to-storage ring electron beam transport line B1 and B2 bending magnets. The inner storage ring shielding wall has three controlled access entrance gates. Inside the shielding are three internal gates dividing the storage ring into three zones. The outer wall has 12 hinged concrete doors for maintenance access. All of these doors and gates are interlocked. The operation of the storage ring chains and sub-chains is as follows:

A. The storage ring area between internal gates "A" and "B" as discussed earlier is a sub-chain of the linac and storage ring. The function of the interlock devices bounded by the two internal gates "A" and "B" are summed as a sub-chain at the storage ring sector 10 entrance gate safety racks and becomes an input for the main storage ring chain at the storage ring sector 6 entrance safety racks (as well as the linac described above).

B. The storage ring has two RF cavities installed in the straight section between sectors 2 and 3 that are powered by a 300kW klystron via a wave guide structure. To allow testing of this RF system and uncontrolled access to the remainder of the storage ring, a third internal gate (gate "C") was installed to form an interlocked area surrounding the cavities. The storage ring sector 2 entrance gate access this area and, along with two interlocked concrete doors, emergency crash-off switches, internal gates "B" and "C", and other devices, form a sub-chain allowing RF testing. As can be seen, internal gate "B" functions in two chains; the linac chain because of the storage ring area between gates "A" and "B" and also the storage ring RF test chain because of the area between internal gates "B" and "C". The interlock devices for the area between internal gates "B" and "C" are summed at the storage ring sector 2 entrance gate safety racks and becomes an input for the main storage ring chain at the storage ring sector 6 entrance racks.

C. The third zone of the storage ring consists of sectors 4 through 9 and is bounded by internal gates "A" and "C". This area is normally accessed via an entrance gate at sector 6 where safety racks bring together interlocked devices within this zone as well as the two other zones discussed above. Additional inputs from the storage ring RF system (indicating it is in an operate mode as opposed to test) and an interlocked utility tunnel transiting under the storage ring and linac appear at this location to form the main storage ring chain. The utility tunnel interlocks are also shared by the linac chain discussed earlier.

The third main ALS interlock chain is the storage ring fill/stored beam chain. It has two functions. It will inhibit filling of the storage ring if the beamline safety shutters are not inserted and it turns off the storage ring RF if a beamline hutch interlock is violated. Beamline interlocks for each sector are summed at that sector and then all sectors are brought together. In order to fill the storage ring, a global fill request is sent to all beamlines to close all beamline safety shutters. This request is one input to an interlock controlling the booster-to-storage ring beam transport line bending magnets B1 and B2. When all safety shutters are closed the interlock is then complete to allow operation of the B1 and B2 magnets. Should a safety shutter open during a fill procedure, the two magnets are disabled. After the storage ring has been filled, the global fill request is removed. This relinquishes control of the safety shutters to the beamline operating stations and reasserts the inhibit of operation for the B1 and B2 bend magnets. This prevents accidental beam transport from the booster during tune-up while the storage ring is in a stored beam mode and the position of beamline safety shutters is unknown. Active radiation monitors outside the storage ring shielding also control these two magnets and the storage ring RF. Should radiation outside the shielding be detected above the trip level, the B1 and B2 magnet power supplies and storage ring RF are turned off.

Normal access to an interlocked beamline hutch is via a request to a programmable logic controller (PLC). The PLC cycles certain machine protection equipment and outputs a command to close the beamline safety shutter. Redundant micro switches sense the shutter position and if the shutter is inserted, key(s) are allowed to be released from the beamline safety shutter control panel. Removal of a key operates an interlock switch that keeps the safety shutter inserted until the key is returned, regardless of any PLC activity to the contrary. These key(s) mate with key switches on the hutch doors that will release a hutch door and capture the key while in the released position. A search push button switch inside the hutch must be reset if the hutch door has been opened or the emergency crash-off push-button inside the hutch has been depressed. Hutchless beamlines are identical except for the hutch door release key(s) and the search requirement. The beamline control panel also allows the ALS beamline safety coordinator the capability of locking out any beamline not meeting ALS standards.

VI. OPERATING EXPERIENCE

After initial debugging during commissioning, the interlock systems have performed very well. The design goal of 400 milliamps of stored beam has been achieved and at the time of this writing, components for the beamline safety shutters and hutches are being fabricated and installed. Beamline operations are expected within the next two to three months.

END

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